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„Life-Space Mobilität“ bei älteren Menschen mit kognitiver Einschränkung nach Entlassung aus der geriatrischen Rehabilitation: Entwicklung von differenzierten Assessmentstrategien, Erfassung des Status und Evaluation von angepassten Interventionsstrategien

vorgelegt von
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I. LISTE DER WISSENSCHAFTLICHEN VERÖFFENTLICHUNGEN ZUR PUBLIKATIONSBASIERTEN DISSERTATION

Im Folgenden sind die Manuskripte gelistet, die in die Dissertationsarbeit eingebracht werden. Die aufgeführte Reihenfolge entspricht nicht der chronologischen Abfolge der jeweiligen Erstellung oder Annahme zur Veröffentlichung, sondern fasst Themenschwerpunkte zusammen.

Manuskript I: Hauer, K., **Ullrich, P.**, Dutzi, I., Beurskens, R., Kern, S., Bauer, J., & Schwenk, M. (2017). Effects of Standardized Home Training in Patients with Cognitive Impairment following Geriatric Rehabilitation: A Randomized Controlled Pilot Study. *Gerontology, 63*(6), 495-506. doi:10.1159/000478263

Manuskript II: Bongartz, M., Kiss, R., **Ullrich, P.**, Eckert, T., Bauer, J., & Hauer, K. (2017). Development of a home-based training program for post-ward geriatric rehabilitation patients with cognitive impairment: study protocol of a randomized-controlled trial. *BMC Geriatr, 17*(1), 214. doi:10.1186/s12877-017-0615-0

Manuskript III: **Ullrich, P.**, Werner, C., Abel, B., Hummel, M., Bauer, J.M., Hauer, K. Assessing life-space mobility: A systematic review of questionnaires and their measurement properties. Paper under review (*Zeitschrift für Gerontologie und Geriatrie*)

Manuskript IV: **Ullrich, P.**, Werner, C., Bongartz, M., Kiss, R., Bauer, J., & Hauer, K. (2019). Validation of a Modified Life-Space Assessment in Multimorbid Older Persons With Cognitive Impairment. *Gerontologist, 59*(2), e66-e75. doi:10.1093/geront/gnx214

Manuskript V: **Ullrich, P.**, Abel, B., Bauer, J. M., & Hauer, K. (2021). Validation of the Life-Space Assessment (LSA-CI) in multi-morbid, older persons without cognitive impairment. Validation of the Life-Space Assessment (LSA-CI) in multi-morbid, older persons without cognitive impairment. *Eur Geriatr Med.* 2021 Jun;12(3):657-662. doi: 10.1007/s41999-020-00441-9.

Manuskript VI: **Ullrich, P.**, Werner, C., Eckert, T., Bongartz, M., Kiss, R., Feißt, M., . . . Hauer, K. (2019). Cut-off for the Life-Space Assessment in persons with cognitive impairment. *Aging Clin Exp Res, 31*(9), 1331-1335. doi:10.1007/s40520-018-1062-2

Manuskript VII: Hauer, K., **Ullrich, P.**, Heldmann, P., Hummel, S., Bauer, J. M., & Werner, C. (2020). Validation of the interview-based life-space assessment in institutionalized settings (LSA-IS) for older persons with and without cognitive impairment. *BMC Geriatr, 20*(1), 534. doi:10.1186/s12877-020-01927-8

Manuskript VIII: Hauer, K., **Ullrich, P.**, Heldmann, P., Bauknecht, L., Hummel, S., Abel, B., . . . Werner, C. (2021). Psychometric Properties of the Proxy-Reported Life-Space Assessment in Institutionalized Settings (LSA-IS-Proxy) for Older Persons with and without Cognitive Impairment. *Int J Environ Res Public Health, 18*(8). doi:10.3390/ijerph18083872

Manuskript IX: **Ullrich, P.**, Eckert, T., Bongartz, M., Werner, C., Kiss, R., Bauer, J. M., & Hauer, K. (2018). Life-space mobility in older persons with cognitive impairment after discharge from geriatric rehabilitation. *Arch Gerontol Geriatr, 81*, 192-200. doi:10.1016/j.archger.2018.12.007

Manuskript X: Werner, C., **Ullrich, P.**, Abel, B., Bauer, J. M., & Hauer, K. (2021). Comment on: "Mobility of Older Adults: Gait Quality Measures Are Associated With Life-Space Assessment Scores" by Suri et al. *J Gerontol A Biol Sci Med Sci*. 2022 Jan 7;77(1):e36-e38. doi:10.1093/gerona/glab237

Manuskript XI: **Ullrich, P.**, Werner, C., Schönstein, A., Bongartz, M., Eckert, T., Beurskens, R., Abel, B., Bauer, J.M., Lamb, S., Hauer, K. Effects of a home-based physical training and activity promotion program in community-dwelling older persons with cognitive impairment after discharge from rehabilitation: A randomized controlled trial. Paper under review (J Gerontol A Biol Sci Med Sci) (geteilte Erst-Autorenschaft mit Werner, C.)

Manuskript XII: **Ullrich, P.**, Werner, C., Bongartz, M., Eckert, T., Abel, B., Schönstein, A., . . . Hauer, K. (2020). Increasing Life-Space Mobility in Community-Dwelling Older Persons With Cognitive Impairment Following Rehabilitation: A Randomized Controlled Trial. *The Journals of Gerontology: Series A*. 2021 Oct 13;76(11):1988-1996. doi:10.1093/gerona/glaa254

Manuskript XIII: Eckert, T., Bongartz, M., **Ullrich, P.**, Abel, B., Werner, C., Kiss, R., Hauer, K. (2019). Promoting physical activity in geriatric patients with cognitive impairment after discharge from ward-rehabilitation – A feasibility study. Eur J Ageing. 2020 Feb 13;17(3):309-320. doi:10.1007/s10433-020-00555-w.

II. VORBEMERKUNGEN

Die vorliegende kumulative Dissertation mit dem Thema der Life-Space - Mobilität in der poststationären Versorgung von älteren Menschen mit kognitiven Einschränkungen kann primär im Schnittstellenbereich der Sportwissenschaften (Bewegungs- und Rehabilitationswissenschaften) und der Medizin (Geriatrie/Altersmedizin und medizinische Versorgungsforschung) verortet werden.

Unterschiedliche Facetten der Life-Space Mobilität von Personen mit kognitiver Einschränkung werden mit einem breiten Methodenspektrum untersucht und dabei verschiedene, teilweise aufeinander aufbauende Forschungsziele verfolgt. Die Arbeit kann in drei Teilstudien gegliedert werden. Neben der Methodenentwicklung, die die Identifikation, Entwicklung und Validierung adäquater Methoden zur Erfassung und Untersuchung der Life-Space Mobilität beinhaltete (Teilstudie I), stellen die epidemiologischen Untersuchungen zu dem Status und den Prädiktoren der Life-Space Mobilität (Teilstudie II) und die Untersuchung der Effekte eines speziell entwickelten Heimtrainingsprogramms auf die Mobilität, mit Fokus auf der Verbesserung der Life-Space Mobilität, bei älteren Menschen mit kognitiver Einschränkung nach Rehabilitationsaufenthalt (Teilstudie III), die drei Schwerpunkte der Arbeit dar.

Die Publikationen wurden überwiegend im Rahmen einer randomisierten, kontrollierten Interventionsstudie zur Evaluation eines Heimtrainingsprogramms für poststationäre geriatrische PatientInnen mit kognitiver Einschränkung („Heimtraining bei kognitiver Einschränkung“ (HeikE); Laufzeit: Januar 2015 bis Dezember 2018) erstellt. Das HeikE-Projekt stellt ein Modellvorhaben nach §45c SGB XI zur Weiterentwicklung der Versorgungsstrukturen und Versorgungskonzepte für an Demenz erkrankte Pflegebedürftige sowie anderen Gruppen von Pflegebedürftigen dar. Die Finanzierung erfolgte über den „Kommunalverband für Jugend und Soziales Baden-Württemberg“ und durch die „sozialen und privaten Pflegeversicherungen”. Die Kostenträger hatten keinen Einfluss auf Studienkonzeption, -design und -durchführung, Datenerfassung, -analyse und -interpretation sowie auf die Publikation der Studienergebnisse.

Die Verfasserin der vorliegenden Arbeit war in folgenden Punkten in Vorarbeiten zur Studie und in die HeikE-Studie selbst involviert:

- Beteiligung bei der Konzeption sowie Durchführung des Pilotprojekts zu Heimtraining bei Menschen mit kognitiver Einschränkung nach Rehabilitation
- Literaturrecherche zu bestehenden Erhebungsmethoden von körperlicher Aktivität und Life-Space Mobilität bei älteren Menschen
- Gemeinsam mit Prof. Dr. Hauer federführend bei der Übersetzung und Anpassung eines etablierten Life-Space Assessment Fragebogens
- Beteiligung bei der Konzeption der Heike-Studie, der Erstellung des Ethikantrags, der Messprotokolle und des Studienprotokolls

- Beteiligung bei der Studienorganisation und -planung, Organisation der Termine mit den Teilnehmenden

- Durchführung des Heimtrainings als Trainerin für die Interventions- wie auch für die Kontrollgruppe

- Dokumentation und Einpflege der Daten (aufgrund des verblindeten Studiendesigns übernahm die Verfasserin der Arbeit die Einpflege der erhobenen Daten, da die Entblindung in ihrer Funktion als Trainerin erfolgt war).

- Erstellung von sechs Manuskripten in Erstautorenschaft und einem Manuskript in geteilter Erstautorenschaft mit Dr. Christian Werner mit Unterstützung von Prof. Dr. Klaus Hauer und den jeweiligen Co-Autoren mit zugrundeliegender Analyse des aktuellen Forschungsstandes, statistischer Datendokumentation und -analyse und Interpretation der Studienergebnisse. Alle Publikationen wurden in einschlägigen internationalen Fachzeitschriften mit Begutachtungsprozessen (Peer-Review Verfahren) veröffentlicht.

- Innerhalb der weiteren Untersuchungen im Rahmen der HeikE-Studie und der PAGER-Studie war die Verfasserin dieser Arbeit als Co-Autorin bei sechs in der Dissertation integrierten Publikationen und bei drei weiteren Publikationen unterstützend bei der Erstellung und finalen Bearbeitung der anderen Manuskripte beteiligt. Auch diese Publikationen wurden in einschlägigen, internationalen Fachzeitschriften mit Begutachtungsprozessen (Peer-Review Verfahren) veröffentlicht.

III. KURZDARSTELLUNG / ABSTRACT (deutsch)

Die publikationsbasierte Dissertation befasst sich mit der Mobilität in der räumlichen Umgebung („Life-Space Mobilität“) von multimorbiden älteren Menschen mit kognitiver Einschränkung nach Entlassung aus der geriatrischen Rehabilitation. Aufgrund ihrer Akkumulation von negativen Einflussfaktoren auf die Mobilität weisen diese Personen ein hohes Risiko für den Verlust der Mobilität auf. Neben der kognitiven Einschränkung gehören Multimorbidität und körperliche Einschränkungen nach dem medizinischen Ereignis zu den Risikofaktoren sowie die kritische Phase des Übergangs von der stationären in die ambulante Versorgung. Mobilität in und außerhalb der Wohnung ist jedoch die Voraussetzung für eine autonome Lebensführung und gesellschaftliche Teilhabe. Neben der Methodenentwicklung zur Erfassung der Life-Space Mobilität in der Zielpopulation wurden in dieser Arbeit auch epidemiologische Untersuchungen zum Status der Life-Space Mobilität durchgeführt und Interventionseffekte eines heimbasierten Versorgungsangebots auf die (Life-Space) Mobilität bei Menschen mit kognitiver Einschränkung nach Entlassung aus der geriatrischen Rehabilitation evaluiert.

Vorbereitend wurde zunächst eine Pilotstudie zur Durchführbarkeit und Effektivität eines poststationären Heimtrainings bei Personen mit kognitiver Einschränkung durchgeführt (Manuskript I). Basierend auf der erfolgreichen Evaluation wurde die HeikE (“Heimtraining bei Kognitiver Einschränkung”) Studie konzipiert (Manuskript II).

Im Zusammenhang von erfolgreicher Rehabilitation, selbstständiger Lebensführung und sozialer Partizipation, ist das Konzept der Life-Space Mobilität als Maß für Mobilität, Selbstständigkeit und Partizipation bedeutsam. Basis für die Evaluation sind adäquate Assessmentinstrumente, jedoch lag zu Studienbeginn kein geeigneter Fragebogen zur Erfassung der Life-Space Mobilität bei hochbetagten Menschen mit kognitiver Einschränkung vor. Teilstudie I (Methodenentwicklung) bestand daher darin, systematisch verfügbare Life-Space Assessment Instrumente zu identifizieren und einzuordnen (Manuskript III), und geeignete Instrumente für die Population der älteren Menschen mit kognitiver Beeinträchtigung zu entwickeln und zu validieren. Dies wurde erfolgreich mit dem „Life-Space Assessment for Persons with Cognitive Impairment“ (LSA-CI) für im häuslichen Umfeld lebende Menschen umgesetzt (Manuskripte IV und V). Ein Cut-off wurde ermittelt zur Unterscheidung von hoher und geringer Life-Space Mobilität zur vereinfachten Beurteilung des Life-Space Mobilitätsstatus in der klinischen Anwendung (Manuskript VI). In einem assoziierten Projekt wurde die Erfassung der Life-Space Mobilität im institutionellen Setting (Krankenhaus, Rehabilitation, Pflegeeinrichtung) mit dem ebenso neu entwickelten „Life-Space Assessment für Institutionalized Settings“ (LSA-IS als selbst- oder Proxy-berichtete Version; Manuskripte VII und VIII) untersucht. Die Instrumente wurden in Populationen mit und ohne kognitive Beeinträchtigungen mit sehr guter Durchführbarkeit eingesetzt. Insbesondere die Gesamtscores der jeweiligen Instrumente wiesen sehr gute Konstruktvalidität, Test-Retest Reliabilität bei im Durchschnitt moderater Veränderungssensitivität auf, in Abhängigkeit von der Effektivität der jeweiligen LSM Intervention. Die Subscores wiesen vergleichbare, in der Tendenz geringfügig schlechtere Evaluationsergebnisse auf, was teilweise auf statistischen Effekte zurückzuführen war.

Mit dem neu validierten Instrument LSA-CI konnte in Teilstudie II (Epidemiologische Untersuchung) der Status der Life-Space Mobilität bei 118 PatientInnen mit kognitiver Einschränkung nach Entlassung in das häusliche Umfeld ermittelt werden. Zudem konnten assoziierte Faktoren aus einer Vielzahl an potenziellen Einflussfaktoren (basierend auf einem etablierten Mobilitäts-Modell) identifiziert werden. Die Analyse zeigt den geringen Life-Space Mobilitäts-Status in der Population auf und erlaubt die Identifikation besonders gefährdeter Personen mit Interventionsbedarf. Insbesondere Frauen wiesen eine reduzierte Life-Space Mobilität auf. Körperliche Leistungsfähigkeit, körperliche Aktivität und soziale Aktivitäten wurden als relevante modifizierbare Einflussfaktoren ermittelt (Manuskript IX), die in die Planung von Interventionen einbezogen werden können. Die Berücksichtigung von Parametern der Gangqualität anstelle der körperlichen Leistungsfähigkeit konnte den Anteil der aufgeklärten Varianz noch steigern (Manuskript X).

In Teilstudie III (Interventionseffekte) wurden die Effekte eines speziell entwickelten 12-wöchigen Heimtrainingsprogramms auf die Mobilität, mit Fokus auf der Verbesserung der Life-Space Mobilität, untersucht. Neben etablierten validierten Tests zur Erfassung der allgemeinen körperlichen Leistungsfähigkeit, Fragebögen zu verschiedenen psychosozialen Variablen (wie Sturzangst, Apathie, depressive Symptomatik) und der sensorbasierten Erfassung der körperlichen Aktivität wurde der neu entwickelte LSA-CI zur Prüfung der Effekte des Heimtrainingsprogramms eingesetzt. Das Trainingsprogramm bestand aus sechs Übungen für Balance und Kraft der unteren Extremitäten zur Verbesserung der körperlichen Leistungsfähigkeit und einem täglichen Spaziergang zur Steigerung der körperlichen Aktivität, unterstützt durch ein speziell entwickeltes Motivationskonzept mit Fokus auf sozialen Kontakten, Monitoring und positivem Feedback. Übergeordnetes Ziel war die Verbesserung der poststationären Versorgungssituation für geriatrische PatientInnen mit kognitiver Einschränkung. Bei den insgesamt 118 älteren Teilnehmenden mit kognitiver Einschränkung konnten signifikante und nachhaltige Effekte auf die körperliche Leistungsfähigkeit und auf Faktoren der Sturzangst in der Interventionsgruppe im Vergleich zur Kontrollgruppe aufgezeigt werden. Effekte auf die körperliche Aktivität konnten nicht festgestellt werden (Manuskript XI). Die Interventionsgruppe wies nach der Intervention eine signifikant bessere Life-Space Mobilität auf, sowohl in Bezug auf den Gesamtscore als auch für den Subscore für den Life-Space, der unabhängig von Hilfspersonen und -mitteln erreicht wurde (Manuskript XII). Zudem konnte eine sehr gute Durchführbarkeit und hohe Adhärenz erreicht werden (Manuskript XIII). Durch das zielgruppenspezifische Heimtrainingsprogramm konnten damit wichtige Parameter für die Selbstständigkeit und Teilhabe signifikant und teilweise nachhaltig verbessert werden. Personen mit kognitiver Einschränkung können dadurch während des Übergangs vom stationären Setting zur ambulanten Versorgung, einer besonders kritischen Phase mit hohem Risiko für Mobilitäts- und Autonomieverlust und Institutionalisierung, in ihrer individuellen Mobilität unterstützt werden. Perspektivisch können Pflegebedürftigkeit und Institutionalisierung gemindert oder verhindert werden.

Die gewonnenen Erkenntnisse sollen Forschern und Klinikern zukünftig helfen, den Status der Life-Space Mobilität von Menschen mit (und ohne) kognitive Einschränkungen im häuslichen Umfeld oder institutionellen Setting bestimmen, sowie die Wirksamkeit von

Therapien und Interventionen bei der gefährdeten Population älterer Menschen mit kognitiven Einschränkungen evaluieren zu können. Zudem ist mit dem HeikE-Programm ein innovatives und niedrigschwelliges, effektives und kostengünstiges heimbasiertes Versorgungsangebot evaluiert worden, welches umgehend in die Versorgungslandschaft implementiert werden kann.

Keywords: Life-Space Mobilität, Aktivität, Partizipation, gesellschaftliche Teilhabe, Entlassung, Assessment, kognitive Einschränkungen

KURZDARSTELLUNG / ABSTRACT (english)

This publication-based dissertation addresses mobility in the spatial environment ("life-space mobility") of older multimorbid persons with cognitive impairment after discharge from geriatric rehabilitation. Due to their accumulation of negative influencing factors on mobility, these persons are at high risk of losing mobility. In addition to cognitive impairment, risk factors include multimorbidity and physical limitations after the medical event, as well as the critical period of transition from inpatient to outpatient care. However, indoor as well as outdoor mobility is a prerequisite for autonomous living and social participation.

In addition to the development of methods for assessing life-space mobility in the target population, this dissertation also included epidemiological studies on the status of life-space mobility and evaluated intervention effects of home-based training on (life-space) mobility in people with cognitive impairment after discharge from geriatric rehabilitation.

In preparation, a pilot study on the feasibility and effectiveness of post-discharge home-based training for persons with cognitive impairment was conducted (Manuscript I). Based on the successful evaluation, the HeikE (“Heimtraining bei Kognitiver Einschränkung”) study was designed (Manuscript II).

In the context of successful rehabilitation, autonomous living and social participation, the concept of life-space mobility as a measure of mobility, independence and participation has become relevant. Adequate assessment instruments are mandatory for the evaluation, however, at the beginning of the study, no adequate questionnaire was available to assess life-space mobility in very old persons with cognitive impairment. Substudy I (Development of methods) therefore consisted of a systematic search to identify and classify available life-space assessment instruments (manuscript III) and the development and validation of adequate instruments for the population of older persons with cognitive impairment. This has been successfully implemented with the "Life-Space Assessment for Persons with Cognitive Impairment" (LSA-CI) for persons living in the community setting (manuscripts IV and V). A cut-off was determined to differentiate between high and low life-space mobility for a simplified rating of the life-space mobility status in clinical use (manuscript VI). In an associated project the assessment of life-space mobility in the institutional setting (hospital, rehabilitation, care facility) was examined using the newly developed "Life-Space Assessment for Institutionalized Settings" (LSA-IS as a self-reported or proxy-reported version; manuscripts VII and VIII). The instruments were tested in populations with and without cognitive impairment with very good feasibility. In particular, the total scores of the respective instruments showed very good construct validity, test-retest reliability with on average moderate change sensitivity, depending on the effectiveness of the respective LSM intervention. The subscores showed comparable evaluation results, which tended to be slightly worse, which was partly due to statistical effects.

With the newly validated LSA-CI instrument, the status of life-space mobility was determined in substudy II (epidemiological investigation) in 118 patients with cognitive impairment after discharge to the community setting. In addition, associated factors from a large number of potentially influencing factors (based on an established mobility model) were identified. The

analysis highlighted the low life-space mobility status in the population and allows the identification of particularly vulnerable persons in need of intervention. Women in particular showed reduced life-space mobility. In addition, relevant modifiable factors were highlighted as a basis for designing interventions: physical performance, physical activity and social activities were identified as modifiable relevant influencing factors (Manuscript IX). Considering parameters of gait quality instead of physical performance could increase the proportion of the explained variance (Manuscript X).

In substudy III (intervention effects), the effects of a specifically developed 12-week home-based training program on mobility, with a focus on improving life-space mobility, were examined. In addition to established validated instruments to assess general physical performance, questionnaires on various psychosocial variables (such as fear of falling, apathy, depressive symptoms) and the sensor-based assessment of physical activity, the newly developed LSA-CI was used to evaluate the effects of the home-based training program. The training program consisted of six exercises for balance and lower extremities strength to improve physical performance and a daily walk to increase physical activity, supported by a specifically developed motivational concept with a focus on social contacts, monitoring and positive feedback. The overall aim was to improve the situation after discharge from geriatric rehabilitation for geriatric patients with cognitive impairment. In 118 older participants with cognitive impairment, significant and sustainable effects on physical performance and on factors related to fear of falling could be demonstrated in the intervention group compared to the control group. Effects on physical activity could not be determined (Manuscript XI). After the intervention, the intervention group showed a significantly better life-space mobility, both for the total score and the subscore for the life-space, which was achieved independently of other persons and equipment (Manuscript XII). In addition, very good feasibility and high adherence could be achieved (Manuscript XIII). Through the target group-specific home training program, important parameters for independence and participation could be significantly and in some cases sustainably improved. Individuals with cognitive disabilities can be supported in their individual mobility during the transition from inpatient setting to outpatient care, a particularly critical phase with a high risk of loss of mobility and autonomy and institutionalization. In the future, the need for long-term care and institutionalization can be reduced or prevented.

The findings should help researchers and clinicians in the future to determine the status of life-space mobility of people with (and without) cognitive impairment in the community or institutional setting, as well as to evaluate the effectiveness of therapies and interventions in the vulnerable population of older persons with cognitive impairment. In addition, with the HeikE-program, an innovative, low-threshold, effective and cost-effective home-based supply offering has been evaluated, which can be implemented immediately in the care landscape.

Keywords: life-space mobility, activity, participation, post-discharge, assessment, cognitive impairment

1 Einleitung und Überblick

Mobilität ist ein menschliches Grundbedürfnis und stellt die Grundlage für die Aktivitäten des täglichen Lebens dar. Zudem ist Mobilität die Voraussetzung für eine autonome Lebensführung und Basis für eine uneingeschränkte Teilhabe am gesellschaftlichen Leben (Rosso et al., 2013; Rowe & Kahn, 1997; Webber et al., 2010). Der Alterungsprozess, akute und chronische Erkrankungen, aber auch Veränderungen des sozialen und räumlichen Umfeldes können die individuelle Mobilität jedoch einschränken. Ältere Menschen mit kognitiver Einschränkung sind besonders bedroht von Verlusten der Mobilität (Ferrucci et al., 2016; O'Connor et al., 2010), insbesondere der außerhäuslichen Mobilität (Duggan et al., 2008; Rosenberg et al., 2013; Wettstein et al., 2015). Ein mögliches Resultat reduzierter Mobilität ist der Verlust der Selbstständigkeit (siehe Abbildung 1), mit Konsequenzen für die betroffene Person selbst, ihr direktes Umfeld, aber auch für die Gesellschaft. Auch wenn viele ältere Menschen im Vergleich zu früheren Generationen deutlich geringere Beeinträchtigungen in ihrer funktionellen Gesundheit aufweisen und mehr gesunde Lebensjahre verbringen (Ziegler & Doblhammer, 2008), ist vor dem Hintergrund des demografischen Wandels und der steigenden Anzahl älterer Menschen in der Bevölkerung westlicher Industriestaaten dennoch mit einer erhöhten Anzahl von Menschen mit eingeschränkter Selbstständigkeit und Mobilität zu rechnen. Etwa die Hälfte der Männer und etwa ein Drittel der Frauen werden im Laufe ihres Lebens pflegebedürftig (Blüher et al., 2017).

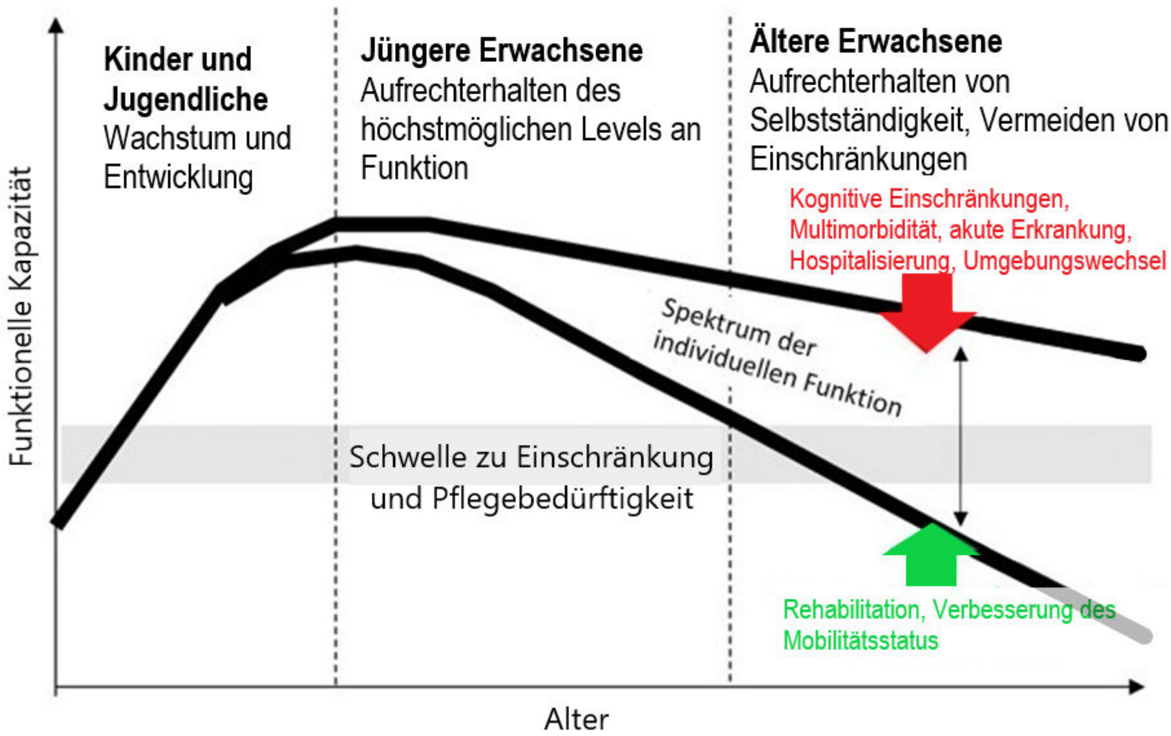

Abbildung 1: Verlauf der funktionellen Kapazität, in Anlehnung an Kalache & Kickbusch 1997 (Kalache & Kickbusch, 1997)

Gemäß dem Grundsatz „Reha vor Pflege“ wird bei drohendem Verlust der Selbstständigkeit (bedingt durch akute Ereignisse oder kontinuierliche Verschlechterung) versucht, mit Hilfe von verschiedenen therapeutischen Maßnahmen die Einschränkungen zu beheben oder zu reduzieren, um dadurch die Mobilität, die Fähigkeit zum selbstständigen Ausüben der Aktivitäten des täglichen Lebens und die Teilhabe zu erhalten oder zu verbessern (Swoboda & Sieber, 2010). Im Einklang mit dem Wunsch der meisten älteren Menschen, im häuslichen Umfeld zu altern (Gitlin, 2003; Lach, 2021; Wiles et al., 2012), ist das Ziel der Rehabilitation meist die Entlassung in das häusliche Umfeld. Jedoch sind die Rehabilitationsmaßnahmen aufgrund ihrer begrenzten Dauer selten in der Lage, das vorhandene Rehabilitationspotential auszuschöpfen. Einschränkungen der Motorik und Funktion, der Kognition sowie Sturzangst gehören zu den häufigsten persistenten Syndromen (Krumholz, 2013). Dementsprechend sind viele Betroffene auch nach ihrer Entlassung aus der strukturierten (stationären) Versorgung in das häusliche Umfeld mit körperlichen, psychischen und sozialen Einschränkungen konfrontiert, häufig bei zeitgleicher Übernahme der anfallenden täglichen Aufgaben, mit Herausforderungen in Bezug auf die Inanspruchnahme medizinisch-therapeutischer Leistungen und die Anpassungen an den „neuen“ gesundheitlichen Zustand (Brandberg et al., 2021). Dieser Übergang von der stationären in die ambulante Versorgung im häuslichen Umfeld erfolgt in der Regel ohne strukturierte Unterstützung bei der Fortführung rehabilitativer Maßnahmen (Becker et al., 2020). So ist es nicht erstaunlich, dass die Phase nach der Entlassung für geriatrische PatientInnen als besonders kritisch gilt (Krumholz, 2013). In Deutschland ist dieser Übergang durch die sektorielle Trennung der stationären und ambulanten Versorgung zusätzlich erschwert (Becker et al., 2020; Ommen et al., 2007).

Obwohl die Leistungsträger gemäß § 5 SGB XI verpflichtet sind, Leistungen zur Prävention und Stärkung gesundheitlicher Ressourcen und Fähigkeiten (auch bei schon Pflegebedürftigen) zu erbringen und nach § 43 SGB V auch verpflichtet sind, ergänzende Leistungen zur Rehabilitation zu erbringen, um die anschließende ambulante ärztliche Behandlung zu sichern, und dafür die erforderliche Koordination von verordneten Leistungen und die Anleitung und Motivation zur Inanspruchnahme zu leisten, und Versicherte nach § 11 SGB V Anspruch auf ein Versorgungsmanagement im Übergang zwischen verschiedenen Leistungsbereichen, vor allem beim Entlassmanagement der Krankenhausbehandlung (§ 39 SGB V) (Schang et al., 2020) haben, gibt es in der Regelversorgung in Deutschland keine strukturierten Programme zur Verbesserung der poststationären Versorgung und Fortführung der Rehabilitation im häuslichen Umfeld.

Programme zur Verbesserung des Übergangs vom institutionellen Setting in das häusliche Umfeld wurden im internationalen Kontext als „Transitional Care“ Programme implementiert und evaluiert (Piraino et al., 2012). Allerdings war die Prävention des körperlichen Abbaus ein zwar relevantes, aber dennoch unterrepräsentiertes Element (Parker et al., 2020), obwohl die Bedeutung der körperlichen Kapazität und der körperlichen Aktivität als Marker für das Wiedereinweisungsrisiko und den allgemeinen Gesundheitszustand in dieser Phase bekannt sind (Fisher et al., 2013). Menschen mit kognitiven Einschränkungen wurden in den meisten dieser Nachsorgeprogramme systematisch vernachlässigt (Chenoweth et al., 2015; Naylor et al., 2014; O'Donnell et al., 2021; Parker et al., 2020; Piraino et al., 2012), ungeachtet der hohen Prävalenz von kognitiven Einschränkungen in Rehabilitationskliniken (Shah et al., 2000) und der Tendenz zu schlechteren Rehabilitations- und Gesundheitsoutcomes (in Bezug auf die Rehospitalisierungsrate und die Mortalität) von Personen mit kognitiver

Einschränkung im Vergleich zu Personen ohne kognitive Einschränkung (Reynish et al., 2021).

So existieren trotz der hohen Relevanz von Mobilität und des hohen Risikos für Mobilitätsverluste in Deutschland für die Zielgruppe der geriatrischen PatientInnen mit kognitiver Einschränkung keine strukturierten Nachsorgeprogramme, die den Übergang von der stationären Versorgung in das ambulante Setting begleiten, Rehabilitationserfolge sichern und zum weiteren Gewinn von funktioneller Leistungsfähigkeit und Mobilität beitragen.

Im Rahmen dieser Studie soll daher ein solches speziell auf die Zielgruppe der Menschen mit kognitiver Einschränkung zugeschnittenes, heimbasiertes Nachsorgeprogramm zur Sicherung und Erweiterung der Rehabilitationsfortschritte evaluiert werden. Insbesondere die Erfassung und die Auswirkungen auf die Mobilität in der räumlichen Umgebung (die „Life-Space Mobilität") stehen in dieser Dissertation im Fokus.

Die Dissertationsschrift ist wie folgt gegliedert: Nach der fachwissenschaftlichen Einordnung wird im ersten Kapitel der theoretische Rahmen erarbeitet, der die Relevanz und Aktualität dieser Arbeit begründet (Kapitel 1). Dem folgt eine kurze Vorstellung der Projekte, in deren Rahmen diese Dissertation entstanden ist (Kapitel 2). Darauf folgen drei Kapitel mit den Schwerpunktthemen dieser Dissertation:

Teilstudie I - Methodenentwicklung: Identifikation und Entwicklung von differenzierten Assessmentstrategien zur Erfassung der Life-Space Mobilität (mit Fokus auf Personen mit kognitiver Einschränkung) (Kapitel 3)

Teilstudie II - Epidemiologische Untersuchung: Erfassung und Analyse des Status der Life-Space Mobilität von Personen mit kognitiver Einschränkung zur Ermittlung des Bedarfs und relevanter modifizierbarer Einflussfaktoren (Kapitel 4)

Teilstudie III - Interventionseffekte: Evaluation einer angepassten Interventionsstrategie in Form eines heimbasierten Nachsorgeprogramms zur Steigerung der allgemeinen Mobilität und der Life-Space Mobilität bei Personen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation (Kapitel 5).

Abschließend werden die Ergebnisse in Kapitel 6 eingeordnet und in Kapitel 7 ein Fazit gezogen sowie ein Ausblick auf künftige Forschungsfragen gegeben.

1.1 Fachwissenschaftliche Einordnung

Die vorliegende kumulative Dissertation mit dem Thema der Mobilität in der räumlichen Umgebung in der poststationären Versorgung von besonders in ihrer Mobilität bedrohten älteren Menschen mit kognitiven Einschränkungen kann im Schnittstellenbereich der Sportwissenschaften, im Speziellen Bewegungs- und Rehabilitationswissenschaften, und der Medizin, im Speziellen Geriatrie/Altersmedizin und medizinische Versorgungsforschung, verortet werden, hat aber auch Schnittstellen mit der Psychologie, Gerontologie, Soziologie und „Public Health". Die Sportwissenschaften als relativ „neue" Wissenschaften untersuchen Sport als Kulturgut und als sich veränderndes Phänomen unserer Gesellschaft und befassen sich mit den Themen Sport, Bewegung und körperliche Aktivität in einer sehr differenzierten Art und Weise unter Berücksichtigung der individuellen und sozialen Bedingungen, Ausprägungen, Wirkungen und Funktionen. Ausgehend von dem Fokus auf den Leistungssport und die Trainingswissenschaft haben die Sportwissenschaften sich zunehmend breiter aufgestellt, und es ist ein erweitertes Sportverständnis entstanden, das Bewegung und körperliche Aktivität auch außerhalb eines eng definierten Sportkontextes mit einschließt. Die Entwicklung neuer Sportarten, die Entdeckung neuer Bewegungsräume und die Einbeziehung aller Altersgruppen in die wissenschaftliche Betrachtung von Sport und Bewegung haben zu einer Vielzahl unerschlossener Teilbereiche geführt und enge Verknüpfungen zu anderen verwandten Wissenschaften entwickelt (Hottenrott et al., 2017). Bei der wissenschaftlichen Untersuchung von Sport und Bewegung über die gesamte Lebensspanne werden auch Aspekte wie die Förderung, der Erhalt und die Wiederherstellung von Gesundheit und Mobilität bzw. die Behandlung von Krankheiten durch Sport und Bewegung in verschiedenen Lebensphasen und Lebenswelten relevant (Hollstein, 2019). Die Einbeziehung der in den Sportwissenschaften eher unterrepräsentierten Gruppe hochaltriger Menschen mit Multimorbidität und kognitiven Einschränkungen und die Einführung von Bewegung und Sport zur Förderung der Gesundheit und Mobilität in der Zielgruppe, verbunden mit der Etablierung von adäquaten Sportangeboten, gehört zu den neueren Entwicklungen in der sportwissenschaftlichen Forschung. Dabei orientiert sich die medizinisch orientierte Sportwissenschaft / Rehabilitationsforschung an den im medizinischen Forschungsbereich üblichen Methoden mit hoher Relevanz der „Evidence-Based Medicine“. So wurden auch in dieser Arbeit aufbauend auf Vorarbeiten Studienhypothesen generiert, adäquate Messinstrumente nach aktuellen Standards entwickelt und validiert, Untersuchungen zu relevanten modifizierbaren Einflussfaktoren durchgeführt und diese für die Planung und Analyse passender Interventionen nach aktuellen wissenschaftlichen Standards genutzt.

1.2 Versorgungssituation von Personen mit kognitiven Einschränkungen nach Entlassung aus der Rehabilitation in das häusliche Umfeld

Die Prävalenz kognitiver Einschränkungen bei der älteren Bevölkerung zwischen 80 und 84 Jahren liegt bei etwa 25% (Petersen et al., 2018), im Rehabilitationssetting reicht sie von 25% bis über 80% (Garcia et al., 1984; Poynter et al., 2011). Während der Hospitalisierung weist etwa die Hälfte der PatientInnen über 65 Jahre eine geringe bis mäßige Mobilität auf (Brown et al., 2004). Mehr als die Hälfte der PatientInnen hat zu Beginn sowohl Mobilitäts- als auch funktionelle Einschränkungen, 52,7% haben auch nach Entlassung noch Mobilitätseinschränkungen und 42,5% noch funktionelle Einschränkungen (van Seben et al., 2019). Der Großteil (etwa zwischen 80 und 88%) der älteren Personen wird nach der (geriatrischen) Rehabilitation in das häusliche Umfeld entlassen (Lindenberg et al., 2014; Tümena et al., 2011) (S.30)). Die Phase nach der Entlassung in das häusliche Umfeld birgt zudem hohe Risiken für geriatrische PatientInnen (Krumholz, 2013), zu den typischen Syndromen, die auch nach Entlassung persistent sind, gehören Einschränkungen der Motorik und Funktion, der Kognition sowie Sturzangst (van Seben et al., 2019). Dennoch müssen die Betroffenen im häuslichen Setting viele Aktivitäten des täglichen Lebens wieder aufnehmen und selbstständig durchführen. Menschen mit kognitiven Einschränkungen weisen dabei ein besonders hohes Risiko für den Verlust der Mobilität und der Selbstständigkeit und eine

Verschlechterung des allgemeinen Gesundheitszustandes nach Entlassung aus der geriatrischen Rehabilitation auf (Chenoweth et al., 2015; Everink et al., 2016; Nikelski et al., 2019; Piraino et al., 2012). Hierfür ist neben der Ursache für die Rehabilitation (in 98% der Fälle geht ein Krankenhausaufenthalt voraus (Lübke, 2020), in vielen Fällen ausgelöst durch ein akutes Ereignis wie Erkrankung oder Sturz), auch die Phase der Hospitalisierung selbst mit häufig angeordneter Bettruhe verantwortlich (Brown, Redden, et al., 2009; Brown et al., 2007). So resultiert die Hospitalisierung sehr oft in einer abrupten negativen Veränderung des Mobilitäts- und Funktionsstatus (Brown, Redden, et al., 2009) und reduzierter Selbstständigkeit (Boyd et al., 2008; Covinsky et al., 2003; Gill et al., 2010). Auch eine Verschlechterung der kognitiven Leistung gehört zu den möglichen Konsequenzen der Hospitalisierung und des Akutereignisses (Chen et al., 2011; Wilson et al., 2012). Ebenso besteht für ältere Menschen nach Entlassung aus dem Krankenhaus ein erhöhtes Sturzrisiko, auch dieses wird durch eine kognitive Einschränkung verstärkt (Hoffman et al., 2019). Zudem führt der zunehmende Ökonomisierungsdruck in den Krankenhäusern zu einer kontinuierlichen Verkürzung sowohl des stationären Aufenthalts im Krankenhaus, als auch des Rehabilitationsaufenthalts (vgl. (Freidel et al., 2017), mit der Folge, dass viele der älteren Rehabilitanden ihr Rehabilitationspotential nicht ausschöpfen können und trotz Rehabilitationsmaßnahme Einschränkungen aufweisen. Insbesondere die in Deutschland herrschende Situation mit strukturell unterschiedlicher Versorgung im stationären und ambulanten Sektor bringt für hochbetagte Menschen nach oder mit akutem medizinischem Bedarf und kognitiver Einschränkung als Begleiterkrankung große Herausforderungen mit sich. Defizite in der Kommunikation, Information und Koordination an den Schnittstellen der einzelnen Sektoren erschweren diesen Übergang (Struckmann et al., 2021). Häufig gelingt die Überführung in die ambulanten und mobilen Rehabilitationsformen nicht (Becker et al., 2020). Um den Übergang in das häusliche Setting nach der Entlassung zu unterstützen, wurden „Transitional Care“ Programme implementiert und evaluiert, jedoch war die Prävention des körperlichen Abbaus ein zwar relevantes, aber dennoch unterrepräsentiertes Element (Parker et al., 2020), obwohl das Niveau der körperlichen Kapazität und der körperlichen Aktivität als Marker für das Wiedereinweisungsrisiko und die Gesundheit in der Übergangphase nach Entlassung identifiziert wurden (Fisher et al., 2013). Auch wurden auch in den meisten “Transitional Care” Programmen Personen mit kognitiver Einschränkung systematisch vernachlässigt (Parker et al., 2020), trotz der hohen Prävalenz von kognitiven Einschränkungen in Rehabilitationskliniken (Shah et al., 2000) und der Tendenz zu schlechteren Rehabilitations- und Gesundheitsoutcomes (wie Wiedereinweisungen und Mortalität) gegenüber Personen ohne kognitive Einschränkungen (Reynish et al., 2021). Der weitere Verlauf der Genesung bzw. Rehabilitation wird nicht weiter unterstützt in Form von strukturierten Maßnahmen (vgl. Abbildung 2), obwohl weitergehende Unterstützung insbesondere bei Menschen mit neu erworbenen Einschränkungen empfehlenswert wäre (Boyd et al., 2008). Geriatrische PatientInnen mit kognitiver Einschränkung sind häufig nicht ausreichend in der Lage, sich selbstständig um Fortführung der therapeutischen Maßnahmen zu bemühen (Nikelski et al., 2019; Njegovan et al., 2001; Wadley et al., 2007).

Verlauf Genesungsprozess / Rehabilitationskette

Therapeutische Maßnahmen:

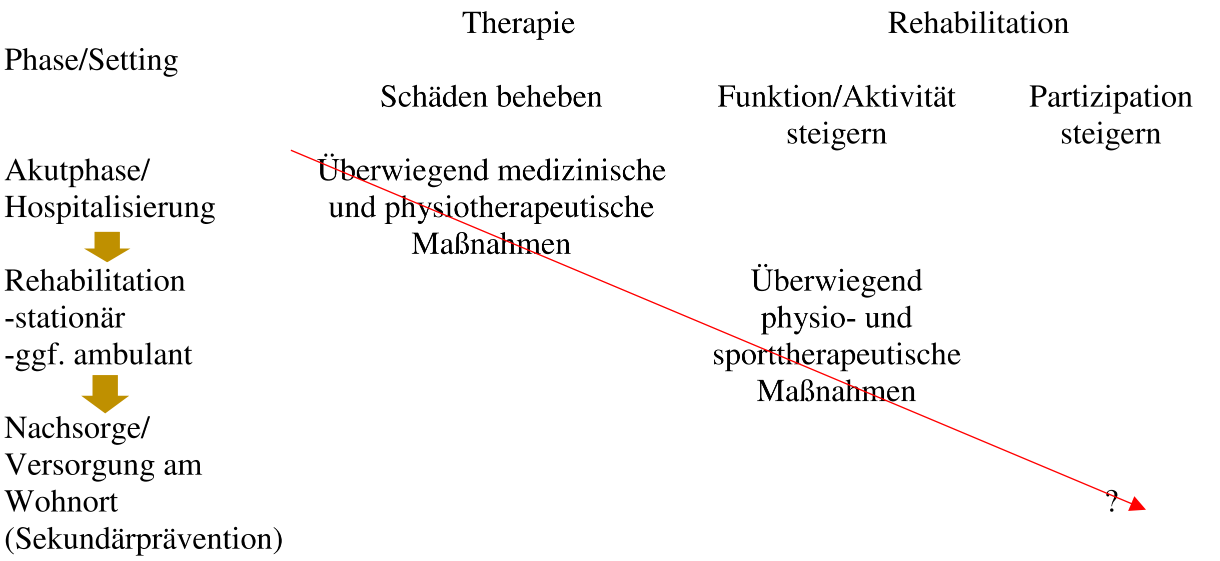

Abbildung 2: Verlauf der Genesung / Rehabilitationskette in Anlehnung an Schüle 2004 (S.26 (Schüle & Huber, 2004))

Diese mangelhafte Versorgung im Übergang von stationärer zu ambulanter Betreuung begründet das Interesse an der Erfassung, Quantifizierung und Verbesserung der Mobilität in dieser kritischen Phase (Krumholz, 2013; Ommen et al., 2007).

Nicht nur aus individueller Perspektive, sondern auch aus Angehörigen- und gesamtgesellschaftlicher (auch wirtschaftlicher) Perspektive ist die Verbesserung der Mobilität in der poststationären Phase ein wichtiges Ziel der sekundären und tertiären Prävention bei älteren Menschen. Neben Ansätzen zur Veränderung der Umwelt (Mollenkopf & Flaschentraeger, 2001) (wie beispielsweise in Projekten wie „Älter werden in Balance“ mit dem Ziel des Ausbaus bewegungsförderlicher Strukturen für ältere Menschen in den Kommunen und Pflegeeinrichtungen) oder über verbesserte Hilfsmittelversorgung (Bertrand et al., 2017) ist ein weiterer wichtiger Ansatz, durch körperliches Training die individuellen Voraussetzungen für Mobilität zu verbessern.

Dementsprechend liegt die Forderung nach geeigneten zielgruppengerechten Trainings- und Aktivitätsprogrammen zur Verbesserung der individuellen Mobilität nahe, die auch Aspekte der Motivation zur Förderung der Adhärenz und Nachhaltigkeit berücksichtigen.

1.3 Definition, Bedeutung und Konzept von „Mobilität“ und „Life-Space Mobilität“

Während sich Mobilität im engeren Sinn eher auf die körperliche Fähigkeit zur Bewegung (wie Gehen, Rennen etc.) bezieht, ist unter Mobilität im weiteren Sinne die allgemeine Fähigkeit zur Fortbewegung gemeint, die zum Erreichen von Zielen in der räumlichen Umgebung und zur Verrichtung alltäglicher Aktivitäten erforderlich ist. Mobilität kann somit definiert werden als „Freiheit der Fortbewegung in all ihren Formen“ (Satariano et al., 2012). Mobilität geht damit über das reine Gehen hinaus, integriert Aspekte der Motivation und inkludiert auch Barrieren, die das gesamte Ausmaß der Mobilität eines Individuums beeinflussen. In diesem Sinn ist Mobilität die Voraussetzung für die Bewältigung alltagsrelevanter Aktivitäten (Rantanen, 2013), für eine autonome Lebensführung und eine uneingeschränkte Teilhabe am gesellschaftlichen Leben (Johnson et al., 2020; Webber et al., 2010). Mobilität ist auch Selbstzweck, da Bewegung mit vielen positiven Folgen für die Gesundheit und die Lebensqualität verknüpft ist (Rantakokko et al., 2016; Rantakokko et al., 2013; Simonsick et al., 2005). Eine gute Mobilität gilt als Schlüssel zum Erhalt der Selbstständigkeit im höheren Lebensalter (Frank & Patla, 2003; Patla & Shumway-Cook, 1999).

1.3.1 Bedeutung von (Life-Space) Mobilität

Die Bedeutung von Mobilität zeigt sich auch darin, dass sie aus subjektiver Perspektive zu den zentralen Themen von älteren Menschen mit Risiko für Mobilitätsverluste gehört (Fried et al., 2011). Insbesondere außerhäusliche Mobilität ist eine zentrale Determinante für die Aufrechterhaltung von Lebensqualität und gesellschaftlicher Teilhabe im Alter und auch von besonderer Relevanz für die Gesundheit (Shimada, Ishizaki, et al., 2010; Simonsick et al., 2005). Dem räumlichen Aspekt der Mobilität wird im Konzept der Life-Space Mobilität Rechnung getragen. Life-Space Mobilität beschreibt das Aktivitätsverhalten einer Person in der räumlichen Umgebung und lässt – je nach Instrument – neben den funktionellen Aspekten auch solche der Partizipation miteinfließen (Johnson et al., 2020; Taylor et al., 2019; Webber et al., 2010). “Life-space really reflects an individual's participation in life,” – so beschrieb Richard Allman, einer der Initiatoren des „University of Alabama at Birmingham Life-Space Assessments“, das Konzept der Life-Space Mobilität und erläutert weiter: “That concept is going to be more and more valuable as we use it to dig even deeper into how we help people continue to live meaningful lives.” (Shepard, 2010).

1.3.2 Operationalisierung von Life-Space Mobilität

Gezielt im Kontext von Mobilität wurde der Begriff „Life-Space“ erstmalig von May et al. 1985 verwendet, bei der Vorstellung des ersten Assessment Instruments zur Erfassung der “Life-Space Mobilität”, der Mobilität in der räumlichen Umgebung (May et al., 1985). Heute sind verschiedene Life-Space Assessment Instrumente bekannt und insbesondere im englischsprachigen Forschungsraum weit verbreitet (Johnson et al., 2020; Taylor et al., 2019). Die meisten der Instrumente zur Erfassung von Life-Space Mobilität berücksichtigen neben der funktionellen/motorischen Leistungsfähigkeit auch soziale oder kontextuelle Unterstützung (vgl. (Baker et al., 2003; Tinetti & Ginter, 1990).

Die Operationalisierung erfolgt über eine Einteilung der räumlichen Umgebung in bestimmte typisch abgegrenzte Life-Space Zonen. Je nach Instrument werden diese Zonen unterschiedlich definiert. Häufig werden die Zonen entsprechend dem „University of Alabama at Birmingham Life-Space Assessment“ (UAB-LSA) (Baker et al., 2003) als am häufigsten eingesetztes Instrument (Taylor et al., 2019) eingeteilt.

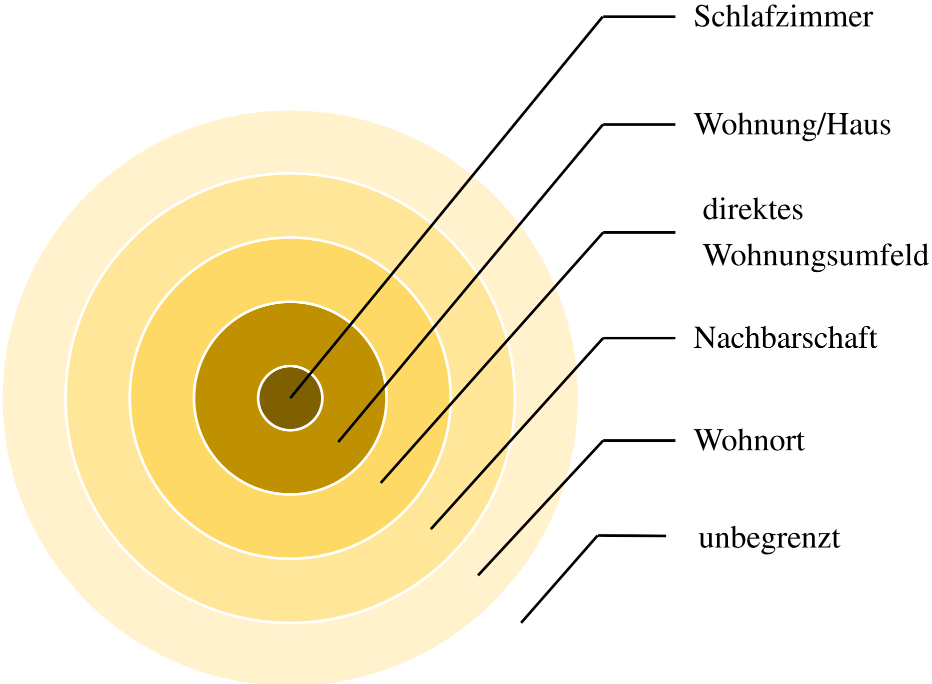

Abbildung 3: Mögliche Operationalisierung der Life-Space Mobilität mit verschiedenen Life-Space Zonen (angelehnt an (Peel et al., 2005)

Die Zonen umfassen für im häuslichen Umfeld lebende Menschen das eigene Schlafzimmer, die anderen Räumlichkeiten in der eigenen Wohnung (oder im eigenen Haus), den Außenbereich des Hauses (wie Terrasse oder Garten), die Nachbarschaft, den gesamten Wohnort und Gebiete außerhalb des Wohnortes (Baker et al., 2003; Peel et al., 2005) (siehe Abbildung 3). Deutliche Unterschiede in Bezug auf die Aufteilung der Zonen lagen für institutionalisierte Settings vor bedingt durch die spezifische Architektur. Die Aktivitäten in den verschiedenen Zonen geben auch Auskunft über den Grad der Partizipation am öffentlichen Leben, da Aktivitäten außerhalb der eigenen Wohnung als Voraussetzung für eine selbstständige Lebensführung und weitreichendere soziale Teilhabe gelten (Rosso et al., 2013).

Abzugrenzen ist der Begriff der „Life-Space Mobilität" von der „Community mobility", die von Patla & Shumway-Cook definiert ist als Fortbewegung außerhalb der häuslichen Umgebung ("locomotion in environments outside the home"; (Patla & Shumway-Cook, 1999), wohingegen Life-Space Mobilität auch die Aktivitäten, die im Haus stattfinden, beinhaltet.

1.4 Einflussfaktoren der Life-Space Mobilität

Mobilität wird in dieser Arbeit als komplexes, multidimensionales Konstrukt betrachtet, dementsprechend gibt es viele unterschiedliche Einflussfaktoren. Gemäß dem Mobilitäts-Modell von Webber gehören dazu Faktoren wie physischer, kognitiver, psychosozialer und finanzieller Status, Bedingungen der Umgebung sowie soziodemographische Faktoren (Webber et al., 2010) (siehe Abbildung 4).

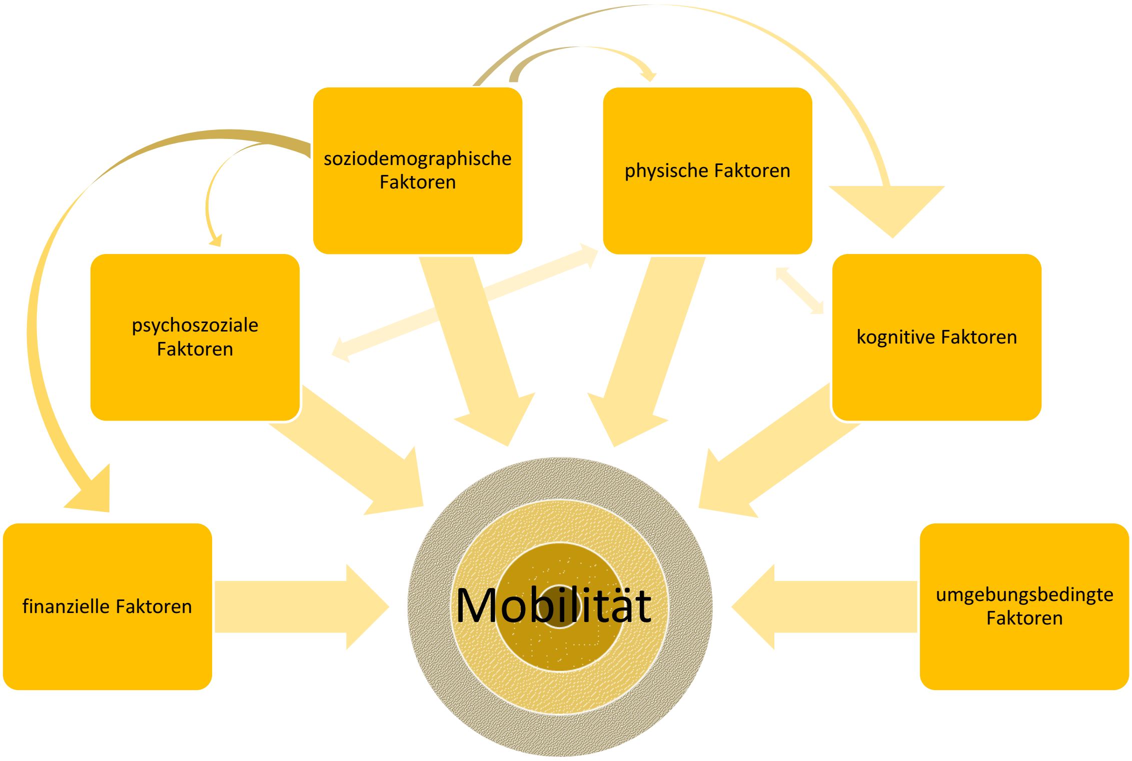

Abbildung 4: Einflussfaktoren auf die (Life-Space) Mobilität aus verschiedenen Domänen (in Anlehnung an (Webber et al., 2010)

Die empirische Gültigkeit des theoriebasierten Modells von Webber et al. konnte von Umstattd Meyer et al. in einer Stichprobe von 6112 älteren Personen gezeigt werden (Umstattd Meyer et al., 2014). Zudem wurden in verschiedenen wissenschaftlichen Studien Zusammenhänge zwischen der Life-Space Mobilität und einzelnen Faktoren aus den verschiedenen Domänen des Modells aufgezeigt. So konnten Assoziationen der Life-Space Mobilität mit nicht (oder kaum) veränderbaren Variablen wie Alter (Tsai et al., 2015), Geschlecht (Peel et al., 2005), Bildungsniveau (Eronen et al., 2016), finanziellem Status (Peel et al., 2005; Phillips et al., 2015), Umgebungsbedingungen (Portegijs et al., 2017; Rantakokko et al., 2015), sowie mit modifizierbaren Faktoren wie motorischer Kapazität (Peel et al., 2005; Portegijs et al., 2014), psychologischen Aspekten (Sturzangst (Auais et al., 2017; Uemura et al., 2013) oder Depression (Polku et al., 2015)) oder Faktoren der sozialen Unterstützung (Auais et al., 2017) aufgezeigt werden.

Viele der oben genannten Faktoren werden wesentlich direkt durch den Alterungsprozess oder indirekt durch mit dem Alterungsprozess assoziierte Ereignisse (Erkrankungen, Verlust von nahestehenden Personen, Renteneintritt etc.) beeinflusst (Ferrucci et al., 2016; Freiberger et al., 2020).

1.5 Einschränkungen der Life-Space Mobilität

Trotz einer großen Vielseitigkeit des Alternsprozesses, ist das körperliche Altern vor allem ein Abbauprozess, mit erhöhtem Risiko für verschiedene Erkrankungen bei älteren Menschen (Franceschi et al., 2018). Einschränkungen oder Verluste im Bereich der physischen Domäne umfassen beispielsweise sensorielle Defizite oder Einschränkungen der motorischen und funktionellen Leistungsfähigkeit. Typische Verläufe für den Verlust motorischer und funktioneller Fähigkeiten gehen von komplexen schweren Tätigkeiten (wie schwere Hausarbeit) und die Balance verlangenden Tätigkeiten aus, weiter über Tätigkeiten mit größerer Ausdauerkomponente (wie Strecken über 400 Meter gehen) und können schließlich zu Einschränkungen in den Basisaktivitäten Aufstehen, Gehen, Treppensteigen führen (Ferrucci et al., 1998; Kingston et al., 2012). Ungünstige soziale Faktoren oder eine ungünstige räumliche Umgebung können die Einschränkungen in der Mobilität im Allgemeinen und insbesondere auch der Mobilität in der Umgebung (im „Life-Space“) weiter verstärken (Balfour & Kaplan, 2002; Mollenkopf et al., 1997). Auf die Auswirkungen kognitiver Einschränkungen wird aufgrund ihrer Relevanz im Rahmen dieser Dissertation im nächsten Kapitel detaillierter eingegangen.

1.5.1 Einfluss der kognitiven Einschränkungen auf die Life-Space Mobilität

Verluste der Kognition zeigen sich beispielsweise in reduzierter Merkfähigkeit, Informationsverarbeitungsgeschwindigkeit und Handlungsplanung/ Exekutivfunktionen (DeCarli, 2003). Das Spektrum des kognitiven Abbaus von älteren Personen reicht von altersgemäßen Entwicklungen zu leichten kognitiven Einschränkungen hin zu demenziellen Erkrankungen. Diese subklinischen kognitiven Einschränkungen Defizite werden häufig als „Mild Cognitive Impairment“ bezeichnet und sind von großer Relevanz, da sie als Übergangsstadium gelten, jährlich entwickeln 5 bis 17% der Betroffenen eine Demenz (Jongsiriyanyong & Limpawattana, 2018). Die Prävalenz von „Mild Cognitive Impairment“ liegt bei den über 60-jährigen zwischen 15 und 20% (Petersen et al., 2018). Bei kognitiven Einschränkungen gehören komplexe Aktivitäten zu den ersten Tätigkeiten, die aufgegeben werden (Njegovan et al., 2001). Dazu gehört auch die außerhäusliche Mobilität (Wahl et al., 2013; Wettstein, Wahl, Shoval, et al., 2014; Wettstein et al., 2015). Aktivitäten wie Reisen oder Nutzung der öffentlichen Verkehrsmittel stellen Interaktionen mit der Umwelt dar, für die kognitive Prozesse erforderlich sind. Kompetenzen in Verhaltensplanung, -initiierung, -ausführung und -kontrolle werden benötigt, genauso werden für das Zurücklegen längerer Distanzen häufig das Kurz- und Langzeitgedächtnis benötigt (Erinnern von Wegstrecken oder Straßennamen) (Wettstein, Wahl, & Diehl, 2014). Zu den typischen Krankheitssymptomen der kognitiven Einschränkung (wie Beeinträchtigungen des Gedächtnisses, der Orientierung, der Aufmerksamkeit oder der Exekutivfunktionen) können auch psychische und Verhaltenssymptome kommen (wie Apathie, Depression, Agitiertheit) (Martin & Velayudhan, 2020), zudem können auch indirekte Folgen wie Angstgefühle und/oder Scham als Reaktion auf die kognitive Einschränkung entstehen und den Rückzug in die häusliche Umgebung verstärken (Weyerer, 2005).

Erschwerend kommt hinzu, dass sich kognitive und funktionelle Einschränkungen wechselseitig negativ beeinflussen (Auyeung et al., 2008; Buchman et al., 2011; Buchman et al., 2012). Mit zunehmendem Alter werden vermehrt kognitive Prozesse zur Gangkontrolle eingesetzt und benötigt (Freiberger, 2018). Diese Prozesse treiben die krankheitsbedingte Einschränkung der Alltagskompetenz und der Mobilität von Personen mit Einschränkungen der kognitiven und physischen Funktionen voran (Pedersen et al., 2014). Auch in Bezug auf das Sturzrisiko zeigt sich die negative Interaktion von körperlichen und kognitiven Einschränkungen: Ältere Menschen mit kognitiven Einschränkungen stürzen zwei bis drei Mal häufiger als ältere Menschen mit intakter Kognition (Beauchet et al., 2019).

1.5.2 Konsequenzen für die Life-Space Mobilität

Die genannten Entwicklungen können zu einer Reduktion der mobilitätsrelevanten Kompetenzen führen. In der Konsequenz kann der genutzte Lebensraum einer Person mit kognitiver Einschränkung immer eingeschränkter werden (Al Snih et al., 2012; Allman, 2006; Barnes et al., 2007). Duggan et al. beschreiben in diesem Zusammenhang das Model einer „kleiner werdenden Welt" („shrinking world", siehe Abbildung 5) bei Personen mit kognitiver Einschränkung (Duggan et al., 2008), die im Rückzug in das eigene häusliche Umfeld enden kann (Ornstein et al., 2015; Smith et al., 2016) als vertrautem geschützten Raum, in dem Einschränkungen der räumlichen Orientierung gut kompensiert werden können.

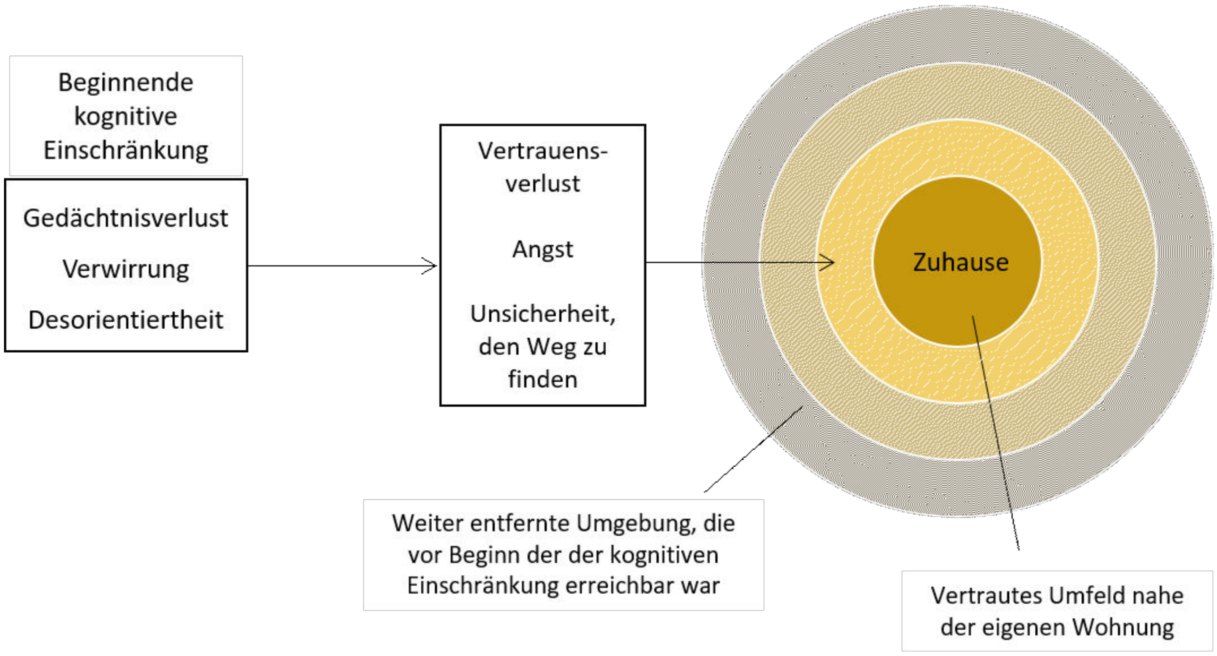

Abbildung 5: *Modell einer durch kognitive Einschränkungen kleiner werdenden Welt nach Duggan et al., 2008*

Mobilitätseinschränkungen in der räumlichen Umgebung gehören sehr häufig zu den ersten Markern für den Verlust der Selbstständigkeit (Shumway-Cook et al., 2003). Dies zeigt sich auch darin, dass eine reduzierte Life-Space Mobilität mit einem erhöhten Risiko für Institutionalisierung (Sheppard et al., 2013) und einer gesteigerten Abhängigkeit von anderen Personen (Verghese & Xue, 2010) verbunden ist. Die hohen Assoziationen von Life-Space Mobilität und für die Gesundheit und Mobilität relevanten Parametern verdeutlichen die Bedeutung des Konzepts als Marker für den Grad der Selbstständigkeit. Sie liefern jedoch auch Hinweise auf das ungünstige Risikoprofil in Bezug auf Mobilitätsverluste von Personen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation: Sowohl eine reduzierte allgemeine Gesundheit und funktionelle Leistungsfähigkeit (Al Snih et al., 2012; Curcio et al., 2013; Peel et al., 2005; Smith et al., 2016) als auch eine geringere kognitive Leistungsfähigkeit (Allman, 2006; Barnes et al., 2007; Curcio et al., 2013) sowie akute medizinische Ereignisse und die Hospitalisierung (Brown, Redden, et al., 2009; Brown et al., 2007) sind negativ mit Life-Space Mobilität assoziiert.

1.6 Verbesserung der Mobilität, mit Fokus auf der Life-Space Mobilität, nach Entlassung aus der geriatrischen Rehabilitation

Zur Verbesserung der Mobilität nach Entlassung aus der Rehabilitation und um die Versorgungslücke in dieser Phase zu schließen, bieten sich, auch unter Berücksichtigung wirtschaftlicher Gesichtspunkte, kostengünstige, niedrigschwellige, heimbasierte Trainingsprogramme an, welche sich als effektiv bei Menschen mit fortgeschrittener kognitiver Einschränkung gezeigt haben (de Almeida et al., 2020), die allerdings nicht als Nachsorgeprogramme im Anschluss an eine Rehabilitation evaluiert wurden. Abgesehen von der Pilotstudie (Hauer et al., 2017) war kein auf Heimtraining zur Stärkung körperlicher Leistungsfähigkeit und Aktivität basierendes Nachsorgeprogramm bekannt, welches speziell für Menschen mit kognitiver Einschränkung entwickelt wurde.

Einige randomisierte kontrollierte Studien zu heimbasiertem Training wurden in gemischten Populationen mit Teilnehmenden mit und ohne kognitive Einschränkungen durchgeführt, jedoch ohne spezielle Strategie, um die Personen mit kognitiver Einschränkung zu unterstützen (Fairhall et al., 2012; Latham et al., 2014; Salpakoski et al., 2014; Sherrington et al., 2004; Tsauo et al., 2005; Turunen et al., 2020). Motivationsprogramme zur Unterstützung der anvisierten Verhaltensänderung wurden in einigen dieser Studien eingesetzt (Fairhall et al., 2012; Latham et al., 2014; Salpakoski et al., 2014; Turunen et al., 2020), keine jedoch war auf Personen mit kognitiver Einschränkung zugeschnitten, obwohl Menschen mit kognitiven Einschränkungen von speziell auf sie zugeschnittenen Methoden profitieren (Huger et al., 2009). Die Ergebnisse dieser Studien waren heterogen, es wurden Steigerungen der körperlichen Leistungsfähigkeit berichtet (Fairhall et al., 2012; Hauer et al., 2017; Latham et al., 2014; Sherrington et al., 2004), aber auch ausbleibende Effekte (Salpakoski et al., 2014; Tsauo et al., 2005; Turunen et al., 2020). Genauso verhielt es sich mit der körperlichen Aktivität, die sowohl objektiv (Turunen et al., 2020) als auch subjektiv (Hauer et al., 2017; Sherrington et al., 2004) erfasst wurde. Effekte auf psychosoziale Parameter wie Sturzangst (Latham et al., 2014; Sherrington et al., 2004), Lebensqualität (Tsauo et al., 2005) oder Life-Space Mobilität (Fairhall et al., 2012; Ullrich et al., 2020) wurden kaum berichtet. Interventionen zur Steigerung der Life-Space Mobilität wurden bislang nur wenige durchgeführt, keine speziell bei Personen mit kognitiver Einschränkung, und von den Studien in gemischten Populationen (Personen mit und ohne kognitive Einschränkungen) wurden nur zwei im häuslichen Umfeld durchgeführt (Fairhall et al., 2012; Makizako et al., 2019), beide jedoch ohne Fokus auf die Versorgungssituation im Übergang vom stationären zum ambulanten Setting. Aspekte der Life-Space Mobilität wurden bislang im Krankenhaus nicht erfasst, fokussiert oder in den Therapien berücksichtigt (entsprechend existierten bislang auch keine adäquaten Messinstrumente zur Erfassung der Life-Space Mobilität bei Aufenthalten von unter zwei Wochen in institutionellen Einrichtungen (vgl. (Hauer et al., 2021; Hauer et al., 2020; Tinetti & Ginter, 1990). Lediglich eine Studie bei älteren PatientInnen mit intakter Kognition ist bekannt, durch die mit Hilfe einer Trainingsintervention während des Krankenhausaufenthalts die Life-Space Mobilität positiv beeinflusst wurde (Brown et al., 2016).

1.7 Fragestellungen / Ziele im Rahmen dieser Arbeit

Die Ziele der vorliegenden Dissertation beinhalteten erstens Assessmentinstrumente zur Erfassung der Life-Space Mobilität zu identifizieren, entwickeln und validieren mit Blick auf die speziellen Bedürfnisse von Personen mit kognitiven Einschränkungen, zweitens den Status der Life-Space Mobilität bei Personen mit kognitiven Einschränkungen nach der Rehabilitation zu beschreiben und Prädiktoren zu ermitteln und drittens die Effekte eines poststationären Heimtrainingsprogramms auf Faktoren der Mobilität in der Zielgruppe zu untersuchen.

1.7.1 Teilstudie I - Methodenentwicklung

Trotz der hohen Relevanz von Life-Space Mobilität für ältere Menschen als Voraussetzungen für Selbstständigkeit und Partizipation lag zu Beginn des Promotionsvorhabens noch kein validierter Fragebogen zur Erfassung der Life-Space Mobilität für den deutschsprachigen Raum vor. Ebenso gab es keinen Fragebogen, der für die besondere Population von Menschen mit kognitiven Einschränkungen konzipiert und validiert war. Teilstudie I befasst sich daher mit der Identifikation von verfügbaren Fragebögen und der Entwicklung neuer Methoden zur Erfassung der Life-Space Mobilität. Dabei standen die Entwicklung und die Validierung von spezifisch angepassten Fragebögen für Populationen mit besonders hohem Risiko für Verlust der Life-Space Mobilität, wie Personen mit kognitiver Einschränkung, im Fokus. Im Rahmen der Untersuchungen haben sich weitere Forschungslücken ergeben, die zu weiteren Validierungsstudien von speziell entwickelten Life-Space Mobilitäts - Fragebögen für Menschen im stationären Setting geführt haben. Die Fragestelllungen in Teilstudie I umfassen folgende Punkte:

Fragestellungen Teilstudie I - Methodenentwicklung: Wie lässt sich die Life-Space Mobility bei Personen mit kognitiver Einschränkung erfassen?	
- Welche Fragebögen zur Erfassung der Life-Space Mobilität gibt es? Werden die wichtigsten psychometrischen Gütekriterien erfüllt? Welche der Fragebögen sind in deutscher Sprache verfügbar?	Manuskript III
- Wie kann ein Fragebogen optimal an die Bedürfnisse von Personen mit kognitiven Einschränkungen angepasst werden?	Manuskript IV
- Inwiefern erfüllt das neu entwickelte „Life-Space Assessment in Persons with Cognitive Impairment“ (LSA-CI) zur Erfassung der Life-Space Mobilität bei im häuslichen Umfeld	Manuskript IV und V

	lebenden älteren Menschen mit (und ohne) kognitiver Einschränkung die psychometrischen Gütekriterien?	
-	Wie lässt sich die Life-Space Mobilität einteilen?	Manuskript VI
-	Inwiefern erfüllt das „Life-Space Assessment in Institutionalized Settings" (LSA-IS; als Selbst- oder Proxy-Bericht) zur Erfassung der Life-Space Mobilität bei geriatrischen Akut-PatientInnen mit (und ohne) kognitiver Einschränkung die psychometrischen Gütekriterien?	Manuskript VII und VIII

1.7.2 Teilstudie II - Epidemiologische Untersuchung

Aufbauend auf den neu entwickelten und validierten Assessmentmethoden wurde im nächsten Schritt die Life-Space Mobilität von älteren Menschen mit kognitiver Einschränkung analysiert in einer besonders kritischen Lebenssituation, im Übergang von der stationären Betreuung nach Rehabilitation in die ambulante Versorgung im häuslichen Umfeld. Neben der Analyse des Ist-Zustandes lag ein Fokus auf der Ermittlung relevanter modifizierbarer Faktoren sowie auf der Identifikation besonders von Mobilitätseinschränkungen bedrohter Personen. Die Determinanten können als Grundlage für die Steuerung von therapeutischen Maßnahmen dienen, aber auch für die Auswahl besonders bedürftiger Personen genutzt werden. In Teilstudie II wurden somit folgende Fragestellungen bearbeitet:

Fragestellungen Teilstudie II - Epidemiologische Untersuchung: Wie ist der Status der Life-Space Mobilität bei Personen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation und welche Einflussfaktoren sind besonders relevant?		
-	Wie ist der Status der Life-Space Mobilität bei älteren Menschen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation?	Manuskript IX
-	Was sind relevante nicht-veränderbare und modifizierbare Faktoren mit Einfluss auf die Life-Space Mobilität?	Manuskript IX und X
-	Welche Personengruppen weisen ein besonders hohes Risiko für eine geringe Life-Space Mobilität auf?	Manuskript IX

1.7.3 Teilstudie III – Interventionseffekte

Im nächsten Schritt folgt die Darstellung der Ergebnisse des spezifisch entwickelten Heimtrainingsprogramms zur Verbesserung der allgemeinen Mobilität und der Life-Space Mobilität im Speziellen. Ein solcher Ansatz in Form eines Heimtrainings zur Verbesserung der motorischen Leistungsfähigkeit und körperlichen Aktivität, kombiniert mit einem Motivationsprogramm, welches auf die Veränderung der Wahrnehmung, Selbsteinschätzung und Motivation und bessere Bewältigung der individuellen Barrieren abzielt (Prohaska et al., 2011), lag für die Phase nach der Rehabilitation bei der Gruppe der hochaltrigen, multimorbiden Menschen mit kognitiven Einschränkungen zu Studienbeginn nicht vor. Lediglich die Ergebnisse des assoziierten Pilotprojekts gaben Hinweise auf die

Durchführbarkeit von heimbasiertem poststationärem Training und lieferten erste Hinweise zur Effektivität in Bezug auf körperliche Leistungsfähigkeit und körperliche Aktivität (Hauer et al., 2017). In Teilstudie III wurden daher die Effekte eines Heimtrainingsprogramms mit zielgruppenspezifischen innovativen motivationspsychologischen Strategien zur nachhaltigen Verbesserung der motorischen Leistungsfähigkeit, der körperlichen Aktivität, des psychosozialen Status und der Life-Space Mobilität für poststationäre geriatrische PatientInnen mit kognitiver Einschränkung untersucht. Übergeordnetes Ziel ist die Verbesserung der poststationären Versorgung und Sicherung der Selbstständigkeit der PatientInnen im häuslichen Umfeld, da wie bereits dargelegt Menschen mit kognitiven Einschränkungen nach Entlassung aus der Rehabilitation ins häusliche Umfeld von Verlusten der Life-Space Mobilität bedroht sind. Die in der stationären Versorgung erzielten rehabilitativen Fortschritte gehen im häuslichen Umfeld ohne adäquate Förderung schnell verloren, und viele dieser PatientInnen ein hohes Risiko für Verlust der Selbstständigkeit und Institutionalisierung aufweisen.

Für Teilstudie III wurden folgende Forschungsfragen zur Effektivität des Programms formuliert:

Fragestellungen Teilstudie III - Interventionseffekte: Ist ein zielgruppenspezifisches poststationäres Heimtrainingsprogramm mit integriertem Motivationskonzept bei Personen mit kognitiver Einschränkung durchführbar und effektiv?	
- Welche Effekte hat das Heimtrainingsprogramm in Bezug auf funktionelle Leistungsfähigkeit und körperliche Aktivität?	Manuskript XI
- Welche Effekte hat das Heimtrainingsprogramm in Bezug auf psychosoziale Parameter?	Manuskript XI
- Welche Effekte hat das Heimtrainingsprogramm in Bezug auf Life-Space Mobilität?	Manuskript XII
- Wie ist die Adhärenz zu Heimtraining und Motivationskonzept?	Manuskript XIII

2 Methodik: Kurzvorstellung der Rahmenprojekte

Die Projekte, innerhalb derer die einzelnen Teilstudien durchgeführt wurden, werden in diesem Kapitel vorgestellt. Im Anschluss an die Publikation zu der Pilotstudie sind zehn der berücksichtigten Manuskripte im Rahmen des HeikE-Projekts entstanden und zwei Manuskripte im Rahmen des PAGER-Projekts. Die Untersuchungen im Rahmen des PAGER Projektes stellen eine Ergänzung der Teilstudie I (Methodenentwicklung) dar zur Erfassung der Life-Space Mobilität im institutionalisierten Setting. Daher wird die Studie hier nur sehr kurz vorgestellt.

2.1 Projekt "HeikE" - Heimtraining bei Kognitiver Einschränkung

Das HeikE-Projekt beinhaltete die Entwicklung, Durchführung und wissenschaftliche Untersuchung eines Heimtrainingsprogramms für poststationäre geriatrische PatientInnen mit kognitiver Einschränkung zur Verbesserung der poststationären Versorgung (Laufzeit: Januar 2015 bis Dezember 2018). Die Durchführung der vom Sozialministerium Baden Württemberg und dem Kommunalverband für Jugend und Soziales Baden-Württemberg geförderten Studie erfolgte am AGAPLESION Bethanien Krankenhaus / Geriatrisches Zentrum am Klinikum der Universität Heidelberg unter der Leitung von Prof. Dr. Klaus Hauer (Ausschreibung zur Förderung von Modellvorhaben nach § 45c SGB XI zur Weiterentwicklung der Versorgungsstrukturen und Versorgungskonzepte insbesondere für demenzkranke Pflegebedürftige). Gemäß §45c SGB IX zielte die Intervention des HeikE-Projekts darauf ab, die poststationäre Versorgungssituation für die bislang unzureichend versorgten geriatrischen PatientInnen mit kognitiven Einschränkungen nach Entlassung aus der geriatrischen Rehabilitation durch ein zielgruppengerechtes, effektives, kostengünstiges und einfach zu implementierendes Heimtrainingsprogramm zu verbessern. Die in der stationären Versorgung erzielten rehabilitativen Fortschritte gehen im häuslichen Umfeld ohne adäquate Förderung schnell verloren, was wiederum mit einem hohen Risiko für Pflegeheimeinweisungen und soziale Isolation verbunden ist. Die vulnerable Zielgruppe hat aufgrund des hohen Alters, Multimorbidität und kognitiver Schädigung besondere Hürden zu bewältigen. Aufbauend auf erfolgreichen Vorarbeiten, die im AGAPLESION Bethanien Krankenhaus durchgeführt worden sind (Hauer et al., 2002; Hauer et al., 2012; Huger et al., 2009; Lemke et al., 2018; Schwenk et al., 2010), wurde zunächst in einer Pilotstudie mit Wartelisten-Kontroll-Design die Durchführbarkeit und Effektivität eines poststationären Heimtrainingsprogramms für Menschen mit kognitiver Einschränkung gezeigt.

MANUSKRIPT I: Effects of Standardized Home Training in Patients with Cognitive Impairment following Geriatric Rehabilitation: A Randomized Controlled Pilot Study

Die randomisierte kontrollierte Pilotstudie mit 34 geriatrischen PatientInnen (durchschnittliches Alter: 81,9 ± 5,7 Jahre alt) mit kognitiver Einschränkung (durchschnittliche Punkte beim Mini Mental Status Examination (MMSE): 18,8 ± 4,7) wurde im Anschluss an die geriatrische Rehabilitation im häuslichen Umfeld der PatientInnen durchgeführt. Nach dem sechswöchigen Training wiesen die Teilnehmenden der Interventionsgruppe im Vergleich zur Wartelisten-Kontrollgruppe eine verbesserte funktionelle Leistungsfähigkeit auf (Short Physical Performance Battery (SPPB) (Guralnik et al., 1994): signifikante Verbesserungen im Gesamtscore (*p* = 0,012), Subtest 5-Chair-Rise Test (*p* = 0,007), Subtest Balance (*p* = 0,066)). Weiterhin zeigten die Teilnehmenden geringere klinisch relevante funktionelle Defizite (Performance Oriented Mobility Assessment (Tinetti, 1986): signifikante Verbesserungen im Gesamtscore (*p* = 0,006), Subtest Balance (*p* = 0,034), und Subtest Gangbild (*p* = 0,019)) und eine gesteigerte körperliche Aktivität (per Fragebogen erfasst: Assessment of Physical Activity for Older Persons Questionnaire (Hauer et al., 2011): signifikante Verbesserung im Gesamtscore (*p* = 0,05)), mit mittleren bis großen Effektstärken (eta^2 = 0,14 – 0,45). Die Effekte in der Interventionsgruppe waren im Vergleich zu den Effekten der Intervention in der Kontrollgruppe mit Zeitverzögerung (Wartelisten-Design) deutlich größer, was für einen zügigen Beginn der Trainingsintervention nach Entlassung spricht (Hauer et al., 2017).

(*Manuskript I: Hauer K, **Ullrich P**, Dutzi I, Beurskens R, Kern S, Bauer J, Schwenk M. Effects of Standardized Home Training in Patients with Cognitive Impairment following Geriatric Rehabilitation: A Randomized Controlled Pilot Study. Gerontology. 2017;63(6):495-506. doi: 10.1159/000478263. Epub 2017 Aug 17. IF: 5,140).*

Die erfolgreiche Evaluation des Pilotprogramms war die Grundlage für die Weiterentwicklung des Heimtrainingsprogramms im Rahmen des HeikE-Projekts. Ein wichtiger Bestandteil des HeikE-Heimtrainingsprogramms in Ergänzung zum Pilotprojekt war die Entwicklung einer zielgruppenspezifischen innovativen motivationspsychologischen Strategie zur nachhaltigen Motivationsbildung bei diesen PatientInnen mit kognitiver Schädigung. Im Studienprotokoll zur HeikE-Studie sind die Hintergründe und Informationen zu Studienablauf und -inhalten erläutert (siehe auch Studienregistrierung: https://www.isrctn.com/ISRCTN82378327).

MANUSKRIPT II: Development of a Home-Based Training Program for Post-Ward Geriatric Rehabilitation Patients with Cognitive Impairment: Study Protocol of a Randomized-Controlled Trail

Alle PatientInnen, die im Zeitraum von August 2015 und April 2017 eine Rehabilitationsmaßnahme absolviert haben, wurden auf das Erfüllen der in Tabelle 1 aufgeführten Einschlusskriterien geprüft. Eingeschlossen wurden geriatrische PatientInnen über 65 Jahre mit leichter bis moderater kognitiver Einschränkung, die nach der Rehabilitationsmaßnahme in ihr häusliches Umfeld zurückkehrten. Alle Assessments erfolgten im häuslichen Umfeld der Teilnehmenden, die Erfassung der Baseline-Daten T1 wurde vor der Randomisierung durchgeführt, T2 nach einem 12-wöchigen Heimtraining und T3 nach weiteren 12 Wochen als Follow-up.

Im Rahmen der randomisierten kontrollierten, doppelt verblindeten Studie mit Interventions- und Placebokontrollgruppe sollten 101 geriatrische PatientInnen nach ihrer Entlassung aus der Rehabilitation ein 12-wöchiges Heimtraining absolvieren.

Nach Entlassung aus der Rehabilitation wurden die Teilnehmenden in ihrem häuslichen Umfeld von einem verblindeten Assessor aufgesucht und untersucht zur Erfassung der Baseline-Daten T1. Die Randomisierung zur Interventions- oder Placebo-Kontrollgruppe erfolgte nach Erfassung der Baselinedaten. Im Anschluss erfolgte die erste von zwei Einweisungen in das Heimtrainingsprogramm oder die Einweisung in das Kontrollgruppenprogramm durch eine/n Trainer/-in. Nach zwölf Wochen erfolgte die Messung der Post-Interventionsdaten sowie ein weiterer Termin nach zwölf Wochen zur Erfassung der Follow-up Daten.

Tabelle 1 Einschlusskriterien für die HeikE-Studie

Einschlusskriterien:
Mini-Mental State Examination (MMSE) (Folstein et al., 1975): 17 bis 26 / Hinweis auf moderate kognitive Einschränkung (Jessen et al., 2017; Monsch et al., 1995; O'Bryant et al., 2008; Thalmann et al., 2002)
Alter ≥ 65 Jahre
4 Meter Gehfähigkeit (ohne Hilfsmittel)
wohnhaft innerhalb 30 km um das Studienzentrum
Entlassung nach Hause
keine terminale Erkrankung
kein Delir
deutschsprachig
schriftliche Einverständniserklärung

Der Studienablauf mit Inhalten ist in Abbildung 6 illustriert. Die Forschungshypothesen inkludierten eine trainingsinduzierte Steigerung der motorischen Leistungsfähigkeit (dokumentiert mit der Short Physical Performance Battery) und eine Steigerung der körperlichen Aktivität (gemessen mit dem PamSys Aktivitätssensor). Zu den Nebenzielkriterien gehörte die in dieser Arbeit fokussierte Steigerung der Life-Space Mobilität (Gesamtscore und Subscores) sowie Verbesserung in psychosozialen Parametern wie Sturzangst, Depression und Apathie in der Interventionsgruppe gegenüber der Kontrollgruppe. Aufgrund der engen Zusammenhänge von funktioneller Leistungsfähigkeit und körperlicher Aktivität wurden auch Verbesserungen der Life-Space Mobilität sowie aufgrund der Verknüpfungen von körperlicher und psychischer Gesundheit auch Effekte in Bezug auf psychosoziale Variablen erwartet.

Die Trainingsintervention für die Interventionsgruppe beinhaltete Übungen und Maßnahmen zur Steigerung der allgemeinen körperlichen Leistungsfähigkeit und der körperlichen Aktivität. Die Übungen wurden von den Teilnehmenden nach dem gemeinsamen Erlernen und Erproben mit dem/r Trainer/-in selbstständig im häuslichen Setting durchgeführt. Je drei Grundübungen zur Verbesserung des Gleichgewichts und der Kraft der unteren Extremitäten wurden an den Trainingszustand des Teilnehmenden angepasst. Die Übungen konnten in ihren Schwierigkeiten gesteigert werden. Ergänzt wurde das Heimtraining durch eine individuell festgelegte Gehstrecke, die nach Möglichkeit einmal täglich bewältigt wurde. Zwei Einweisungstermine, ein großes Poster mit den Trainingsübungen (siehe Manuskript I und II, Anhang C) und ein detailliertes Trainingsmanual mit ergänzenden Erläuterungen, Tipps und Empfehlungen zur Progression unterstützten das Erlernen und die Durchführung. Die Steuerung, Progression und Kontrolle des Trainings sowie die Unterstützung bei Problemen erfolgte über die weiteren drei Hausbesuche und die wöchentlichen Telefonate. Das Training wurde begleitet durch ein zielgruppenspezifisch angepasstes Motivationsprogramm, um die Verhaltensänderung positiv zu unterstützen und die Nachhaltigkeit zu sichern. Die Motivationsstrategie beinhaltete das Setzen von Zielen, das Führen eines Trainingstagebuchs zum Monitoring, soziale Unterstützung durch den/die Trainer/in und gezielte motivierende Hinweise auf Konsequenzen verbesserter Mobilität. Details zu den Komponenten des Motivationsprogramm sind auch im Manuskript XIII zu finden (Eckert, 2019).

Die Kontrollgruppe erhielt bei jedem Hausbesuch einen Newsletter: Zwei der Newsletter enthielten Informationen zu gesundem Trink- und Ernährungsverhalten und drei der Newsletter enthielten unspezifische Übungen in sitzender Position für Rumpf und obere und untere Extremitäten. Die Trainingsintensität wurde nicht gesteigert.

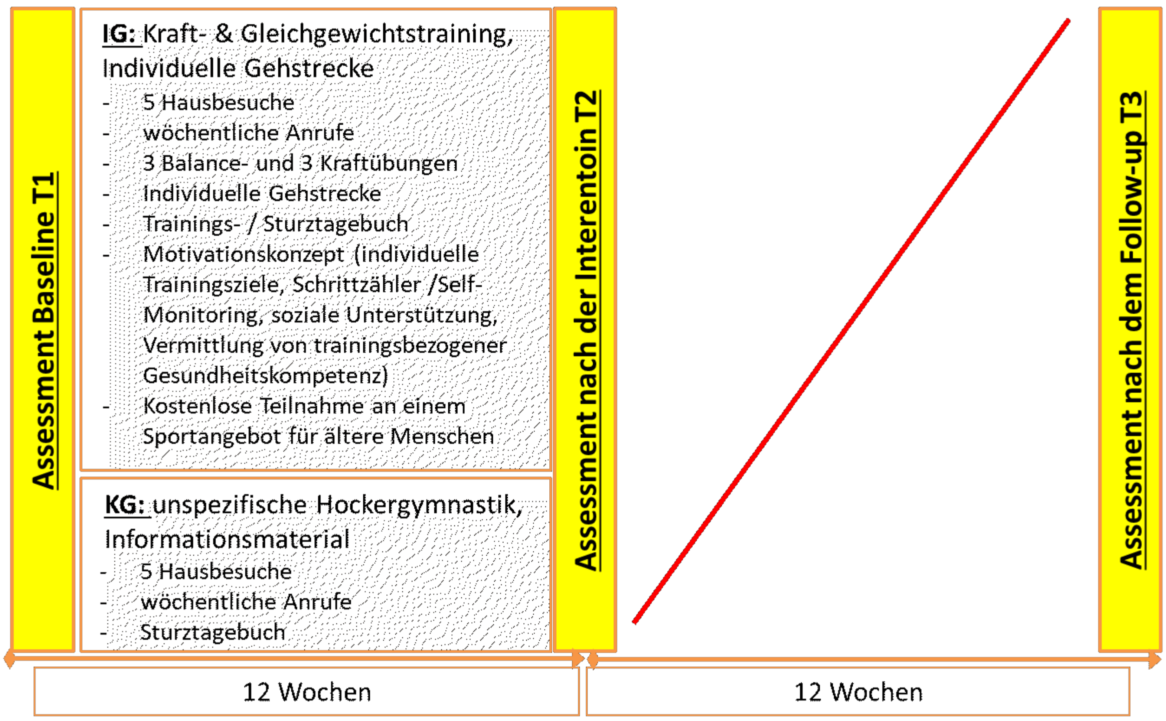

Abbildung 6: Studienablauf mit Inhalten

Primärziel der Heike-Studie war, die Effektivität des Programms im Hinblick auf die körperliche Leistungsfähigkeit und das körperliche Aktivitätsverhalten zu zeigen. Zu den Sekundärzielen gehörte die Entwicklung von adäquaten Methoden zur Erfassung verschiedener relevanter Parameter sowie die Überprüfung der Effektivität des Heimtrainingsprogramms in Bezug auf die Steigerung der Life-Space Mobilität (Bongartz et al., 2017).

*(Manuskript II: Bongartz M, Kiss R, **Ullrich P**, Eckert T, Bauer J, Hauer. Development of a home-based training program for post-ward geriatric rehabilitation patients with cognitive impairment: study protocol of a randomized-controlled trial. BMC Geriatr. 2017 Sep 12;17(1):214. doi: 10.1186/s12877-017-0615-0. IF: 3,921)*

2.2 Projekt „Pager“: Körperliche Aktivität von geriatrischen PatientInnen in der Frührehabilitation

Die PAGER-Studie („Physical Activity in Geriatric Early Rehabilitation“ / „Körperliche Aktivität von geriatrischen PatientInnen in der Frührehabilitation) hatte zum Ziel, die körperliche Aktivität von geriatrischen PatientInnen im Akutkrankenhaus zu Beginn und Ende des Aufenthalts zu erfassen und untersuchen. Neben dem primären Ziel der Studie (Untersuchung der körperlichen Aktivität in dieser Personengruppe mittels eines sensorgestützten Aktivitätsmonitors, die Bestimmung von potenziellen Prädiktoren und die Analyse von Veränderungen des Aktivitätsverhaltens während des Krankenhausaufenthalts) war ein zweites Ziel die Beschreibung und Analyse der Life-Space Mobilität in dieser Population anhand eines spezifisch angepassten Assessmentinstruments zur Erfassung der Life-Space Mobilität im stationären Setting. Das Life-Space Assessment für institutionalisierte Settings (LSA-IS) wurde im Rahmen dieser Studie entwickelt und validiert (siehe auch Studienregistrierung: Deutsches Register klinischer Studien, Nummer: DRKS00016028; https://www.drks.de/drks_web/navigate.do?navigationId=trial.HTML&TRIAL_ID=DRKS00016028).

Die PAGER-Studie stellte den Rahmen für die Validierungsstudien des an ein institutionelles Setting angepassten Instruments zur Erfassung der Life-Space Mobilität dar und wurde im Rahmen der Methodenentwicklung genutzt, um auch die Life-Space Mobilität von Personen in Krankenhaus, Rehabilitationsklinik oder Pflegeheim, welche sich durch setting-spezifische Einflussfaktoren und eine spezielle Architektur auszeichnen, erfassen zu können.

3 Teilstudie I – Methodenentwicklung: Erfassung von Life-Space Mobilität

Die Erfassung von Mobilität ist von Bedeutung für einzelne Personen, um den Mobilitätsstatus messen, Einschränkungen der Mobilität feststellen und angemessene Unterstützung oder Therapie anbieten zu können, aber auch im Rahmen von klinischen Studien. Hier liegen die Ziele darin, Mobilität und damit assoziierte Probleme definieren, vergleichen oder einordnen zu können, die Effektivität von Therapien oder Interventionen abbilden oder Zusammenhänge zwischen Mobilität und Risikofaktoren aufdecken zu können (Chung et al., 2015). Teilweise werden Assessmentinstrumente (insbesondere Assessmentinstrumente zur Selbstauskunft) auch zur patientenzentrierten Versorgung, Ressourcenallokation oder in der Industrie zur Zulassung und zum erweiterten Nutzennachweis genutzt (vgl. (Kirchberger et al., 2020).

3.1 Hintergrund zur Erfassung der Mobilität

Die Mobilität wurde im klinischen Kontext, aber auch in der Forschung überwiegend in Form von Tests der motorischen Leistungsfähigkeit / Kapazität oder körperlichen Aktivität erfasst (Soubra et al., 2019). Viele der bislang zur Erfassung der Mobilität entwickelten und eingesetzten Instrumente erfassen, gemessen an dem Modell von Webber (Webber et al., 2010); siehe auch Kapitel 1.4 Einflussfaktoren der Life-Space Mobilität) nur einzelne Aspekte der Mobilität wie die körperliche Leistungsfähigkeit (beispielsweise Gehen, Treppensteigen und Funktion der unteren Extremitäten) (Chung et al., 2015). Dabei wird häufig der Transfer der Fähigkeiten in die alltäglichen Aktivitäten nicht berücksichtigt, obwohl die motorische Kapazität nicht gleichzusetzen ist mit dem Verhalten im Alltag (Giannouli et al., 2016; Parker et al., 2001). Viele Mobilitätstests werden zudem unter künstlichen Bedingungen durchgeführt und reflektieren damit nicht, wozu eine Person unter Alltagsbedingungen mit diversen Störungen (wie Unebenheiten, laute Geräusche, Beeinträchtigungen durch andere Menschen) in der Lage ist (Frank & Patla, 2003). Mobilität, insbesondere außerhäusliche Mobilität, ist ein multidimensionales Konstrukt, welches kaum im Alltags-Setting von älteren Menschen operationalisiert wurde (Baker et al., 2003; Taylor et al., 2019). „Global Positioning Systems“ (GPS)-basierte Messungen werden zunehmend eingesetzt und haben den Vorteil der Objektivität, erfassen jedoch nur die außerhäusliche Mobilität, können nur bedingt die Art der Fortbewegung erfassen und müssen darüber hinaus vom Nutzer akzeptiert und getragen werden (Chung et al., 2021). Ein universal optimales Assessmentinstrument gibt es nicht: Methodische, aber auch praktische Aspekte führen zu unterschiedlichen Ansprüchen an das Instrument, jedoch werden insbesondere für die Rehabilitation Instrumente benötigt, die Mobilität im Sinne von Aktivität, dem Erfüllen der sozialen Rollen und der Partizipation messen (Bussmann & Stam, 1998).

Daher erscheint, gemessen an dem Mobilitäts-Modell von (Webber et al., 2010), das Konzept des Life-Space Assessment angemessen, um sowohl motorische Fähigkeiten im Sinne der Voraussetzung für Mobilität, aber auch motivationale Aspekte und Aspekte wie Partizipation zu erfassen (Stalvey et al., 1999). Fragebögen zur Erfassung der Life-Space Mobilität stellen gut untersuchte patientenzentrierte Gesundheitsindikatoren in der allgemeinen

Alterungsforschung dar (Johnson et al., 2020; Taylor et al., 2019). Die psychometrischen Gütekriterien eines Assessmentinstruments für eine bestimmte Population lassen sich jedoch nicht unbedingt auf andere Populationen übertragen. Zu Beginn der HeikE-Studie waren solche Fragebögen weder in deutscher Sprache verfügbar oder validiert, noch für besonders von Mobilitätseinbußen bedrohte Personengruppen wie ältere Menschen mit kognitiven Einschränkungen (oder auch während eines Aufenthalts in medizinischen Institutionen) konzipiert und validiert.

Die Gefahr bei der Verwendung von Fragebögen, gerade bei Personen mit kognitiver Einschränkung, liegt in der subjektiven Bewertung der Mobilität mit dem Risiko bewusster oder unbewusster Verzerrung (Bhandari & Wagner, 2006; Sallis & Saelens, 2000; Shephard, 2003), ihre Vorteile liegen in den geringen Kosten, der einfachen Handhabung und der relativ schnellen Datenerfassung. Die Voraussetzung für eine zuverlässige Erfassung des Mobilitätsstatus und auch der Mobilitätsveränderungen sind geeignete Messinstrumente, welche die psychometrischen Gütekriterien erfüllen, insbesondere Validität, Test-Retest Reliabilität, und Veränderungssensitivität (Kimberlin & Winterstein, 2008; Lamb & Keene, 2017; Roach, 2006). Darüber hinaus sollten die Instrumente gut durchführbar und auch praktisch und passend für die Zielgruppe sein (VanSwearingen & Brach, 2001). Daher ist die Prüfung der psychometrischen Gütekriterien von Assessmentinstrumenten eine wichtige Aufgabe im Rahmen der Gesundheits- und Rehabilitationsforschung.

Die im Rahmen dieser Dissertation untersuchten Gütekriterien sind Validität, Reliabilität, Veränderungssensitivität sowie Praktikabilität / Durchführbarkeit (siehe Tabelle 2).

Tabelle 2: *Relevante psychometrische Gütekriterien*

Validität	Validität bezeichnet in diesem Kontext den Grad der Genauigkeit, mit dem ein Assessmentinstrument das misst, was es vorgibt zu messen. Es gibt viele unterschiedliche Arten, Validität zu messen (vgl. (Mokkink et al., 2010)). Zu den häufig untersuchten und in diesem Kontext relevanten die konkurrente Validität, die bei Verfügbarkeit eines Goldstandards untersucht werden kann, indem das Instrument mit diesem verglichen wird. In Abwesenheit eines Goldstandards oder bei der Messung von Attributen, die nicht direkt erfasst werden können, wird in der Regel auf Berechnungen von Korrelationen mit verwandten Konstrukten oder Faktoren (Konstruktvalidität) zurückgegriffen, um die Gültigkeit eines Instruments darzulegen (Kimberlin & Winterstein, 2008).
Reliabilität	Unter Reliabilität wird die Zuverlässigkeit eines Instrumentes verstanden, zu unterschiedlichen Zeiten (Test-Retest-Reliabilität) oder bei unterschiedlichen Untersuchern (Inter-Rater-Reliabilität) zu demselben Ergebnis zu gelangen.
Veränderungs-sensitivität	Veränderungssensitivität bedeutet, dass intraindividuelle Veränderungen über die Zeit identifizieren lassen. Insbesondere bei Messinstrumenten, die zur Evaluation von Interventionen und Therapien eingesetzt werde, ist die Veränderungssensitivität relevant (VanSwearingen & Brach, 2001).
Praktikabilität /	Interpretierbarkeit bedeutet, dass eine Zuordnung einer

Durchführbarkeit / Interpretierbarkeit	allgemeinverständlichen Bedeutung zu einem Wertebereich möglich ist. Praktikabilität bezieht sich auf Aspekte wie Dauer, Akzeptanz beim Untersucher, Vorhandensein von Boden- und Deckeneffekten oder der Vollständigkeit bzw. Rate von fehlenden oder unvollständigen Antworten.

Die Ziele in Teilstudie I bestanden darin, verfügbare Instrumente systematisch zu sammeln und zu klassifizieren und geeignete Fragebögen zu entwickeln sowie umfassend unter Berücksichtigung von Durchführbarkeit, Validität, Reliabilität und Veränderungssensitivität zu evaluieren. Die in diesem Kapitel beantworteten Fragestellungen wurden in den Manuskripten III bis VIII bearbeitet.

3.2 Übersicht über Assessment-Instrumente zur Erfassung der Life-Space Mobilität

Das Ziel des systematischen Reviews bestand darin, verfügbare Fragebögen zur Erfassung der Life-Space Mobilität zu identifizieren, um die Auswahl und den Einsatz in Studien zu erleichtern, mit besonderer Berücksichtigung der in deutscher Sprache verfügbaren Fragebögen. Bisher publizierte oder geplante Reviews zu Life-Space Assessment Instrumenten waren wenig umfassend und fokussierten auf die meistgenutzten Fragebogen, berücksichtigten damit nicht neuere Entwicklungen oder bewerteten nicht gezielt die psychometrische Gütekriterien (Cino et al., 2021; Johnson et al., 2020; Taylor et al., 2019). Daher wurde im Rahmen dieser Dissertation ein systematisches Review durchgeführt, um eine möglichst große Anzahl der verfügbaren Fragebögen mit ihren psychometrischen Eigenschaften zu sammeln, zu klassifizieren und zu bewerten.

MANUSKRIPT III: Assessing life-space mobility: A systematic review of questionnaires and their measurement properties.

Mit Hilfe einer systematischen Literatursuche in den Datenbanken Pubmed, PSYCINFO, COCHRANE LIBRARY, CINAHL und Web of Science wurden 13 Instrumente zur Erfassung der Life-Space Mobilität identifiziert. Weitere Studien zu den psychometrischen Eigenschaften der identifizierten Fragebögen wurden ebenso berücksichtigt. Die Auswertung basiert auf den COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) Richtlinien (Gagnier et al., 2021; Mokkink et al., 2018; Mokkink et al., 2010). Die meisten der Instrumente bauen auf dem „University of Alabama at Birmingham Life-Space Assessment“ auf. Die Mehrheit der Fragebögen wurde für im häuslichen Umfeld lebende Personen konzipiert und drei für Personen in Institutionen. Mehrheitlich waren die Fragebögen zur Selbstauskunft gedacht. In insgesamt 37 Validierungsstudien wurden hauptsächlich Validität und Reliabilität geprüft, jedoch in unterschiedlichem Umfang und Qualität. Aspekte der Durchführbarkeit wurden kaum berichtet und die Veränderungssensitivität wurde wenig untersucht. In Abhängigkeit von Studienziel und Studienpopulation können vier Assessmentinstrumente empfohlen werden (Baker et al., 2003; Hauer et al., 2021; Hauer et al., 2020; Ullrich, Werner, Bongartz, et al., 2019), alle sind in deutscher Sprache verfügbar (das UAB-LSA wurde kürzlich übersetzt und hinsichtlich der Validität geprüft (Mümken et al., 2021)). Neben der Identifikation von Assessment-Instrumenten war ein weiteres Ziel, das Konzept im deutschsprachigen Forschungsraum zu verbreiten, den Einsatz von Life-Space Mobilitäts-Fragebögen zu vereinfachen, die Auswahl zu erleichtern und damit die Berücksichtigung des Life-Space Konzepts in Studien zu fördern.

*(Manuskript III: **Ullrich P**, Werner C, Abel B, Hummel M, Bauer JM, Hauer K. Assessing life-space mobility: A systematic review of questionnaires and their measurement properties. Paper under review, Zeitschrift für Gerontologie und Geriatrie).*

Drei der in das systematische Review eingeschlossenen Fragebögen wurden im Rahmen des HeikE-Projekts und des PAGER-Projekts entwickelt und validiert (Hauer et al., 2021; Hauer et al., 2020; Ullrich, Werner, Bongartz, et al., 2019), die Hintergründe und Validierungsstudien werden im Folgenden vorgestellt.

3.3 Entwicklung neuer Assessmentinstrumente zur Erfassung der Life-Space Mobilität mit Fokus auf Personen mit kognitiver Einschränkung

Der meistgenutzte Fragebogen zur Erfassung der Life-Space Mobilität ist das „University of Alabama at Birmingham Life-Space Assessment" (UAB-LSA) (Taylor et al., 2019). Aufgrund seiner umfassenden Erfassung der Ausdehnung der Mobilität, der Häufigkeit und der Unabhängigkeit bei den Aktivitäten in der räumlichen Umgebung und dabei relativ kurzen Durchführungsdauer ist es besonders gut zur Abbildung der über den reinen Life-Space hinausgehenden Mobilität und für den Einsatz in Studien oder Therapie geeignet. Daher wurde dieser Fragebogen als Grundlage für die Neuentwicklung eines für Menschen mit kognitiven Einschränkungen geeigneten Life-Space Mobilitäts-Assessment Instruments herangezogen. Die Übersetzung des Fragebogens vom Englischen in die deutsche Sprache wurde gemäß den Richtlinien von Beaton et al. 2000 (Stage I-IV) (Beaton et al., 2000) und Guillemin et al. (Guillemin et al., 1993) durchgeführt. Das Vorhandensein kognitiver Einschränkungen erschwert jedoch eine korrekte Erfassung (Bhandari & Wagner, 2006; Sallis & Saelens, 2000; Shephard, 2003) durch Gedächtnisverlust, Aufmerksamkeitsdefizite, Defizite in der zeitlichen Orientierung, zudem können Schwierigkeiten bei langen Erhebungszeiträumen auftreten. Um diesen Einschränkungen entgegenzukommen, wurden Anpassungen vorgenommen. Zum einen wurde der Erhebungszeitraum von vier Wochen (Baker et al., 2003) auf eine Woche gekürzt, um Verzerrungen durch fehlende oder falsche Erinnerung zu vermeiden (Boissy et al., 2011) und dennoch eine gewisse Repräsentativität zu gewährleisten (Carp & Carp, 1981). Ein weiterer Vorteil der einen Woche lag in der Einmaligkeit der einzelnen Wochentage. Die Reduktion lässt sich zudem begründen mit dem geringeren außerhäuslichen Aktivitätsverhalten und der geringeren Variabilität der außerhäuslichen Mobilität bei Personen mit demenzieller Erkrankung (Wahl et al., 2013; Wettstein et al., 2015). Aufgrund des reduzierten Observationszeitraums musste das Scoring für die Häufigkeit der Nutzung der verschiedenen Life-Space Zonen im Fragebogen angepasst werden (1 Punkt: 1 bis 3 Mal in der Woche; 2 Punkte: 4 bis 6 Mal in der Woche; 3 Punkte: täglich). Mögliche Ergebnisse für den Gesamtscore liegen damit zwischen 0 (permanent im

Bett) und 90 (tägliche Aktivitäten außerhalb des Wohnortes ohne Hilfsmittel oder Hilfspersonen; im Vergleich Gesamtscoring des UAB-LSA: 0-120 (Baker et al., 2003)).

Ergänzend wurde eine in der Erfassung der körperlichen Aktivität älterer Menschen mit kognitiven Einschränkungen bewährte Fragetechnik eingesetzt (Hauer et al., 2011). Diese zielte darauf ab, die Vollständigkeit zu verbessern, Angst vor fehlerhaften Antworten oder „Versagen" zu nehmen und durch das Setzen von Ankern den Tag zu strukturieren (Hauer et al., 2011). Bezüge zu typische Aktivitäten und Abläufe (Durante & Ainsworth, 1996) und präzise (Rück-)Fragen wurden implementiert, um die Genauigkeit und Korrektheit abzusichern (Shephard, 2003). Die Befragungen wurden standardisiert interviewbasiert im persönlichen Gespräch mit der zu befragenden Person durchgeführt.

3.4 Erfassung der Life-Space Mobilität bei im häuslichen Umfeld lebenden Personen

MANUSKRIPT IV: Validation of a Modified Life-Space Assessment in Multimorbid Older Persons With Cognitive Impairment.

Im Rahmen der HeikE-Studie wurden die zu Studienbeginn (Baseline T1) erhobenen Daten genutzt, um die Konstruktvaliditát, Test-Retest-Reliabilität und Durchführbarkeit sowie unter Berücksichtigung der Post-Interventionsdaten (im Rahmen der HeikE-Studie) die Veränderungssensitivität des angepassten Life-Space Assessments (LSA-CI) zu prüfen. Die Validierung des modifizierten Life-Space Assessments wurde in einer Population von 118 älteren Menschen mit kognitiver Einschränkung (durchschnittliches Alter 82,3 ± 6,0 Jahre alt, MMSE 23,3 ± 2,4) im häuslichen Umfeld durchgeführt. Die Durchführbarkeit war exzellent mit 100% erfolgreicher Erfassung, einer durchschnittlichen Assessmentdauer von 4.1 Minuten und weder Boden- noch Deckeneffekten für den LSA-CI Gesamtscore. Korrelationen (Spearmans Rang oder Punkt-biseriale Korrelationskoeffizienten) des LSA-CI Gesamtscores und der drei Subscores mit verschiedenen Konstruktvariablen, die in Anlehnung an das Modell für Mobilität von (Webber et al., 2010) gewählt worden waren, zeigten enge Zusammenhänge mit Variablen der körperlichen Leistungsfähigkeit (r_s = 0,27-0,56), der körperlichen Aktivität und der außerhäuslichen Aktivität (r_s = 0,23-0,63). Auch Assoziationen mit sturzbezogenen psychosozialen Variablen (r_s = |0,24-0,44|) und demographischen Charakteristika (r_{pb} = |0,27-0,32|) wurden aufgezeigt. Die Intraklassen-Korrelations-Koeffizienten (IKK) als Maß für die Test-Retest Reliabilität wiesen für den Gesamtscore sehr hohe und für die drei Subscores moderate bis sehr hohe Werte auf (IKK = 0,65-0,91). Die Veränderungssensitivität für den Gesamtscore für die Life-Space Mobilität war exzellent (Standardized Response Means (SRM) = 0,80), für die Subscores jedoch deutlich geringer (SRM = 0,35-0,60) (Ullrich, Werner, Bongartz, et al., 2019).

*(Manuskript IV: **Ullrich P**, Werner C, Bongartz M, Kiss R, Bauer J, Hauer K. Validation of a Modified Life-Space Assessment in Multimorbid Older Persons With Cognitive Impairment. Gerontologist. 2019 Mar 14;59(2):e66-e75. Doi: 10.1093/geront/gnx214; IF: 5,271).*

Ergänzend wurde zur breiteren klinischen Einsetzbarkeit auch die Validierung in einer Subgruppe von Personen ohne kognitive Einschränkung durchgeführt.

MANUSKRIPT V: Validation of the Life-Space Assessment (LSA-CI) in multi-morbid, older persons without cognitive impairment.

In einer Subgruppe von Personen ohne kognitive Einschränkungen gemäß dem etablierten Cut-off von 24 (Anthony et al., 1982; Tombaugh & McIntyre, 1992) konnten sehr gute Durchführbarkeit, Konstruktvalidität, Test-Retest-Reliabilität und vergleichbare Veränderungssensitivität gezeigt werden. Damit ist die Anwendbarkeit bei älteren Menschen mit milder bis moderater kognitiver Einschränkung wie auch bei Personen ohne kognitive Einschränkung gegeben und der Einsatz in Studien mit gemischten Populationen möglich (Ullrich et al., 2021).

*(Manuskript V: **Ullrich P**, Abel B, Bauer JM, Hauer K. J. Validation of the Life-Space Assessment (LSA-CI) in multi-morbid, older persons without cognitive impairment. Eur Geriatr Med. 2021 Jan 11. Doi: 10.1007/S41999-020-00441-9; IF: 1,710).*

Zur einfachen klinischen Einteilung wurde zudem ein Grenzwert für die Einteilung in hohe und geringe Life-Space Mobilität in der Zielgruppe unter Zuhilfenahme von GPS basierten Messungen der außerhäuslichen Mobilität als Gold-Standard berechnet.

MANUSKRIPT VI: Cut-off for the Life-Space Assessment in persons with cognitive impairment.

Grenzwerte zur Einteilung des Life-Space Mobilitäts-Status wurden bis dahin theoretisch begründet (Sawyer, 2010) oder datengestützt, um Personen unter Zuhilfenahme von Receiver Operating Curves (ROC) in Bezug auf ihre Einschränkungen in den Aktivitäten des täglichen Lebens (Activities of Daily Living (ADL)) (Portegijs et al., 2016) bzw. instrumentellen ADLs (Shimada, Sawyer, et al., 2010) einzuteilen. Die Einteilung des Life-Space Mobilitäts-Status wurde bis dahin weder datengestützt berechnet noch speziell für die Zielpopulation der älteren Menschen mit kognitiver Einschränkung genannt. Die GPS-basierte Erfassung der außerhäuslichen Aktivität als wichtigem klinischen Marker (Eronen et al., 2016; Jacobs et al., 2008; Tung et al., 2014) fungierte hier als Goldstandard (Rutjes et al., 2007). Es wurde ein Grenzwert von 26,75 mit einer Sensitivität von 78,1% und einer Spezifität von 84,2% identifiziert, um in dieser Population eine geringe von einer hohen Life-Space Mobilität zu unterscheiden (Ullrich, Werner, Eckert, et al., 2019).

*(Manuskript VI: **Ullrich P**, Werner C, Eckert T, Bongartz M, Kiss R, Feißt M, Delbaere K, Bauer JM, Hauer K. Cut-off for the Life-Space Assessment in persons with cognitive impairment. Aging Clin Exp Res. 2019 Sep;31(9):1331-1335. Doi: 10.1007/s40520-018-1062-2. Epub 2018 Nov 7; IF: 3,636).*

3.5 Erfassung der Life-Space Mobilität bei älteren Personen im stationären Setting

Neben dem primären Ziel in Teilstudie I (Methodenentwicklung), die Erfassung der Life-Space Mobilität bei im häuslichen Umfeld lebenden Personen mit kognitiver Einschränkung zu ermöglichen, fiel als weitere Forschungslücke der Mangel an geeigneten Instrumenten zur Erfassung der Life-Space Mobilität im stationären Setting auf (Krankenhaus, Rehabilitation, Pflegeeinrichtungen). Auch in diesem Setting halten sich viele Personen mit hohem Risiko für Verlust der Mobilität (vgl. Kapitel 1.4 Einflussfaktoren der Life-Space Mobilität und 1.5 Einschränkungen der Life-Space Mobilität) auf. Aufenthalte in Institutionen, unabhängig davon, ob es sich um ein Pflegeheim, eine Kurzzeitpflegeeinrichtung, ein Krankenhaus oder eine Rehabilitationseinrichtung handelt, zeichnen sich durch eine grundsätzlich spezifisch strukturierte Umgebung und Abläufe aus (Brown et al., 2007). Das einzige speziell für das Pflegeheim entwickelte Assessment Instrument war bislang der Nursing Home Life-Space Diameter (NHLSD) (Tinetti & Ginter, 1990). Dieses umfasst einen Observationszeitraum von zwei Wochen und ist damit für kürzere Aufenthalte oder für eine Verlaufsbeobachtung bei einer Aufenthaltsdauer von unter vier Wochen ungeeignet, obwohl diese die Regel in Einrichtungen zur Kurzzeitpflege oder Rehabilitation oder in Krankenhäusern sind. Aufgrund der hohen Bedeutung der Mobilität und körperlichen Aktivität als Prädiktoren für den Verlauf nach Entlassung (Ostir et al., 2013) kann die Erfassung von Life-Space Mobilität im Krankenhaus oder der Rehabilitation relevant sein.

Für solche Zwecke wurde im Rahmen der PAGER-Studie ein weiterer Fragebogen zur Erfassung der Life-Space Mobilität auf Basis des NHLSD und des LSA-CI (Ullrich, Werner, Bongartz, et al., 2019) beziehungsweise UAB-LSA (Baker et al., 2003) entwickelt, das „Life-Space Assessment for Institutionalized Settings“ (LSA-IS). Das LSA-IS wurde sowohl für den Einsatz als Interview („self-report“) konzipiert, analog zum UAB-LSA (Baker et al., 2003) oder LSA-CI (Ullrich, Werner, Bongartz, et al., 2019), aber auch für den Einsatz bei Pflegekräften, um auch Personen mit stärkerer kognitiver Einschränkung oder ohne Möglichkeit zur Selbstauskunft einschließen zu können, analog zum NHLSD. Ein Beobachtungszeitraum von einem Tag wurde gewählt, wodurch Verläufe der Life-Space Mobilität auch über kurze Zeiträume beobachtet werden können. Aufgrund der starken Einschränkungen von Personen im Akutkrankenhaus während der Frührehabilitation waren Ergebnisse im unteren Bereich der Skala zu erwarten, jedoch wurden für den breiten Einsatz des Instrumentes auch in Pflegeeinrichtungen bewusst auch weitergehende Zonen (außerhalb des Krankenhausbereiches) berücksichtigt, um mögliche Deckeneffekte bei höherer Life-Space Mobilität in anderen Institutionen wie Pflegeheimen auszuschließen.

Von besonderer Relevanz als Schwerpunkt in dieser Dissertation, aber auch speziell in diesem Setting war die Berücksichtigung von Personen mit kognitiver Einschränkung. Die Ergebnisse für die Gruppe der Personen mit kognitiver Einschränkung sind in den Manuskripten daher auch gesondert berichtet.

MANUSKRIPT VII: Validation of the interview-based life-space assessment in institutionalized settings (LSA-IS) for older persons with and without cognitive impairment.

Der Untersuchung der Validität, Test-Retest Reliabilität und Veränderungssensitivität der interviewbasierten Version wurde an 119 PatientInnen (durchschnittlich 83,0 ± 6,2 Jahre alt) während der stationären Frührehabilitation durchgeführt. Die Befragung war erfolgreich mit 100% vollständiger Erfassung und einer durchschnittlichen Assessmentdauer von 3,2 ± 1,2 Minuten. Es traten weder Boden- noch Deckeneffekte für den LSA-IS Gesamtscore auf. Die Korrelationen (Spearmans Rang oder Punkt-biseriale Korrelationskoeffizienten) des LSA-IS Gesamtscores mit verschiedenen Konstruktvariablen reichten von gering bis hoch, abhängig von der Nähe der Konstruktvariablen zum Konstrukt der Life-Space Mobilität (r = 0,208 – 0,716). Eine gute Test-Retest Reliabilität (IKK = 0,704) sowie eine hohe Veränderungssensitivität (SRM = 0,806) konnten aufgezeigt werden. Für die drei Subscores konnten die Ergebnisse des Gesamtscores bestätigt werden, lediglich das Ergebnis für die Test-Retest Reliabilität für den maximalen Life-Space (LSA-IS-M) in der Gruppe der Personen mit kognitiver Einschränkung und die Veränderungssensitivität der Subscores fielen durch geringe Werte auf. Die Ergebnisse von Personen ohne und von Personen mit kognitiver Beeinträchtigung wiesen keine wesentlichen Unterschiede auf, lediglich das genannte Ergebnis für die Test-Retest Reliabilität des LSA-IS-M Subscores wich etwas ab (Hauer et al., 2020).

*(Manuskript VII: Hauer K, **Ullrich P**, Heldmann P, Hummel S, Bauer JM, Werner C. Validation of the interview-based life-space assessment in institutionalized settings (LSA-IS) for older persons with and without cognitive impairment. BMC Geriatr. 2020 Dec 10;20(1):534. doi: 10.1186/s12877-020-01927-8; IF: 3,921).*

MANUSKRIPT VIII: Psychometric Properties of the proxy-reported Life-Space Assessment in Institutionalized Settings (LSA-IS-proxy) for Older Persons with and without Cognitive Impairment.

Für die proxy-basierte Erfassung der Life-Space Mobilität stellen Kenntnisse der erhebenden Person (Studienmitarbeitende, ärztliches Personal oder Pflegepersonal) über die Abläufe in der Einrichtung und Einblick in das Alltagsverhalten des zu Untersuchenden eine Voraussetzung dar. Auch hier konnte bei 94 während ihres stationären Aufenthalts teilnehmenden geriatrischen PatientInnen (durchschnittliches Alter 83,3 ± 6,1 Jahre) mit und ohne kognitive Einschränkungen eine exzellente Durchführbarkeit ohne Boden- oder Deckeneffekte für den Gesamtscore berichtet werden. Es gab eine sehr hohe Übereinstimmung zwischen den Ergebnissen der interviewbasierten und der proxy-berichteten Version (IKK für die absolute Übereinstimmung = 0,77). Die Ergebnisse der Korrelationen stimmten überein mit den Erwartungen in Abhängigkeit der Nähe der Konstrukte, mit geringen bis hohen Korrelationskoeffizienten (r = 0,21 – 0,59).

Die Test-Retest Reliabilität war gut (IKK = 0,74). Signifikante Veränderungen im Verlauf der Behandlungen konnten gezeigt werden, mit jedoch geringer statistischer Aussagekraft (SRM = 0,44). Insgesamt gab es vergleichbare Ergebnisse in den beiden Gruppen von Personen mit und ohne kognitive Einschränkungen. Die Ergebnisse für die Subscores bestätigten die Ergebnisse für den Gesamtscore, jedoch traten Bodeneffekte bei den Subscores auf (Hauer et al., 2021).

*(Manuskript VIII: Hauer K, **Ullrich P**, Heldmann P, Bauknecht L, Hummel S, Abel B, Bauer JM, Lamb SE, Werner C. Psychometric Properties of the proxy-reported Life-Space Assessment in Institutionalized Settings (LSA-IS-proxy) for Older Persons with and without Cognitive Impairment. Int. J. Environ. Res. Public Health 2021, 18(8), 3872; https://doi.org/10.3390/ijerph18083872; IF: 3,390).*

Beide Assessmentinstrumente sind grundsätzlich konzipiert für den Einsatz in unterschiedlichen institutionellen Einrichtungen, auch wenn die formale Validierung im Krankenhaus erfolgt ist und für Rehabilitations- und Pflegeeinrichtungen (Kurzzeitpflege, Pflegeheime) noch aussteht.

3.6 Zusammenfassung der Ergebnisse von Teilstudie 1 - Methodenentwicklung

Zusammenfassend lässt sich feststellen, dass 13 Assessmentinstrumente identifiziert wurden, die zur Erfassung von Life-Space und Life-Space Mobilität zur Verfügung stehen. Am häufigsten genutzt wurde das UAB-LSA, auf dessen Basis die hier vorgestellten Instrumente zur Erfassung der Life-Space Mobilität bei Personen mit und ohne kognitive Einschränkungen entwickelt wurden. Die psychometrischen Gütekriterien Validität, Reliabilität und Veränderungssensitivität für die neu entwickelten Instrumente LSA-CI und LSA-IS als selbst- oder Proxy-berichtete Version werden zufriedenstellend erfüllt und die Instrumente können für den Einsatz empfohlen werden.

4 Teilstudie II – Epidemiologische Untersuchung: Status und Prädiktoren der Life-Space Mobilität bei älteren Personen mit kognitiver Einschränkung nach Entlassung in das häusliche Umfeld

Da eine geringe Life-Space Mobilität mit einer Vielzahl von Konsequenzen assoziiert ist (erhöhtes Auftreten von Stürzen und Frakturen (Lo et al., 2014), funktionellen Einschränkungen (Shimada, Sawyer, et al., 2010), Pflegeheimeinweisungen (Sheppard et al., 2013) und Mortalität (Boyle et al., 2010)), wurde explorativ in Teilstudie II untersucht, wie sich der Zustand der Life-Space Mobilität in der Population von Menschen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation darstellt. Zudem wurde untersucht, ob einzelne Faktoren der verschiedenen von Webber et al. postulierten Domänen (Webber et al., 2010) (siehe Kapitel 1.4 Einflussfaktoren der Life-Space Mobilität) in einem systematischen Zusammenhang mit der Life-Space-Mobilität in der Zielpopulation stehen.

Obwohl die einzelnen Faktoren in verschiedenen Studien untersucht wurden, gab und gibt es wenig Studien zum Status der Life-Space Mobilität in Populationen mit besonders großem Risiko für Verluste der Life-Space Mobilität. Die meisten Studien wurden in der allgemeinen älteren Bevölkerung durchgeführt. Diese zeigte einen relativ hohen Life-Space Mobilitäts-Status gemessen an den Life-Space Mobilitäts-Ergebnissen und den beschreibenden Charakteristika der untersuchten Population (vgl. (Al Snih et al., 2012; Auais et al., 2017; Crowe et al., 2008; Kuspinar et al., 2020; Moored et al., 2021; Peel et al., 2005; Silberschmidt et al., 2017; Umstattd Meyer et al., 2014)). In wenigen Studien wurde die Life-Space Mobilität von Personen mit besonders hohem Risiko für Einschränkungen oder für Subgruppen mit einzelnen Risikofaktoren analysiert wie Personen mit orthopädischen Erkrankungen (Suzuki et al., 2014), nach Schlaganfall (Estima et al., 2015; Yang et al., 2017), in Palliativbehandlung (Phillips et al., 2014) und nach Krankenhausaufenthalt (Brown, Roth, et al., 2009). Bislang gab es jedoch keine Untersuchungen von Personen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation, trotz ihres hohen Risikos für eine eingeschränkte Life-Space Mobilität und damit assoziiertem Verlust der Selbstständigkeit.

4.1 Status und Prädiktoren der Life-Space Mobilität

Im Rahmen des HeikE-Projekts wurde der Status der Life-Space Mobilität von Menschen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation in einer epidemiologischen Untersuchung analysiert.

MANUSKRIPT IX: Life-space mobility in older persons with cognitive impairment after discharge from geriatric rehabilitation.

Die Querschnittsanalyse ergab das Bild einer eher immobilen Population mit insgesamt eingeschränkter Life-Space Mobilität. Die Life-Space Mobilität basierend auf dem LSA-CI Gesamtscore lag im Durchschnitt bei 23,9 ± 13,2 Punkten. Von den untersuchten Personen wiesen 65% der untersuchten Personen einen geringen Life-Space auf (gemäß dem Cut-off von 26,75 (Ullrich, Werner, Eckert, et al., 2019)). Auch die Untersuchung der Subscores, die Auskunft über das Ausmaß der Raumnutzung gibt (ohne Berücksichtigung der Häufigkeit), zeigt, dass die Mobilität in der räumlichen Umgebung stark eingeschränkt ist. Selbst mit maximaler Unterstützung (LSA-CI-M; mit Unterstützung durch Hilfsmittel oder -person sofern nötig) hat etwa ein Drittel innerhalb der untersuchten Woche seine Nachbarschaft nicht verlassen. Die Abhängigkeit von anderen Personen in der Population wird auch deutlich bei der Betrachtung des LSA-CI-E Subscores (Ausdehnung der Raumnutzung innerhalb der erfragten Woche nur mit Hilfsmittel oder selbstständig): Fast 80% der Personen haben ihre Nachbarschaft ohne Hilfe einer Person nicht verlassen und etwa 60% haben ohne Hilfsperson ihre Wohnung/ihr Haus nicht verlassen. Komplett selbstständig (ohne Hilfsmittel oder -person) haben etwa 50% der Teilnehmenden ihr Schlafzimmer nicht verlassen, weniger als 8% der Teilnehmenden waren in der Lage, sich ohne Hilfsmittel oder -personen außerhalb ihrer Nachbarschaft zu bewegen (siehe Tabelle 3).

Tabelle 3 Nutzung der Life-Space Zonen unter Berücksichtigung der Selbstständigkeit

LSA-CI-M	Anteil an Personen, die ihre Nachbarschaft nicht verlassen haben	32,5%
	Anteil an Personen, die ihre Wohnung/ihre Haus nicht verlassen haben	6,0%
LSA-CI-E	Anteil an Personen, die ohne Hilfsperson ihre Nachbarschaft nicht verlassen haben	76,9%
	Anteil an Personen, die ohne Hilfsperson das direkte Wohnungsumfeld nicht verlassen haben	59,8%
LSA-CI-I	Anteil an Personen, die ohne Hilfsmittel und ohne Hilfsperson ihre Nachbarschaft nicht verlassen haben	92,4%
	Anteil an Personen, die ohne Hilfsmittel und ohne Hilfsperson ihr Schlafzimmer nicht verlassen haben	49,6%

Anmerkungen: Basierend auf den drei Subscores des LSA-CI: LSA-CI-M = Maximal Life-Space, höchste Zone erreicht mit (wenn nötig) Hilfsmittel und/oder -person; LSA-CI-E = Equipment-assisted Life-Space, höchste Zone erreicht mit (wenn nötig) Hilfsmittel; LSA-CI-I = Independent Life-Space, höchste selbstständig erreichte Zone (ohne Hilfsmittel oder-person).

Zur Analyse potenziell relevanter Einflussfaktoren wurde das Mobilitäts-Model von (Webber et al., 2010) herangezogen (siehe Kapitel 1.4 Einflussfaktoren der Life-Space Mobilität). Aus jeder der Domänen wurden eine oder mehrere Variablen gewählt, die für eine Korrelationsanalyse herangezogen und in Abhängigkeit der Höhe der Korrelation und der Kollinearität in ein Regressionsmodell eingeschlossen wurden.

Faktoren der physischen Domäne wiesen besonders hohe Zusammenhänge mit der Life-Space Mobilität auf. Dies entspricht den Ergebnissen in epidemiologischen Studien in der allgemeinen älteren Bevölkerung (Al Snih et al., 2012; Peel et al., 2005). Die Faktoren für die motorische Leistungsfähigkeit wurden lediglich von Parametern für allgemeine und außerhäusliche körperliche Aktivität übertroffen (die jedoch keiner einzelnen Domäne zuzuordnen sind und aufgrund ihrer Verknüpfung mit körperlicher Leistungsfähigkeit und psychosozialen Faktoren schon per Konzept hohe Übereinstimmungen mit Life-Space Mobilität aufweisen). Unter den psychosozialen Variablen waren insbesondere soziale Aktivitäten relevant. Im Regressionsmodell verblieben Geschlecht, körperliche

Leistungsfähigkeit, körperliche Aktivität und soziale Aktivitäten als relevante Einflussfaktoren (Ullrich et al., 2018).

Dies verdeutlich zum einen die hohe Bedeutung von körperlichen Fähigkeiten (= Kapazitäten) für die Mobilität, weist zum anderen aber auch auf den engen Zusammenhang zwischen körperlicher Aktivität und Life-Space Mobilität hin, und zeigt durch die hohen Assoziationen zu sozialen Aktivitäten die konzeptionelle Nähe zur Partizipation. Weibliches Geschlecht ist mit einem höheren Risiko für eine reduzierte Life-Space Mobilität assoziiert. Die geringere Mobilität von Frauen wurde auch schon in anderen Studien ermittelt (Zunzunegui et al., 2015). Die trotz Berücksichtigung einer Vielzahl von Faktoren relativ geringe Varianzaufklärung der Life-Space Mobilität verdeutlicht noch einmal die Komplexität des Konstrukts Life-Space Mobilität (Zijlstra & Giannouli, 2021). Möglicherweise würden Aspekte der Motivation oder Einstellung zu Bewegung und körperlicher Aktivität zur Aufklärung beitragen (siehe (Seinsche et al., 2020)). Im Mobilitäts-Modell nach Webber spielen motivationale Faktoren keine gesonderte Rolle, auch wenn sie dem Bereich der psychosozialen, kognitiven und soziodemographischen Faktoren zugeordnet werden können und vermutlich eine große Rolle beim Erreichen von Zielen spielen.

*(Manuskript IX: **Ullrich P**, Eckert T, Bongartz M, Werner C, Kiss R, Bauer JM, Hauer K. Life-space mobility in older persons with cognitive impairment after discharge from geriatric rehabilitation. Arch Gerontol Geriatr. 2019 Mar - Apr;81:192-200. Doi: 10.1016/j.archger.2018.12.007. Epub 2018 Dec 27; IF: 3,250).*

Ergänzend wurde in einer weiteren Studie der Zusammenhang von sensorbasiert erfassten Parametern der Gangqualität und Gangquantität mit der Life-Space Mobilität dargestellt.

MANUSKRIPT X: Comment on: "Mobility of Older Adults: Gait Quality Measures Are Associated With Life-Space Assessment Scores" by Suri et al.

Diese Studie ergänzt die vorherigen Ergebnisse und weist auf die Bedeutsamkeit von Gangparametern hin. Mit Hilfe eines 3-axialen Akzelerometers, Gyroskops und Magnetometers, angebracht am unteren Rücken der Teilnehmenden über einen Zeitraum von 48 Stunden im regulären Alltag (Bongartz et al., 2019; Chigateri et al., 2018), wurden bei einer Subgruppe von 92 Teilnehmenden Zusammenhänge von Life-Space Mobilität und Parametern der Gangqualität im Alltag untersucht. Die Analysen zeigten signifikante Assoziationen mit der Kadenz, der “Harmonic Ratio” (in anterior-posteriorer, medial-lateraler, vertikaler Richtung), der anterior-posterioren “Step regularity”, Drehdauer und Drehwinkel sowie durchschnittlicher und maximaler Drehgeschwindigkeit (mean and peak turning velocity) ($r = |0{,}216 - 0{,}448|$, $p \leq 0{,}001 - 0{,}038$). Im Regressionsmodell wurden neben der körperlichen Aktivität, sturzangstbedingtem Vermeidungsverhalten, sozialen Aktivitäten und Geschlecht auch signifikante Einflüsse von einzelnen Parametern der Gangqualität ermittelt. Parameter die für Geschmeidigkeit des Gangbildes und die Qualität der Drehbewegung waren unabhängig mit Life-Space Mobilität assoziiert, was darauf hinweist, dass die klassischen Methoden zur Erfassung der funktionellen Leistungsfähigkeit unter Laborbedingungen den Messungen im Alltag unterlegen zu sein scheinen (Werner et al., 2021).

*(Manuskript X: Werner C, **Ullrich P**, Abel B, Bauer JM, Hauer K. Comment on: "Mobility of Older Adults: Gait Quality Measures Are Associated With Life-Space Assessment Scores" by Suri et al. J Gerontol A Biol Sci Med Sci. 2021 Aug 13:glab237. doi: 10.1093/gerona/glab237; IF: 6,053).*

4.2 Zusammenfassung der Ergebnisse von Teilstudie II – Epidemiologische Untersuchung

Schlussfolgernd ist eine insgesamt sehr geringe Life-Space Mobilität in der Population der Menschen mit kognitiven Einschränkungen nach Entlassung aus der Rehabilitation erkennbar sowie die große Abhängigkeit von Hilfspersonen und Hilfsmitteln für die Nutzung weitergehender Bereiche in der räumlichen Umgebung. Frauen weisen einen generell reduzierten Life-Space Mobilitäts-Status auf und sollten für und in Interventionen besonders berücksichtigt werden. Zur Verbesserung der Life-Space Mobilität bieten sich insbesondere Faktoren der körperlichen Leistungsfähigkeit (motorische Kapazität sowie qualitative Gangparameter) und der körperlichen Aktivität als Interventionsziele an sowie eine Förderung sozialer Aktivitäten, um die Life-Space Mobilität positiv zu beeinflussen.

5. Teilstudie III - Interventionseffekte: Verbesserung der allgemeinen Mobilität und der Life-Space Mobilität bei älteren Personen mit kognitiver Einschränkung nach Entlassung aus der Rehabilitation

Wie in den Kapiteln 1.2 Versorgungssituation von Personen mit kognitiven Einschränkungen nach Entlassung aus der Rehabilitation in das häusliche Umfeld, 1.4 Einflussfaktoren der Life-Space Mobilität, und 1.5 Einschränkungen der Life-Space Mobilität erörtert, weisen geriatrische PatientInnen mit kognitiver Einschränkung eine Vielzahl von negativen Einflussfaktoren für die Gesundheit und die Selbstständigkeit auf. Dementsprechend weist auch nach Entlassung aus der geriatrischen Rehabilitation ein Großteil dieser Personen eine reduzierte Life-Space Mobilität auf (Ullrich et al., 2018). Damit im Einklang stehen die Untersuchungen von Loyd et al., die besagen, dass im Anschluss an die Entlassung aus dem Krankenhaus über 50% der älteren akut erkrankten Menschen Einschränkungen in ihrer Life-Space Mobilität aufweisen und etwa ein Drittel auch sechs Monate nach Entlassung weiterhin einen reduzierten Status gegenüber dem Life-Space Mobilitäts-Status vor dem Krankenhausaufenthalt hat (Loyd et al., 2018).

In der Regelversorgung gab es bislang keine strukturierten Programme, die den Übergang von der stationären Versorgung in das häusliche Umfeld älterer multimorbider Personen mit kognitiver Einschränkung und damit besonders hohem Risiko für Verlust der Selbstständigkeit begleiten (siehe Kapitel 1.6 Verbesserung der Mobilität, mit Fokus auf der Life-Space Mobilität, nach Entlassung aus der geriatrischen Rehabilitation) und damit die Rehabilitationskette am Wohnort fortführen. Die Fortschritte, die während der Rehabilitationsmaßnahmen erfolgten, können somit bei Ausbleiben fortführender Therapiemaßnahmen häufig nicht erhalten werden.

Ziel des HeikE-Projekts war, ein adäquates Nachsorgeprogramm für die spezielle Zielgruppe der Menschen mit kognitiven Einschränkungen anzubieten, um die erreichten Rehabilitationserfolge zu sichern und gegebenenfalls weiter auszubauen, um so die Selbstständigkeit und Partizipation der Teilnehmenden zu erhalten.

5.1 Effekte einer randomisierten kontrollierten Studie zur Steigerung der allgemeinen Mobilität und der Life-Space Mobilität bei Personen mit kognitiver Einschränkung nach Rehabilitation

MANUSKRIPT XI: Effects of a home-based physical training and activity promotion program in community-dwelling older persons with cognitive impairment after discharge from rehabilitation: A randomized controlled trial.

Übergeordnetes Ziel war die Verbesserung der poststationären Versorgungssituation für geriatrische PatientInnen mit kognitiver Einschränkung. Bei den insgesamt 118 älteren Teilnehmenden (82,3 ± 6,0 Jahre alt) mit kognitiver Einschränkung (Mini-Mental State Examination: 23,3 ± 2,4 Punkte). Die Ergebnisse der HeikE-Studie belegen den positiven Einfluss des spezifisch entwickelten Heimtrainingsprogramms mit integriertem Motivationsprogramm auf die körperliche Leistungsfähigkeit, gemessen mit der SPPB.

Signifikante und nachhaltige Effekte auf die körperliche Leistungsfähigkeit wurden dokumentiert mit einem Benefit für die Interventionsgruppe nach 12-wöchigem Training von 1,9 Punkten (95% Konfidenzintervall (95%KI): 1,0-2,8; $p < 0.001$) und nach 12-wöchigem Follow-up von 1,3 Punkten (95%KI: 0,4-2,2; $p < 0,001$). Effekte auf die körperliche Aktivität in der Interventionsgruppe im Vergleich zur Kontrollgruppe konnten nicht gezeigt werden.

Neben der erfolgreichen Verbesserung der motorisch-funktionellen Leistungsfähigkeit konnten auch positive Effekte auf sturzbezogene psychosoziale Parameter und die Life-Space Mobilität festgestellt werden. Die Effekte auf die Life-Space Mobilität werden in diesem Artikel nur kurz dargestellt und wurden detailliert in Manuskript XII analysiert.

Die vorliegenden Studienergebnisse belegen nicht nur die Effektivität des spezifisch entwickelten Heimtrainingsprogramms mit Verbesserungen der motorischen und funktionellen Leistungen im Vergleich zur Kontrollgruppe bei Personen mit kognitiver Einschränkung, sondern zeigen auch, dass die Verbesserungen der motorischen Leistung ein Ausmaß von klinischer Relevanz haben (Goldberg et al., 2012; Ries et al., 2009). Die Verbesserungen von 1,9 Punkten im SPPB Gesamtscore übertreffen die in anderen Studien aufgezeigten Grenzwerte von 1,0 Punkten für substantielle und klinisch relevante Veränderungen (Perera et al., 2006). Zudem wurde dieser Grenzwert für eine jüngere und motorisch deutlich fittere Population berechnet, obwohl für Personen mit fortgeschrittenen Einschränkungen der motorischen Leistungsfähigkeit wie in der HeikE-Studie auch kleine Steigerungen der motorischen Leistung zu weitreichenden subjektiven Verbesserungen im Alltag führen können (Guralnik et al., 2020). Auch klinisch bedeutsame Veränderungen in Bezug auf die Gehgeschwindigkeit konnten im Rahmen der Intervention erzielt werden (Perera et al., 2006). Dabei konnte auch ein Grenzwert, berechnet zur Identifikation von Personen mit Mobilitätseinschränkungen, überschritten werden (Cawthon et al., 2021).

Obwohl das Heimtrainingsprogramm erfolgreich umgesetzt werden konnte, zeigten sich keine Effekte auf die körperliche Aktivität. Möglicherweise würde eine längerfristige und kontinuierliche engmaschigere Unterstützung Effekte auf die körperliche Aktivität bewirken, wie in einer Studie von Lautenschlager et al. aufgezeigt (Lautenschlager et al., 2008).

Die Vergleichbarkeit zu anderen Studien ist limitiert, da abgesehen von der Pilotstudie keine Studien zur Verbesserung der poststationären Versorgung durch Heimtraining bei geriatrischen PatientInnen mit kognitiver Einschränkung bekannt sind. Studien zur Verbesserung der Nachsorge nach Krankenhaus- oder Rehabilitationsaufenthalt in gemischten Populationen zeigten im Vergleich etwas geringere Effekte auf die motorische Leistungsfähigkeit bei PatientInnen nach Hüftfraktur (Latham et al., 2014) und auf die Gehgeschwindigkeit bei älteren Personen mit "Frailty"-Syndrom (Fairhall et al., 2012). Einigen Studien zeigten dagegen keine Verbesserungen der motorischen Leistungsfähigkeit (Salpakoski et al., 2014; Sherrington et al., 2004; Tsauo et al., 2005; Turunen et al., 2020).

*(Manuskript XI: **Ullrich P**, Werner C, Schönstein A, Bongartz M, Eckert T, Beurskens R, Abel B, Bauer JM, Lamb S, Hauer K. Effects of a home-based physical training and activity promotion program in community-dwelling older persons with cognitive impairment after*

discharge from rehabilitation: A randomized controlled trial. Paper under review (J Gerontol A Biol Sci Med Sci).

Die Ergebnisse mit Fokus auf die Life-Space Mobilität wurden gesondert und ausführlich in einem weiteren Manuskript dargestellt, auch unter Berücksichtigung der Subscores, die sich nur auf die räumliche Ausdehnung der Aktivitäten beziehen.

MANUSKRIPT XII: Increasing Life-Space Mobility in community-dwelling older persons with cognitive impairment following rehabilitation: A randomized controlled trial.

Nach der 12-wöchigen Intervention wiesen die Teilnehmenden der Interventionsgruppe eine signifikant höhere Life-Space Mobilität auf, sowohl in Bezug auf den Gesamtscore (Benefit b von 8,15 Punkten; 95%KI: 2,89-13,41; $p = 0{,}003$) als auch für den Subscore LSA-CI-E, den Life-Space, der unabhängig von Hilfspersonen und -mitteln erreicht wurde (Independent Life-Space; $b = 0{,}39$; 95%KI: 0,00-0,78; $p = 0{,}048$). Die Verbesserung des Subscores für den unabhängigen Life-Space weist auf eine erfolgreiche Veränderung der individuellen motorisch-funktionellen Leistungsfähigkeit durch das Training hin. Die Ergebnisse belegen, dass eine Steigerung der Life-Space Mobilität bei Personen mit kognitiver Einschränkung durch ein gezieltes Training der körperlichen Leistungsfähigkeit und Aktivität möglichst außerhalb der eigenen Wohnung mit Unterstützung von zielgruppengerechten Motivationsstrategien erreicht werden kann (Ullrich et al., 2020).

*(Manuskript XII: **Ullrich P**, Werner C, Bongartz M, Eckert T, Abel B, Schönstein A, Kiss R, Hauer K. J. Increasing Life-Space Mobility in community-dwelling older persons with cognitive impairment following rehabilitation: A randomized controlled trial. J Gerontol A Biol Sci Med Sci. 2020 Oct 6:glaa254. Doi: 10.1093/gerona/glaa254; IF: 6,053)*

5.2 Wirksamkeit der speziell für Personen mit kognitiver Einschränkung entwickelten Motivationsstrategien

Ergänzend wurde eine Untersuchung über die Wirksamkeit der speziell entwickelten Motivationsstrategien durchgeführt, welche spezifisch für die Zielgruppe entwickelt wurden, um positive und nachhaltige Effekte zu sichern.

MANUSKRIPT XIII: Promoting physical activity in geriatric patients with cognitive impairment after discharge from ward-rehabilitation: a feasibility study.

Die vor allem unter Berücksichtigung des fortgeschrittenen Alters und reduzierten Mobilitätsstatus niedrige Zahl von Studienabbrechern und die hohe Adhärenz der Teilnehmenden unterstreichen die Eignung des spezifischen Heimtrainings, das auf evidenzbasierten Kommunikationskonzepten aufgebaut wurde und kognitive sowie psychosoziale Aspekte der kognitiven Einschränkung berücksichtigt. Die umfassenden Analysen zur Adhärenz und Akzeptanz des im Heimtrainingsprogramm inkludierten Motivationsprogramms belegen die Umsetzbarkeit dieses motivationspsychologischen Konzepts zur Unterstützung des Heimtrainingsprogramms in der Zielgruppe von älteren Menschen mit kognitiver Einschränkung nach Entlassung aus der stationären Rehabilitation, insbesondere die persönlichen Kontakte wurden positiv bewertet. Ein Abfallen der Adhärenz wurde schon in vergleichbaren Studien beschrieben, deutet aber womöglich daraufhin, dass ein kontinuierlicher enger Support bei der Zielpopulation zu größeren Effekten führen könnte (Eckert, 2019).

(Manuskript XIII: Eckert T, Bongartz M, ***Ullrich P****, Abel B, Christian W, Kiss R, Hauer K. Promoting physical activity in geriatric patients with cognitive impairment after discharge from ward-rehabilitation: a feasibility study. Eur J Ageing. 2020 Feb 13;17(3):309-320. doi: 10.1007/s10433-020-00555-w. eCollection 2020 Sep; IF: 2,711).*

5.3 Zusammenfassung der Ergebnisse von Teilstudie III - Interventionseffekte

Die HeikE-Intervention wurde von den Teilnehmenden sehr gut angenommen. Die Effektivität in Bezug auf nachhaltige Steigerungen der motorischen Leistungsfähigkeit und sturzangstbezogene Variablen konnte erfolgreich dargelegt werden, auch die Life-Space Mobilität konnte signifikant über den Interventionszeitraum gesteigert werden. Das HeikE-Programm bietet sich daher an als kostengünstiges, effektives Versorgungsangebot zur Sicherung der Rehabilitationserfolge, Unterstützung des weiteren Rehabilitationsprozesses und der Sekundär- und Tertiärprävention im häuslichen Umfeld bei geriatrischen PatientInnen mit kognitiven Einschränkungen.

6. Schlussfolgerung

Ziel der vorliegenden Arbeit war, die Life-Space Mobilität älterer Menschen mit kognitiven Einschränkungen messbar zu machen, den Status nach der Rehabilitation umfassend zu analysieren und zu prüfen, ob Steigerungen der (Life-Space) Mobilität durch eine spezifische Intervention möglich sind.

6.1 Zusammenfassung der Ergebnisse

Im Rahmen dieser Dissertationsschrift wurden verschiedene Instrumente zur Erfassung der Life-Space Mobilität ermittelt und begutachtet, um auch die Auswahl eines adäquaten Life-Space Assessment Instruments für unterschiedliche Populationen und Settings zu erleichtern. Zudem wurden weitere Instrumente ergänzt, die auch bei Menschen mit kognitiver Einschränkung einsetzbar sind. Die im Rahmen der HeikE und Pager Studie entwickelten und validierten Instrumente können zur Erfassung der Life-Space Mobilität von Personen mit und ohne kognitive Einschränkungen sowohl im häuslichen Umfeld als auch im institutionellen Setting eingesetzt werden (Teilstudie I - Methodenentwicklung).

Desweiteren wurde der reduzierte Status der Life-Space Mobilität in der besonders gefährdeten Population von Menschen mit kognitiver Einschränkung untersucht, welche von Autonomieverlust und Verlust der gesellschaftlichen Teilhabe stark bedroht ist. Der geringe Mobilitätsstatus belegt den dringenden Bedarf an Rehabilitationsmaßnahmen im häuslichen Umfeld nach Entlassung aus der stationären Rehabilitation zur Verbesserung der Mobilität. Unter Berücksichtigung einer ganzheitlichen Perspektive wurden unveränderbare sowie modifizierbare Determinanten von Life-Space Mobilität aufgezeigt, welche helfen können, den Interventionsbedarf zu ermitteln oder Interventionen zu konzipieren. Neben körperlicher Leistungsfähigkeit, körperlicher Aktivität und sozialen Aktivitäten wurde das Geschlecht als Determinante der Life-Space Mobilität ermittelt. Die ermittelten Determinanten weisen auf das erhöhte Risiko für Mobilitätseinschränkungen bei Frauen hin und sollten bei der Entwicklung von Interventionen berücksichtigt werden. Auch innovativ gemessene sensorbasierte Parameter der Gangquantität und -qualität als Prädiktoren wurden im Rahmen dieser Arbeit vorgestellt und diskutiert (Teilstudie II - Epidemiologische Untersuchungen).

Abschließend wurde ein innovatives zielgruppenspezifisches Heimtrainings- und Motivationsprogramm zur Verbesserung der poststationären Versorgung für die Zielgruppe vorgestellt, welches gemäß § 45c SGB XI zur Weiterentwicklung der Versorgungsstrukturen als Modellprojekt realisiert wurde. Das Heimtrainingsprogramm wurde erfolgreich im habituellen Setting der Teilnehmenden nach ihrer Entlassung ins häusliche Umfeld implementiert und bewirkte neben der Verbesserung der Life-Space Mobilität auch Verbesserungen der motorischen Kapazität und sturzangstbezogener Variablen. Auch die Entwicklung und Integration eines innovativen Motivationsprogramms wurde im Rahmen der Studie evaluiert. In einer weiteren nicht inkludierten Publikation wurde die Kosteneffektivität in Bezug auf Verbesserungen motorisch relevanter Endpunkte dargelegt (Eckert et al., 2021). Die Befunde dieser Arbeit zeigen, dass Verbesserungen der motorischen Leistung und der Life-Space Mobilität auch bei sehr vulnerablen, multimorbiden Menschen mit kognitiven Einschränkungen durch ein heimbasiertes, überwiegend autonom absolviertes Trainings- und

Motivationsprogramm gelingen können. Das heimbasierte Trainingsprogramm stellt damit einen vielversprechenden Ansatz zum Schließen der existierenden Versorgungslücke in der poststationären Phase dar (Teilstudie III – Interventionseffekte).

6.2 Limitationen

Spezifische Limitationen für die einzelnen Studienfragen sind in den einzelnen Publikationen genannt und diskutiert, daher werden nur die für alle Untersuchungen gültigen Limitationen genannt. Zunächst sind diese Ergebnisse auf die spezielle Personengruppe von Menschen mit beginnender bis moderater kognitiver Einschränkung nach der Rehabilitation limitiert, was auch dem Studienziel entsprach. Die Übertragung auf andere Gruppen kann nicht ohne weiteres erfolgen, auch wenn nahe liegt, dass ähnliche Ergebnisse in anderen Populationen mit Multimorbidität und/oder milder bis moderater kognitiver Einschränkung erzielt werden könnten. Eine weitere grundsätzliche Limitation ist die subjektive Erfassung der Life-Space Mobilität. Insbesondere bei Menschen mit kognitiver Einschränkung ist mit Verzerrung der Wahrnehmung oder fehlendem Erinnerungsvermögen zu rechnen. Die Validierungsstudien, in diesem Zusammenhang insbesondere die hohen Korrelationen mit objektiven Mobilitätsparametern, belegen jedoch die hohe psychometrische Güte über die Gesamtgruppe hinweg.

6.3 Fazit und Ausblick

Ziel dieser Dissertation war es, einen Beitrag zur Verbreitung des Konzepts der Life-Space Mobilität zu leisten, adäquate Möglichkeiten zur Erfassung dieser zu entwickeln, die spezielle Situation von Personen mit kognitiver Einschränkung nach der Rehabilitation im Hinblick auf die Life-Space Mobilität zu untersuchen und Möglichkeiten zur Verbesserung dieser vorzustellen, um zu einem besseren Verständnis von Prozessen, die zum Verlust der Life-Space Mobilität führen, beizutragen. Besonders der in der Forschung bislang unterrepräsentierte Aspekt der Verbesserung von Life-Space Mobilität bei besonders bedrohten Populationen wurde berücksichtigt.

Die hier vorgestellten Ergebnisse haben theoretische und praktische Implikationen, zum Beispiel für die Erfassung von Life-Space Mobilität, die Untersuchung von Einflussfaktoren auf die Mobilität, die Gestaltung von Trainingsinterventionen oder die Förderung individueller Mobilität von vulnerablen Populationen, insbesondere derer mit kognitiven Einschränkungen, nach Entlassung aus der Rehabilitation.

Auf Basis der Schlussfolgerungen und der Limitationen dieser kumulativen Dissertation ergeben sich in den einzelnen Forschungsbereichen verschiedene Schwerpunkte für zukünftige Untersuchungen im Bereich der Verbesserung der Versorgung von Menschen mit kognitiven Einschränkungen.

Validierungsstudien der hier vorgestellten Assessmentinstrumente zur Erfassung der Life-Space Mobilität in anderen Personengruppen könnten dazu führen, dass die Instrumente ihren breiten Einsatz finden sowie dazu beitragen, Ergebnisse verschiedener Populationen vergleichen zu können. Mit den vorgestellten Assessmentinstrumente kann künftig die Mobilität älterer Menschen mit und kognitive Einschränkungen in verschiedenen

Lebenssituationen und -settings untersucht werden. Perspektivisch wären längsschnittliche Mobilitätsdaten interessant, um Veränderungen der Life-Space Mobilität über die Zeit aufzeigen und Prädiktoren zu ermitteln. Künftige Forschungsschwerpunkte umfassen auch die weitergehende Analyse der Faktoren mit Einfluss auf die Life-Space Mobilität, beispielsweise mit Verweis auf Studien, die einen stärkeren Einfluss motivationaler Komponenten andeuten (Seinsche et al., 2020). Weitere Studien sind notwendig, um hier mehr Einblick in die die Life-Space Mobilität bestimmenden Faktoren zu erhalten. Auch eine prospektive Beobachtungsstudie zur Analyse der prädiktiven Fähigkeiten des Life-Space Assessment analog zu der Analyse von Abellan van Kan et al. bezüglich der Gehgeschwindigkeit (Abellan van Kan et al., 2009) wäre eine interessante und im klinischen Alltag einfach zu erhebende Möglichkeit mit weitreichenden Konsequenzen.

Die erfolgreiche Evaluation des HeikE-Projekts hat zur Bewilligung des durch den Innovationsfonds des G-BA geförderten „Geriatrische Rehabilitationserfolge nachhaltig sichern" (GeRas)-Projekts geführt (https://innovationsfonds.g-ba.de/projekte/neue-versorgungsformen/geras-geriatrische-rehabilitationserfolge-nachhaltig-sichern.430). Das GeRas-Projekt baut inhaltlich auf die Kernelemente des HeikE-Projekts auf. Damit ist die Überleitung in die Regelversorgung zur nachstationären Sicherung der Rehabilitationserfolge bei geriatrischen PatientInnen vorbereitet. Die Prüfung des hier vorgestellten Konzepts zur Verbesserung der poststationären Versorgung bei stärker von kognitiven Einschränkungen oder Demenz betroffenen Personen oder auch in anderen besonders von Immobilität betroffenen Personen- oder PatientInnengruppen mit geringfügigen Anpassungen an deren spezifische Bedürfnisse wäre aussichtsreich. So könnte die bestehende Versorgungslücke in der poststationären Versorgung nicht nur für geriatrische Patienten bzw. Menschen mit milder bis moderater kognitiver Einschränkung zu schließen.

Mögliche künftige Schwerpunkte können auch die längerfristige Beobachtung und Analyse der Auswirkungen solcher Programme auf Pflegebedürftigkeit, Institutionalisierung und Mortalität sein. Ebenso sollten Effekte auf verwandte und relevante Faktoren wie Teilhabe in der Gesellschaft / Partizipation evaluiert werden, um die Auswirkungen solcher niedrigschwelliger Heimtrainingsprogramm noch besser abschätzen zu können. Auch der Transfer der erzielten Trainingseffekte in Bezug auf verbesserte Bewegungssicherheit oder eine Reduzierung von Stürzen ist bislang nicht untersucht. Aus der Perspektive der Trainingswissenschaften wären Untersuchungen von Dosis-Wirkungs-Beziehungen solcher Heimtrainingsprogramme in Bezug auf die körperliche Leistungsfähigkeit, körperliche Aktivität und Life-Space Mobilität relevant.

Durch die fortschreitende Digitalisierung und das Mehr an Erfahrung im Umgang mit digitalen Angeboten der künftigen Älteren könnte eine Verlagerung der persönlichen Kontakte ins Digitale geschehen, was einerseits eine Möglichkeit wäre, Kosten zu sparen, andererseits aber auch ermöglichen könnte, bei vergleichbaren Kosten die Anzahl der persönlichen (digitalen) Kontakte zu steigern, um so die Adhärenz und Effektivität weiter zu verbessern.

Die vorliegende Dissertation erlaubt einen sehr differenzierten Blick auf unterschiedliche Aspekte der Life-Space Mobilität. Einschränkungen der Life-Space Mobilität stellen für die

Betroffenen einen Verlust an Lebensqualität dar, beeinträchtigen die gesellschaftliche Partizipation und sind nicht zuletzt mit erhöhtem Hilfs- und/oder Pflegebedarf und damit steigenden Kosten verbunden. Auch bei kognitiver Einschränkung, Multimorbidität und initial deutlich eingeschränkter Life-Space Mobilität lässt diese sich durch angepasste zielgruppenspezifische Interventionsprogramme verbessern. Die Erkenntnisse sollten genutzt werden, um die Life-Space Mobilität so lange wie möglich aufrechtzuerhalten, dies sollte nicht nur das Ziel der Betroffenen selbst sondern auch der Gesellschaft sein.

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Abbildungs- und Tabellenverzeichnis

Abkürzungsverzeichnis

ADL: Activities of daily living

GeRas: Geriatrische Rehabilitationserfolge nachhaltig sichern

GPS: Global Positioning Systems

HeikE: Heimtraining bei kognitiver Einschränkung

KI: Konfidenzintervall

LSA-CI: Life-Space Assessment in Persons with Cognitive Impairment

LSA-IS: Life-Space Assessment in Institutionalized Settings

MMSE: Mini Mental State Examination

ROC: Receiver Operating Curve

SPPB: Short Physical Performance Battery

UAB-LSA: University of Alabama at Birmingham Life-Space Assessment

vgl.: vergleiche

z. B.: zum Beispiel

Anhang A: Erklärung gemäß § 8 Abs. (1) c) und d) der Promotionsordnung der Fakultät

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**FAKULTÄT FÜR VERHALTENS-
UND EMPIRISCHE KULTURWISSENSCHAFTEN**

Promotionsausschuss der Fakultät für Verhaltens- und Empirische Kulturwissenschaften der Ruprecht-Karls-Universität Heidelberg / Doctoral Committee of the Faculty of Behavioural and Cultural Studies of Heidelberg University

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Ich erkläre, dass ich die vorgelegte Dissertation in dieser oder einer anderen Form nicht anderweitig als Prüfungsarbeit verwendet oder einer anderen Fakultät als Dissertation vorgelegt habe. / I declare that I did not use the submitted dissertation in this or any other form as an examination paper until now and that I did not submit it in another faculty.

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Anhang B

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Liste mit weiteren Publikationen und Kongressbeiträgen

Nachfolgende Publikationen wurden in Co-Autorenschaft der Verfasserin dieser Dissertation erstellt. Sie stehen teilweise in Verbindung mit dem Projekt, wurden jedoch aufgrund ihrer Abweichung von der thematischen Ausrichtung der Dissertation nicht in diese integriert.

Weitere Publikationen als Co-Autor im Rahmen des HeikE-Projekts in Peer-review Journals

- Abel B, Bongartz M, Eckert T, **Ullrich P**, Beurskens R, Mellone S, Bauer JM, Lamb SE, Hauer K. Will We Do If We Can? Habitual Qualitative and Quantitative Physical Activity in Multi-Morbid, Older Persons with Cognitive Impairment. Sensors (Basel). 2020 Dec 16;20(24):7208. doi: 10.3390/s20247208.

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Anhang C: Manuskripte für die publikationsbasierte Dissertation

- Manuskript I: Hauer K, **Ullrich P**, Dutzi I, Beurskens R, Kern S, Bauer J, Schwenk M. Effects of Standardized Home Training in Patients with Cognitive Impairment following Geriatric Rehabilitation: A Randomized Controlled Pilot Study. Gerontology. 2017;63(6):495-506. doi: 10.1159/000478263. Epub 2017 Aug 17.

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Effects of Standardized Home Training in Patients with Cognitive Impairment following Geriatric Rehabilitation: A Randomized Controlled Pilot Study

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Keywords

Dementia · Cognitive impairment · Home-based exercise · Geriatric rehabilitation · Balance · Strength · Physical activity

Abstract

Background: Post-ward geriatric rehabilitation programs have hardly been developed and validated, which leaves a substantial gap in rehabilitative care in older adults and hinders full exploitation of maintained, but often unrecognized rehabilitation potentials. Geriatric rehabilitation patients with cognitive impairment represent a highly vulnerable population which is often affected by a lack of an ongoing support at the intersection between ward-based and post-ward rehabilitation. ***Objective:*** To determine the effect of a standardized home-based training program in geriatric patients with cognitive impairment following ward-based rehabilitation. ***Methods:*** A randomized controlled, single-blinded intervention trial (RCT) with wait list control design was used. Geriatric patients (n = 34; age: 81.9 ± 5.7 years) with cognitive impairment (MMSE: 18.8 ± 4.7), identified by predefined in- and exclusion criteria, were consecutively recruited from a geriatric rehab ward. Patients in the intervention group (IG, n = 17) performed a 6-week strength and functional home training. The control group (CG, n = 17) started an identical training 6 weeks later with an initial usual care period during the intervention for the IG. Functional performance (Short Physical Performance Battery; SPPB), clinically relevant functional deficits (Performance Oriented Assessment; POMA), and physical activity (Assessment of Physical Activity For Older Persons questionnaire; APAFOP) represented primary outcome measurements complemented by additional secondary outcome parameters. ***Results:*** The IG significantly increased functional performances in SPPB (total score: $p = 0.012$; chair rise: $p = 0.007$, balance: $p = 0.066$), reduced gait and balance deficits in POMA (total score: $p = 0.006$; balance: $p = 0.034$; gait: $p = 0.019$), and increased physical activity (APAFOP; $p = 0.05$) compared to the CG. Effect sizes showed medium to large effects for significant parameters (eta^2 = 0.14–0.45). Training benefits and adherence were more pronounced following the immediate onset of post-ward training compared to a delayed start (eta^2 = 0.06–0.23). ***Conclusion:*** Results of this pilot study show that a feasible and easy to handle, home-based reha-

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bilitation program increased functional performance and physical activity in a vulnerable, multimorbid patient group with cognitive impairment, in particular when the post-ward training onset was not postponed.

Introduction

Although cognitive impairment (CI) is prevalent in 30–80% of patients admitted to inpatient rehabilitation, only a limited number of rehabilitation programs have been developed and evaluated for this vulnerable patient group. This is surprising since this group shows an increased number of risk factors affecting their health status compared to cognitively intact patients. Those are: higher multimorbidity [1], loss of independence [2], and increased need of care and institutionalization [3]. CI is associated with an increased risk for a negative rehabilitation outcome, a smaller functional recovery during inpatient rehabilitation and a lower functional status at discharge [4]. Further, if transitional care interventions following inpatient rehabilitation are provided, persons with the highest risk (e.g., with CI, comorbidities) are often excluded [5].

Besides their insufficiently exploited rehabilitation potential, previous research indicated that rehabilitation programs are generally suitable to improve functional performance in cognitively impaired persons (cf. [6] for a review). Therefore, effective rehabilitation programs at the transition from geriatric inpatient rehabilitation to the home environments are needed for these patients [5]. Effective post-ward rehabilitation programs may not only increase the ability to perform activities of daily living (ADL; as the most important predictor of societal costs of care of community-dwelling patients) and improve functional performances and mobility, but moreover they may allow proper preservation of autonomy (a most appraised goal of geriatric rehabilitation). Particularly, patients with CI may have limited access to medical services including post-ward rehabilitation (e.g., transport to participate in rehabilitation programs is considered a typical barrier) [7].

Previous findings indicate that home-based programs are feasible in community-dwelling older individuals, which can be considered high-functioning cohorts of older adults compared to geriatric patients with CI [8–13], showing adherence rates of 72–91% in the training groups. However, beneficial effects of the presented programs are inconsistent with some studies indicating performance improvements [8], while others showed decelerated deterioration of physical function and mobility [9] or did not find any training-related effects [11–13]. Further, the respective studies showed methodological inconsistencies, e.g. using questionnaire-based assessment methods to register physical activity and mobility [10–12], did not provide sufficient information on motor performance measures [10] or did not register key motor features (i.e., gait, balance, strength) as primary endpoints [10, 11].

Publications on home-based exercise programs focusing on patients with CI following discharge from a geriatric hospital are scarce. This is surprising since our research group as well as others were able to show that supervised ward-based [14] and post-ward programs [15] are effective in improving strength, motor function, and physical activity in this specific population. However, solutions to increase sustainability of rehabilitation programs will have to be low-cost as rapidly increasing budgets for medical care in older persons already endanger adequate and effective health care. To date, interventions at the transition from geriatric inpatient rehabilitation to the home environments have been evaluated in heterogeneous patient populations [16–20]. Most programs included cognitively intact patients [16, 17], while only few implemented subgroups of cognitively impaired patients [18–20] and found conflicting results. Some studies reported beneficial effects of home-based training on measures of motor performance [16, 18, 20], while others did not [17]. Further, behavioral aspects such as physical activity, which is crucial for the sustainability of rehabilitation programs and a prominent indicator of durable behavioral change, have hardly been investigated in recent studies. Only 2 studies registered physical activity levels using questionnaires in community-dwelling older adults [8, 13], but none found intervention-related improvements in physical activity levels of older adults living at home. Another not yet thoroughly examined topic is the timing of post-ward rehabilitation in patients with CI. Timely outpatient follow-up is a key component of transitional care models that have been successful in reducing readmission rates [21]. Due to legal reconciliation, reconstruction works at the patients' homes to establish a disability-friendly environment or specific transitional measures (i.e., short-term care), the transition from the hospital back into their home environments is often delayed, and rehabilitative actions are postponed. However, research on rehabilitation onset in the group of geriatric patients with CI is lacking, and it remains unknown whether a timely onset of post-ward rehabilitation improves functional outcomes in this vulnerable group. In elderly patients after cardiac surgery, early rehabilitation during inpatient rehabilitation increased gait autonomy at the end of the rehabilitation program (more than 90% of patients submitted to early rehabilitation showed significant increases in walking distance) [22]. Further, early cardiac rehabilitation (i.e., within 28 days of admission) significantly improved functional status (i.e., gait capacity and fitness level) compared to a delayed rehabilitation start (i.e., 29–365 days following admission) in patients with acute coronary syndrome [23]. That is, for every 1-day delay, patients were 1% less likely to improve their motor performance. Similarly, a systematic review by Haykowski et al. [24] yielded evidence that each week that cardiac rehabilitation is delayed required an additional month of training to achieve the same level of benefit.

Therefore, the aim of this study was to develop and validate an easy-to-implement and low-cost post-ward rehabilitation program, which is feasible for frail, multimorbid patients suffering from CI at the transition from geriatric inpatient rehabilitation to their home environments. We hypothesized that the training program is (a) suitable and feasible to be implemented at patients' homes, (b) improves key motor performance (i.e., gait performance, balance performance, and strength), (c) increases physical activity within the observation period, and (d) an early onset of training is better suited to improve training adherence and effectiveness following hospital discharge compared to a later onset of training.

Methods

Study Design

We present a randomized, controlled pilot study with wait list control group design. Patients in the intervention group (IG) took part in a standardized 6-week home training. Patients assigned to the control group (CG) received usual care and were not contacted during the first observational period (period: T1–T2). After the first training period, CG started to exercise according to the wait list control design (period: T2–T3) to document the effect of delayed onset of training. The study conforms to the Helsinki Declaration and was approved by the ethic committee of the Medical Department of the University of Heidelberg.

Participants

Patients admitted to rehabilitation at a geriatric hospital (AGAPLESION Bethanien Hospital, Heidelberg, Germany) between 10/2011 and 7/2012 were consecutively screened for predefined inclusion criteria: (1) Mini-Mental State Examination (MMSE) score <24, (2) age >65 years, (3) ability to stand or walk 5 m without support, (4) no severe somatic or psychiatric disease, (5) no premature termination of rehabilitation period, (6) residence <35 kilometers to the study center, (7) no simultaneous participation in other studies, (8) written informed consent. A person not involved in study organization randomly assigned patients to the study groups.

Intervention

The home training program was specifically developed for the target sample to be feasible and effective in multimorbid, frail older adults. The main contents of the training program were postural control and strength, each addressed by 3 exercises. The training intervention was derived from an exercise program developed by our research group, which was feasible and effective to increase strength and functional performances in patients with CI [15] and has additionally been used on a website providing interactive motor training and functional assessment for persons with CI (http://bewegung-bei-demenz.de/). We did not include specific gait training as we felt that an unsupported gait task might represent a high fall risk as compared to supported balance and transfer tasks.

During the first training session, the program was explained and supervised by a professional trainer experienced in communication strategies for cognitively impaired persons. Dementia-specific strategies included emotional aspects such as reassurance of training progress, positive feedback, and personal care/empathy, as described in patient-centered communication techniques developed for individuals with dementia [25]. Further, simple structures of motor tasks and haptic support during motor actions were provided, and the use of verbal cues instead of complex verbal instructions was fostered by the trainer [26]. To foster participation and to provide assistance, exercises were illustrated on a large poster (60 × 120 cm; Fig. 1) at patients' homes, and a comprehensive manual of key elements for each exercise (including safety instructions, e.g., using a chair or a nearby wall for support during balance tasks) was developed and provided to the participants. Postural balance tasks included standing in progressively challenging positions (side by side stance, semi-tandem stance, tandem stance). Strength exercises targeted basic ADL-related key motor functions, including functional strength (such as ankle lifts, chair rises, and stair rises). Participants were instructed to perform 2 series of 7–10 repetitions for each exercise. Balance positions were maintained for 30 s. Progression of training was facilitated by increasing task difficulty (e.g., narrowing standing positions, reduction of postural stabilization by reducing handgrip) and by increasing the workload (number of repetitions in strength-related tasks, single vs. double stand, reducing arm support). Participants were instructed to exercise at least once per day, but encouraged to exercise as often as possible. Training intensity was adjusted to individuals' performance levels, and participants were instructed to stop exercising or reduce difficulty when feeling exhausted or overtaxed. Subjects were contacted weekly to document training adherence, to increase compliance and to adjust individual training levels/tasks based on a manual delivered discussed at beginning of intervention. Proxies or carers were informed about the program and instructed to support participants. No other care or therapy except for the intervention program was offered to the participants in both groups. During the first observation period (T1–T2), CG did not receive any additional support or contact except for baseline and postinterventional assessment.

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(For legend see next page.)

Measurements

Standardized measurements were performed before randomization at the end of ward-based rehabilitation (T1), at the end of the 6-week training period (T2, RCT design), and after a 6-week follow-up period (T3; training for the initial CG). Assessors were trained in documenting motor performances in patients with CI [15] and were blinded to randomization.

Clinical characteristics, i.e. functional status (Barthel index), social status (living independently/with spouse, support by proxies/public care service, proxies living in same facility, or 24-h care service), psychological status (Geriatric Depression Scale, GDS) [27], and cognitive status (MMSE) [28] were documented at baseline. Functional performances were assessed by well-established, validated tests: the performance-based Short Physical Performance Battery (SPPB), including subtests of chair rise, balance and gait performance [29] and Tinetti's Performance Oriented Motor Assessment (POMA) [30], including subtest on gait and balance. In addition, results of the SPPB gait test and chair rise test were documented as absolute duration (seconds) not transcribed into to SPPB scoring to assess qualitative performance.

Physical activity was documented by the Assessment of Physical activity for Older Persons (APAFOP), a questionnaire developed and validated for persons with CI [31]. APAFOP captured total physical activity by multiplication of metabolic equivalent levels of activities and times spend in the respective activity over a period of 24 h using specific memory techniques to increase the accuracy of reports. Adherence to the training intervention was documented as number of training sessions within the training period, and training-related adverse events were prospectively documented by standardized weekly telephone calls [32].

Technical measures focused on Sit-to-Stand (STS) performances and were assessed using accelerometer-based body fixed sensors (DynaPort® Hybrid, McRoberts, The Hague, the Netherlands) which have been validated in geriatric patients [33]. For STS, patients performed the chair rise test representing an established functional assessment in older adults [29]. We analyzed parameters with a high impact on successful STS performance; that is total duration and duration of hip extension/flexion as well as maximum angular velocity (during hip extension/flexion) of both the stand-to-sit as well as sit-to-stand movements. Because of technical reasons (i.e., availability of the assessment unit) as well as floor effects within the study group, only a subsample of patients was included in the accelerometer-based assessment.

Statistical Analysis

An a priori power analysis using a repeated measure analysis of variance (ANOVA) design including 2 groups and 2 repeated measurements yielded a total sample size of $n = 28$ ($\alpha = 0.05$; critical $F = 4.23$; power = 0.8). The effect size is based on an RCT comparing 12 weeks of group-based resistance/functional training and low-intensity placebo activity in 122 older adults with CI [17]. Results showed an average improvement of 26% in functional performance (POMA score; effect size: $eta^2 = 0.22$). Estimating a dropout of ~20%, the sample size was estimated to be 34 participants.

Fig. 1. Exercise poster for exercises used in the study. Displayed are balance exercises (i.e., side by side, semi-tandem, and tandem stance) on the right and strength exercises (i.e., calf raise, sit to stand transfer, and stair rise) on the left side. rep., repeats.

Table 1. Baseline comparison of study groups

Parameter	IG (n = 17)	CG (n = 17)	p value
Age, years	81.4±6.6	83.3±5.7	0.379
Weight, kg	67.0±13.7	68.5±15.7	0.772
Gender, female	65%	71%	–
Ward rehabilitation, days	22.9±6.5	21.5±8.9	0.615
MMSE score	19.5±4.6	18.2±4.4	0.401
GDS score	4.0±3.4	5.6±2.3	0.390
ADL-Barthel score	71.2±17.7	67.1±17.1	0.496
POMA score	16.4±5.8	17.7±6.2	0.464
SPPB score	4.5±2.7	4.5±2.8	0.999
APAFOP score	26.0±1.2	25.7±1.1	0.342

p values represent comparison between study groups for mean ± SD at baseline. MMSE, Mini-Mental State Examination; GDS, Geriatric Depression Scale; ADL, activities of daily living; SPPB, Short Physical Performance Battery; POMA, Performance Oriented Motor Assessment; APAFOP, Assessment of Physical Activity in Older Persons.

Exploratory data analysis determined the variability and distribution of outcome variables. Unpaired *t* test and χ^2 test were used for baseline comparison and comparisons of training/contact frequency. Primary study endpoints were the total scores of SPPB, POMA, and APAFOP. Secondary endpoints were subscores of the SPPB (chair rise, balance, gait) including duration of walking and chair rise during subtests of SPPB, and results of technical STS assessment including movement durations (total, flexion, extension), and maximum angular velocities (flexion/extension). Between-group differences were analyzed by ANOVAs with repeated measures for intervention effects (T1–T2) within the RCT design. To examine the effects of an early versus delayed training onset, ANOVAs with repeated measures for intervention effects (IG: T1–T2; CG: T2–T3) within the wait list design were used. Time × Group effects were given for between-group analysis of intervention effects. Time effects were given to document time-related effects only. Effect sizes were documented as partial eta^2, a measure sensitive to various kinds of linear and nonlinear relationships. Values ranging from 0.01 to 0.06 indicate low; values from 0.06 to 0.25 medium, and values above 0.25 large effect sizes [34]. All analyses were calculated using Statistical Package for Social Sciences (SPSS) version 23.0 (IBM Corp., New York, NY, USA), and significance levels were set at $\alpha = 5\%$.

Results

Among 561 patients screened for participation, 34 (age range: 69–94 years) matching our predefined inclusion criteria were included in the study. Primary causes for exclusion were cognitive status ($n = 292$), readmission to the hospital ($n = 57$), and institutionalization ($n = 56$). Six

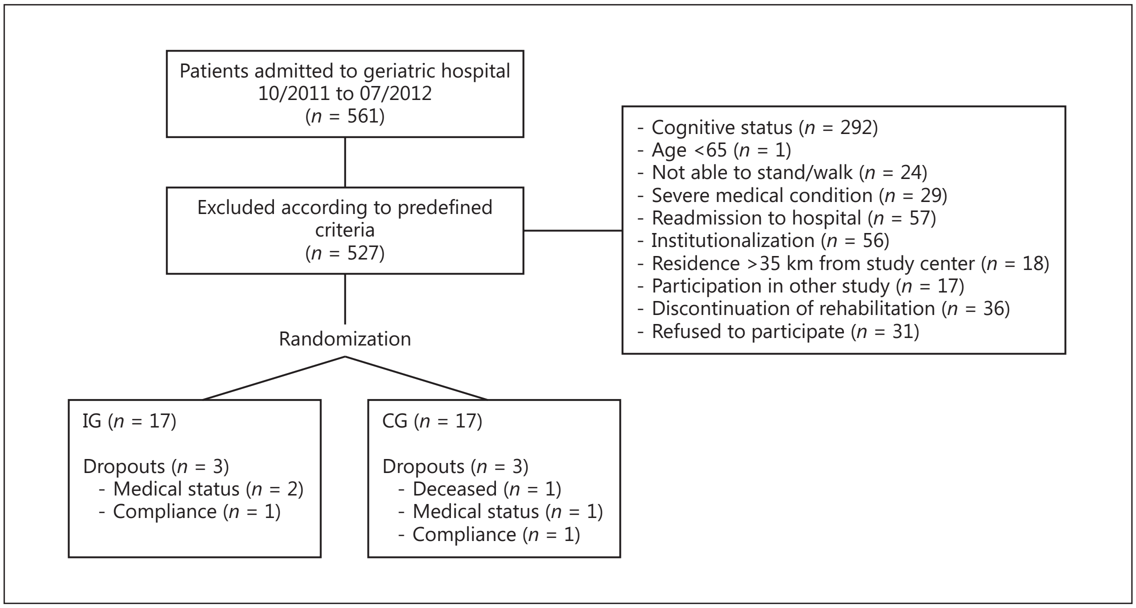

Fig. 2. Flowchart of patient recruitment. A total of 561 patients were screened for inclusion; 527 were excluded according to predefined exclusion criteria; 34 were randomized into the study groups (intervention group [IG]: $n = 17$, control group [CG]: $n = 17$).

patients dropped out after randomization within the first training period (IG: $n = 3$; CG: $n = 3$). Figure 2 shows the recruitment procedure according to the CONSORT statement [35]. IGs did not differ at baseline, indicating a successful randomization (Table 1). Compliance to training was high and no adverse training-related events occurred.

Effects of Home-Based Training

The training intervention significantly increased performance in primary study endpoints for motor performance as well as for physical activity (Table 2). Results of the SPPB indicated overall, significant improvement in key motor performances (increase in SPPB total score by 40%). In subtests specifically addressed in the training program (i.e., chair rise and balance), performance significantly increased in IG compared to CG. In the subtest not specifically addressed during training (i.e., walking), performance improved in both groups with a clinically relevant increase in the IG resulting in significant Time but not Time × Group effects. SPPB results expressed as absolute time-based performance and not scoring results further confirmed results based on scoring. Similarly, results of the POMA indicated a significant overall reduction of gait and balance deficits (increase in total POMA score by 24%) as well as a reduction in both subperformances of gait and balance in IG compared to CG. Effect sizes ranging from 0.23 to 0.45 for the significant results of the SPPB and from 0.16 to 0.25 for the POMA indicated medium to large effects of the intervention (Table 2), documenting not only statistically significant but clinically relevant improvements [36]. When training results were combined for both training groups (immediate training in IG and delayed training in CG) to increase sample size and statistical power, the above-documented results were confirmed and ANOVAs additionally indicated significant performance improvements in subscores of SPPB (+18%, $p = 0.001$, $\text{eta}^2 = 0.33$ for SPPB – balance; +23%, $p = 0.043$, $\text{eta}^2 = 0.15$ for SPPB – gait).

Sensor-Based Outcome Measures

For a subsample of participants, additional sensor-based assessments were performed during STS (Table 3). Despite the very small number of participants, interventional effects led to significant improvements during stand-to-sit transfers (total duration, duration of extension/flexion, and maximal angular velocity during extension: $p = 0.006–0.044$; $\text{eta}^2 = 0.35–0.55$) and during sit-to-stand transfers (extension duration: $p = 0.018$, $\text{eta}^2 = 0.44$) based on very large effect sizes achieved.

Table 2. Effects of intervention

	IG (n = 14)		CG (n = 14)		Time effects		Time × Group effects	
	T1	T2	T1	T2	p value	ES	p value	ES
Primary outcomes								
SPPB – total, score	5.0±2.7	7.0±2.7	4.4±2.9	4.7±2.4	**0.001**	0.35	**0.010**	**0.23**
POMA – total, score	18.6±7.5	23.0±4.4	18.4±7.0	18.6±5.2	**0.003**	0.29	**0.006**	**0.25**
APAFOP, score	26.2±1.1	27.2±2.0	25.7±1.2	25.7±1.2	**0.037**	0.16	**0.050**	**0.14**
Secondary outcomes								
SPPB – chair rise, score	0.6±0.8	1.5±1.4	0.7±1.3	0.7±1.1	**0.007**	0.25	**0.007**	**0.25**
SPPB – balance, score	2.9±0.9	3.6±0.7	2.6±0.7	2.7±0.7	**0.024**	0.18	0.066	0.12
SPPB – gait, score	1.4±1.3	1.9±1.3	1.1±1.4	1.3±1.1	**0.040**	0.15	0.395	0.03
SPPB – gait speed, m/s[a]	0.5±0.2	0.6±0.2	0.4±0.2	0.4±0.2	0.069	0.19	0.153	0.12
SPPB – chair rise, s[b]	20.9±5.7	16.0±4.0	19.1±9.8	24.4±12.0	0.912	<0.01	**0.009**	**0.45**
POMA – balance, scores	11.0±3.4	13.3±1.7	11.5±3.4	11.7±1.8	**0.012**	0.22	**0.034**	**0.16**
POMA – gait, scores	7.6±4.5	9.7±2.8	6.9±3.9	6.9±3.9	**0.019**	0.19	**0.019**	**0.19**

Presented is a between-group comparison for effects of intervention for "Time × Group" and "Time" effects. p values are given for ANOVAs with repeated measures, effect sizes are given as partial eta^2. IG, intervention group; CG, control group; POMA, Performance Oriented Motor Assessment; SPPB, Short Physical Performance Battery; APAFOP, Assessment of Physical Activity in Older Persons; ES, effect size. Figures in bold indicate significant p values and ES with moderate to large effect (>0.06). [a] IG (n = 9), CG (n = 9). [b] IG (n = 9), CG (n = 5).

Table 3. Effects of intervention (sensor-based measures)

	IG (n = 8)		CG (n = 5)		Time effects		Time × Group effects	
	T1	T2	T1	T2	p value	ES	p value	ES
Sit-to-stand								
Duration, s	1.8±0.4	1.4±0.2	2.0±0.6	2.5±0.9	0.706	0.02	0.064	0.30
Flex. duration, s	0.9±0.2	0.8±0.2	1.0±0.4	1.1±0.4	0.745	0.02	0.451	0.06
Ext. duration, s	0.9±0.3	0.6±0.1	0.9±0.2	1.4±0.6	0.334	0.13	**0.018**	**0.44**
Max. ang. vel. flex., °/s	86.2±35.9	106.0±54.5	74.0±21.1	60.4±10.0	0.893	<0.01	0.239	0.14
Max. ang. vel. ext., °/s	42.2±22.7	37.7±17.5	46.9±26.5	41.4±15.4	0.364	0.12	0.919	0.001
Stand-to-sit								
Duration, s	2.2±0.5	1.5±0.3	2.0±0.8	2.4±0.7	0.990	0.00	**0.014**	**0.47**
Flex. duration, s	1.1±0.3	0.7±0.2	1.0±0.4	1.3±0.3	0.887	<0.01	**0.015**	**0.46**
Ext. duration, s	1.0±0.2	0.8±0.2	0.9±0.4	1.1±0.4	0.837	0.01	**0.044**	**0.35**
Max. ang. vel. flex., °/s	41.1±13.8	46.5±27.1	36.8±17.7	31.5±12.4	0.998	0.00	0.369	0.08
Max. ang. vel. ext., °/s	75.3±22.6	107.7±50.1	81.8±39.0	52.5±10.3	0.677	0.03	**0.006**	**0.55**

Presented are results of STS performance during the chair stand test for ANOVAs with repeated measures for between-group comparison (Time × Group effect) according to the RCT design and Time effects for motor effects of intervention. Effect size is given as partial eta^2. IG, intervention group; CG, control group; flex., hip flexion phase; ext., hip extension phase; max. ang. vel., maximum angular velocity; ES, effect sizes. Figures in bold indicate significant p values and ES with moderate to large effect (>0.06).

Table 4. Immediate versus delayed onset of training

	Immediate (n = 14)		Delayed (n = 13)		Time effects		Time × Group effects	
	T1	T2	T2	T3	p value	ES	p value	ES
Primary outcomes								
SPPB total, score	5.0±2.7	7.0±2.7	4.4±2.1	5.2±2.3	**<0.001**	**0.47**	0.068	0.13
POMA total, score	18.6±7.5	23.0±4.4	18.2±5.1	18.6±4.9	**0.004**	**0.29**	**0.016**	**0.21**
APAFOP, score	26.2±1.1	27.2±2.0	25.6±1.2	26.0±1.3	**0.011**	**0.23**	0.258	0.05
Secondary outcomes								
SPPB – chair rise, score	0.6±0.7	1.5±1.3	0.7±1.3	0.9±1.3	**0.002**	**0.33**	0.053	0.14
SPPB – balance, score	2.9±0.9	3.6±0.6	2.6±0.7	3.0±0.7	**0.002**	**0.33**	0.384	0.03
SPPB – gait, score	1.4±1.3	1.9±1.3	1.1±0.9	1.3±0.9	**0.043**	**0.15**	0.440	0.02
SPPB – gait speed, m/s[a]	0.5±0.2	0.6±0.2	0.3±0.2	0.4±0.2	**0.037**	**0.23**	0.311	0.06
SPPB – chair rise, s[b]	20.9±5.7	16.0±4.0	25.1±12.1	17.4±6.5	**0.001**	**0.60**	0.351	0.07
POMA – balance, score	11.0±3.4	13.3±1.7	11.6±1.9	11.8±2.0	**0.004**	**0.28**	**0.011**	**0.23**
POMA – gait, score	7.6±4.5	9.7±2.8	6.5±3.7	6.8±3.6	**0.023**	**0.19**	0.082	0.12

Presented is a between-group comparison for effects of training onset for "Time × Group" and time-related effects. p values are given for analysis of variance, repeated measures, effect sizes are given as partial eta^2. POMA, Performance Oriented Motor Assessment; SPPB, Short Physical Performance Battery; APAFOP, Assessment of Physical Activity in Older Persons; ES, effect sizes. Figures in bold indicate significant p values and ES with moderate to large effect (>0.06). [a] Immediate (n = 9), delayed (n = 10). [b] Immediate (n = 9), delayed (n = 6).

Immediate versus Delayed Onset of Training

Adherence rates significantly differed between an immediate and delayed onset of training (p = 0.025, eta^2 = 0.19). Patients in the immediate group completed 40.9 ± 25.9 training sessions (i.e., average of 0.97 training sessions per day) while patients in the delayed group conducted 20.8 ± 16.5 training sessions on average (i.e., 0.49 training sessions per day on average). Regarding functional performance, significant improvements or at least a trend to improved functional performance in the immediate training group compared to the delayed training group could be observed (p = 0.011–0.082; eta^2 = 0.12–0.23; Table 4). This finding is supported by medium effect sizes found in 7 out of 11 parameters (eta^2 = 0.06–0.23) that were present despite the rather small sample size. Further, each registered parameter showed a significant effect of Time (p = 0.001–0.043, eta^2 = 0.15–0.60), indicating that both training groups increased motor performance and physical activity following the home-based training.

Discussion

This study investigated the effects of a home-based post-ward training program on functional performance and physical activity in patients with CI. Our main results can be summarized as follows: (1) the program was feasible to be implemented in cognitively-impaired patients following hospital discharge, (2) the training intervention significantly improved key motor features and increased physical activity levels, and (3) training-related performance improvements benefit from an early onset of training after hospital discharge.

Feasibility and Safety of the Home-Based Training

Our results are in line with previous studies including home-based exercise in patients with Alzheimer disease [8] and with studies investigating supervised ward-based and post-ward [15] interventions in patients with CI. Findings indicate that a home-based training program is feasible and well-accepted in this vulnerable target population. Patients in our study conducted 0.97 training sessions per day on average and thus met the prospected training goal. Even those who trained less during the training period reached at least 60% of the intended training sessions while others conducted up to 300% (range: 26–129 session per day). In the present study, a motivational approach (i.e., assessors and supervisors used a dementia-specific communication approach) was used [15], which is based on established care models such as validation, personal assistance by home visits and weekly phone calls, easy to understand, visualized training instructions on a poster, individually tailored exercises allowing proper progression of intensity, and the introduction of safety rules. Particularly, the weekly phone contact may have played a major role in adherence as it represented an ongoing and reliable personal contact with multiple options to interact and to strengthen adherence and personal commitment.

Results indicate that a high training adherence can be achieved despite relevant cognitive and advanced functional impairment. No training-induced adverse events occurred (i.e., no falls or injuries during exercises), indicating that even challenging exercises, as included in the presented program (e.g., balance tasks, STS training, stair rise), did not lead to an increased risk in patients with a high risk for falls. Thus, we consider the home-based training program safe and feasible to be implemented at patients' homes following ward-based rehabilitation.

Effects of Home-Based Training on Motor Performance

Our home-based intervention significantly increased key motor performances as indicated by results of the SPPB and decreased deficits in gait and balance as indicated by results of POMA. Training effects seem specific as performances specifically improved in exercises trained in our home-based program (i.e., balance, STS) compared to those on which the training did not specifically focus on (i.e., walking). These findings comply with the well-documented principle of training specificity [37]. The documented training effects are relevant for ADL competence as they were achieved in key motor performances such as postural control or transfer tasks, representing major competences in everyday life. In addition, deficits in such key motor performances (especially STS transfers) represent high-impact risk factors for falls in a multimorbid population with CI with a particular risk for falls [38].

The program led to high training effects as indicated by large effect sizes in this comparatively small study sample. Findings are in line with studies on supervised group-based physical exercise in cognitively impaired persons [15, 39]. The high impact of our home-based training using simple and low-cost interventions provides evidence that the potential of patients included in ward-based rehabilitation may currently not be fully exploited. In addition, study results confirm that training in persons with low basic performance levels is highly rewarding when an individually tailored program with adequate progression of training intensity and difficulty is applied [8, 20].

Training effects were assessed by different assessment strategies but almost all indicated improvements in functional performance. We used well-established clinical assessment methods (POMA, SPPB) [29, 30], developed for persons with motor impairment and validated in subsamples of persons with CI, as well as advanced methods based on body-fixed sensors [33]. The latter allow reliable insight into relevant functional performances not ascertainable by established clinical measures. In our study, body-fixed sensors were used to evaluate their potential to document training effects on STS performances with high sensitivity to change as a major issue in intervention studies. Using technically driven measures, we were able to detect significant effects in a number of parameters, although we only used a small sample with advanced functional deficits. The extraordinary large effect sizes found for the sensor-based assessments during STS ($eta^2 = 0.35–0.55$) highlight their potential to sensitively document interventional effects, providing detailed insight into biomechanics of the STS transfer (i.e., flexion/extension ranges, angular velocities), a motor performance measure with high relevance for future specification and optimization of training interventions. As shown in Table 4, duration of a major phase of the transfer task (movement of trunk to create a sufficient momentum for upper-forward motions) as well as related ankle velocities were positively affected by the training intervention. Further, such sensor-based biomechanical measures have been shown to be of greater clinical relevance compared to the manually recorded STS measures in older adults (i.e., instrumented STS times were associated with participants' health status, while manually recorded STS times were not) [40].

Effects of Home-Based Training on Physical Activity

Previous research on home-based training in patients with CI lacks objective measures of physical performance and focused on functional decline instead [8]. However, it is crucial to increase the sustainability of performance benefits when formal rehabilitation programs end. The key to such efforts is behavioral modifications to increase physical activity, leading to higher sustainability of training effects as achieved during ward-based rehabilitation. In our study, we documented physical activity to evaluate the effect of the intervention in a highly sedentary study sample, severely affected by motor and cognitive impairments often associated with specific symptoms (i.e., apathy, spatiotemporal disorientation or risk of falling limiting outdoor activities, or decreased adherence to interventional programs) [38]. In contrast to previous studies [8, 13], we were able to show that physical activity can be increased in the vulnerable population of CI patients using home-based exercise programs, as documented by a comprehensive questionnaire developed and successfully validated in patients with CI [31].

Effects of Immediate versus Delayed Home-Based Training

The design of this pilot study allowed the investigation of the effect of a delayed onset of the post-ward training, a factor which, to the best of our knowledge, has not been investigated with regard to post-ward rehabilitation programs in patients with CI yet. The transition from the hospital to the home environment is often delayed. Reasons are manifold and range from reconstruction works at the patients' homes to install disability-friendly environments to short-term care in nursing homes. A recent systematic review on post-ward adherence to rehabilitation programs further indicated that an early onset of care (i.e., early medical consultations and appointments with medical staff as well as timely self-monitoring of activity following hospital discharge) improved uptake of and adherence to rehabilitation programs in cardiac patients [41] and yielded more pronounced training benefits compared to a delayed onset of training [23, 24]. In line with these findings, results of our study showed that adherence rates significantly decreased when post-ward training is delayed by 6 weeks. Patients in the delayed training group only conducted half of the sessions compared to the group with immediate onset. This deficit in participation was also mirrored in the functional performances of patients. Although the sample size in our study was rather small and both groups increased performance following training, effect sizes indicate that the majority of functional outcomes further improved following an immediate onset of training. That is, performance improvements in SPPB and POMA were more pronounced following an immediate start of the training. Thus, post-ward rehabilitation programs should be implemented as soon as possible following hospital discharge to fully exploit the rehabilitation potentials of patients with CI.

Limitations

The major limitation of the current study is its small sample size, reducing the statistical power to identify significant effects. However, significant improvements and trends as achieved in this study, associated with the large effect sizes found, indicate a high effectiveness of the training program in this vulnerable, multimorbid, and cognitively impaired patient group. Further, based on the study design (wait list control design), no follow-up data were available for the training groups. Thus, retention of training results could not be obtained from our data set.

Conclusions

Results of this pilot study document high effectiveness of a post-ward, home-based training program specifically tailored for patients with CI. Thus, the implementation of home-based interventions involving training of key motor performances seems feasible and valuable in this vulnerable patient group, particularly when implemented shortly after hospital discharge. Further, innovative, sensor-based assessment tools are suitable to extend established clinical measurements, allow new insights into the biomechanics of key motor performances and may be used to further specify and optimize training interventions in cognitively impaired patients.

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Statement of Ethics

The study conforms to the latest version of the Helsinki Declaration and was approved by the Ethics Committee of the Medical Department at the University of Heidelberg.

Disclosure Statement

The authors declare that there is no conflict of interest associated with this work.

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Author Contributions

K.H.: study concept, design, and management, supervision of data collection, statistical design and analysis, interpretation of data, and preparation of manuscript. P.U.: acquisition of participants, study management, data analysis, interpretation of data, and preparation of manuscript. R.B.: preparation of manuscript, data analysis. All authors contributed to interpretation of data, drafting the article, and final approval of the version to be published.

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STUDY PROTOCOL Open Access

Development of a home-based training program for post-ward geriatric rehabilitation patients with cognitive impairment: study protocol of a randomized-controlled trail

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Abstract

Background: Geriatric patients with cognitive impairment (CI) show an increased risk for a negative rehabilitation outcome and reduced functional recovery following inpatient rehabilitation. Despite this obvious demand, evidence-based training programs at the transition from rehabilitation to the home environments are lacking. The aim of this study is to evaluate the efficacy of a feasible and cost-effective home-based training program to improve motor performance and to promote physical activity, specifically-tailored for post-ward geriatric patients with CI.

Methods: A sample of 101 geriatric patients with mild to moderate stage CI following ward-based rehabilitation will be recruited for a blinded, randomized controlled trial with two arms. The intervention group will conduct a 12 week home-based training, consisting of (1) Exercises to improve strength/power, and postural control; (2) Individual walking trails to enhance physical activity; (3) Implementation of patient-specific motivational strategies to promote behavioral changes. The control group will conduct 12 weeks of unspecific flexibility exercise. Both groups will complete a baseline measurement before starting the program, at the end of the intervention, and after 24 weeks for follow-up. Sensor-based as well as questionnaire-based measures will be applied to comprehensively assess intervention effects. Primary outcomes document motor performance, assessed by the Short Physical Performance Battery, and level of physical activity (PA), as assessed by duration of active episodes (i.e., sum of standing and walking). Secondary outcomes include various medical, psycho-social, various PA and motor outcomes, including sensor-based assessment as well as cost effectiveness.

Discussion: Our study is among the first to provide home-based training in geriatric patients with CI at the transition from a rehabilitation unit to the home environment. The program offers several unique approaches, e.g., a comprehensive and innovative assessment strategy and the integration of individually-tailored motivational strategies. We expect the program to be safe and feasible in geriatric patients with CI with the potential to enhance the sustainability of geriatric rehabilitation programs in patients with CI.

Trial registration: International Standard Randomized Controlled Trial (#ISRCTN82378327). Registered: August 10, 2015.

Keywords: Home-based training, Post-ward (patients) geriatric rehabilitation, Cognitive impairment, Physical activity promotion, Motor performance

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Background

The prevalence of cognitive impairment (CI) in patients admitted to geriatric rehabilitation units ranges from 30% to 80%, depending on sample characteristics and cut-off criteria [1, 2]. CI is accompanied with high demands for the health care systems, as decreased cognitive functioning is associated with increased care costs in this vulnerable population [3]. Compared to cognitively-intact patients, patient with CI show an increased number of risk factors affecting their health status, i.e., multi-morbidity [4], lower functional status [5], an increased risk of falling [6], and higher institutionalization and mortality rates [2]. Particularly, CI is often associated with specific motor-related symptoms, such as impaired functioning (i.e., deficits in balance and gait performance) [7–9], reduced participation in activities of daily living (ADL; i.e., shopping, dressing, or eating) [9] and reduced outdoor activities [10]. Further, a higher probability of neuropsychiatric symptoms is typical in patients with CI (i.e., apathy, anxiety, depression, irritability and agitation) [11–13], resulting in a loss of motivation to become physically active [14]. Patients with CI show an increased risk for negative rehabilitation outcome, leading to limited functional recovery during inpatient rehabilitation [15] and a lower functional status at hospital discharge [5]. Also, their access to medical services is limited, including post-ward rehabilitation (e.g., traveling too far to participate in rehabilitation programs is considered a typical barrier) [16]. These findings indicate the need for appropriate rehabilitation concepts for geriatric patients with CI at the transition from inpatient rehabilitation to their home environments and innovative, individually-tailored training concepts with low entry barriers are required. Effective post-ward rehabilitation programs may increase the ability to perform ADL, representing one of the most important predictor of societal costs of care of community-dwelling patients and improve functional performances and mobility (i.e., allowing proper preservation of autonomy).

Home-based training programs represent suitable exercise regimens that have been shown feasible and save in community-dwelling older adults with CI [17–21]. However, results of these home-based training programs are inconsistent. Some studies indicated improvements in motor performance [17, 18], while others only showed decelerated deterioration of physical function and mobility [22] or did not find any effects on performance [20, 21]. Further, studies showed methodological inconsistencies, e.g., not providing sufficient information on registered motor performance measures [20], not measuring key motor features (i.e., gait, balance, strength) as primary endpoints [19, 20], or using rather small sample sizes [18, 21].

Publications on home-based training programs in the vulnerable group of post-ward patients with CI are still scarce or inconclusive, despite overwhelming evidence based on supervised ward-based and post-ward programs are effective in improving motor function and physical activity (PA) in these specific population [23, 24]. Interventions at the transition from geriatric inpatient rehabilitation to the home environments have only been evaluated in heterogeneous patient populations [25–29]. Most programs included cognitively intact patients [25, 26] and only few studies integrated sub-groups of cognitively-impaired patients [27–29]. Some studies reported beneficial effects of home-based training on motor performance and mobility [25, 29], while others did not find training-related performance improvements [26, 27]. Furthermore, Moseley and colleagues indicated that patients with CI showed worse adherence rates compared to cognitive-intact persons during a home-based training program [27]. Hence, motivational strategies should be integrated into physical exercise programs to promote adherence and increase participation. The importance of motivational strategies is further emphasized by Heyn and colleagues [30], who explicitly state that previous interventions did not integrate appropriate motivational concepts to foster participation and enhance motivation in older adults with CI.

Surprisingly, behavioral aspects, such as PA have hardly been investigated in home-based training programs, although such behavioral changes are crucial for the sustainability of rehabilitation programs. Primary aim of most programs was to improve motor performance and only a few studies documented PA using questionnaires [17, 18, 21]. None found training-related improvements and none objectively registered PA using sensor-based assessment strategies. The latter is astonishing since, due to recall and response bias, questionnaire-based assessments are less valid and reliable in cognitively-impaired older adults [31]. Thus, assessment strategies including objective sensor-based as well as subjective questionnaire-based measurements are advised to comprehensively register changes in activity behavior following training interventions.

The current study protocol addresses the situation of multi-morbid and frail geriatric patients with mild to moderate CI following inpatient rehabilitation. Primary aim of the study is the development and evaluation of a safe and feasible home-based exercise program to improve motor performance and to promote PA (i.e., initiate sustained behavioral changes) in the vulnerable group of multi-morbid, geriatric patients with CI, suitable to be implemented in existing health care plans.

Methods/Design

Study design

The presented study is a blinded randomized-controlled trial (RCT) with two arms (i.e., an intervention group [INTV] and a control group [CTRL]; Fig. 1) and will be

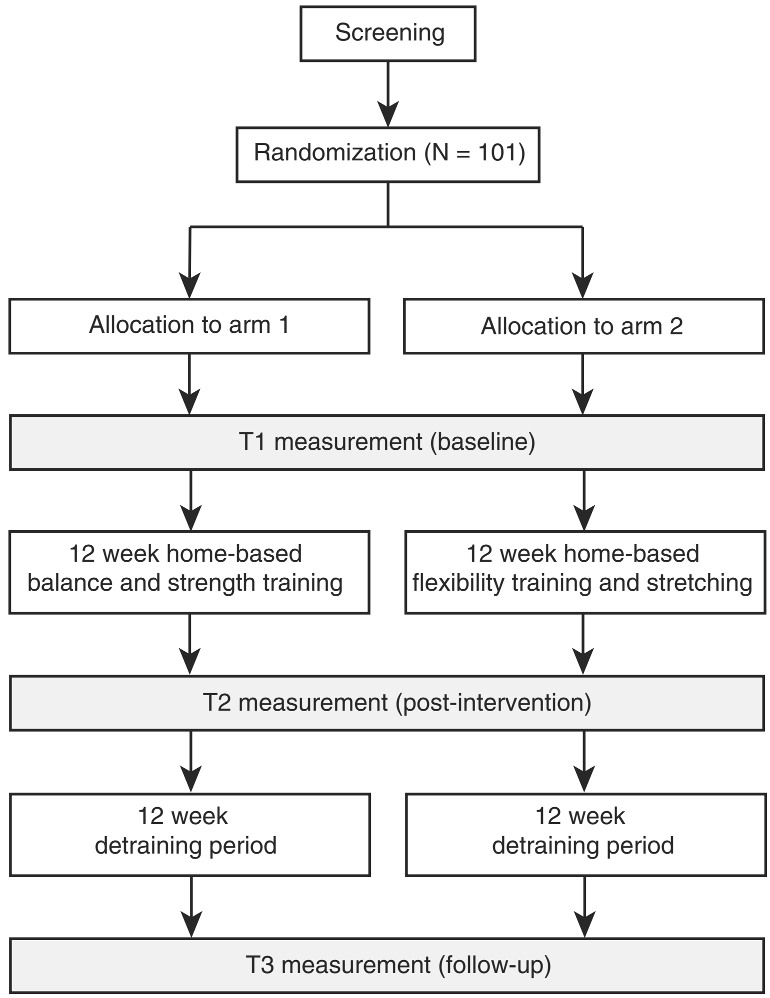

Fig. 1 Schematic illustration of the study design

implemented according to CONSORT guidelines [32]. Ethical approval according to the ethical standards of the Helsinki declaration was obtained from the internal review board at the Medical Faculty of the University of Heidelberg, Germany (reference#: S-252/2015). The study protocol has been registered with the "International Standard Randomized Controlled Trial Number" (ISRCTN) trial register (http://www.isrctn.com/ISRCTN82378327).

Sample characteristics

Inclusion criteria are (1) patients admitted to ward-based rehabilitation in a geriatric hospital in Heidelberg, Germany; (2) age ≥ 65 years; (3) mild to moderate CI (Mini-Mental-State-Examination [MMSE]: 17–26); (4) ability to walk 4 m without support; (5) residency within 30 km of the study center; (6) discharge from rehabilitation unit to home environment; (7) no terminal disease/ no delirium; (8) German-speaking; and (9) written informed consent from participant or care giver. All patients admitted to the geriatric inpatient rehabilitation at the AGAPLESION Bethanien Hospital are consecutively screened for inclusion.

Measures

After inclusion of the participants, primary and secondary outcome parameters are registered at baseline (T1), following the training intervention (T2), and 12 weeks after the training is completed (T3). At baseline, additional descriptive parameters (i.e., age, gender, height, weight, Barthel Index) are registered. Blinded assessors will conduct the measurements at the patients' home.

Motor performance

Key motor performances will be assessed using the Short-Physical-Performance-Battery (SPPB) including sub-tests of static balance, walking performance and sit-to-stand performance [33]. Outcome parameters are the total SPPB score (i.e. 0–12 scores) calculated as the summation of each sub-test score and the scores in each of the sub-tests (i.e. 0–4 scores) [33]. The "Timed Up and Go-test" (TuG) is performed to assess basic functional mobility [34]. Outcome parameter is the time in seconds needed to perform the task.

Additionally, objective performance measures are registered for SPPB using advanced body-fixed motion sensors (DynaPort MT, McRoberts B.V., The Hague, Netherlands). The sensor is attached to subject's lower back at the height of the second lumbar vertebra. The measurement system (106.6 × 58 × 11.5 mm, 55 g) contains three pre-calibrated seismic accelerometers (sensor range: ± 2 g, resolution: 1 mg) and three gyroscopes (range: ± 100 deg./s, resolution: 0.0069 deg./s). Data is recorded at a sampling rate of 100 Hz. Outcome parameters are defined as body sway in terms of Center of Pressure (CoP) displacements in mm and CoP velocity in mm/s to evaluate static balance performance. During the 5-times-chair-rise test, sit-to-stand and stand-to-sit durations in seconds and maximum angular velocities in deg./s are calculated.

Physical activity

PA will be registered using a small-scaled (51 × 30 × 16 mm, 24 g) activity monitor (PAMSys, BioSensics, Cambridge, MA, USA), attached on subjects' chest using adhesive bands. The activity monitor includes a tri-axial accelerometer sensor registering accelerations in three perpendicular directions (accelerations in the frontal, vertical, and lateral directions) at a sampling frequency of 40 Hz. Additionally, a second activity monitor (uSense) will be used for validation purpose. The uSense sensor is a non-commercial prototype, developed by the EU-funded "FARSEEING" project allowing detailed quantitative as well as qualitative data analysis. The sensor (42 × 10 × 68 mm, 36 g) includes a 9-axis inertial platform (accelerometer, gyroscope, magnetometer) registering acceleration and orientation in X, Y and Z direction at a sampling frequency of 100 Hz and is attached to subjects' lower back using adhesive bands.

Raw data from both activity monitors is transferred to a stationary computer for offline analysis using established algorithms [35]. Outcome parameters are number and duration (registered in minutes) of postural episodes (lying, sitting, standing, and walking), cadence defined as steps per minute, number of steps (i.e., total number of steps, number of steps per gait episode) and sit-to-stand/stand-to-sit transitions (number of sit-to-stand/stand-to-sit transitions). The uSense sensor additionally registers qualitative gait parameters (e.g., mean step duration [s], step regularity [%], turning velocity [deg/s]) during each walking episode. Participants are asked to wear the monitor continuously for 48 h.

Life-space

The University of Alabama at Birmingham Study of Aging Life-Space Assessment has been used to document the mobility of community-dwelling older people [36]. Life-space zones range from a person's bedroom (level 0) to beyond the person's home town (level 5). For each life-space zone, subjects report how often they travel to that area per week and whether they need assistance. Higher scores indicate high life-space mobility from 0 ("totally bed-bound") to 120 points ("traveled out of town every day without assistance") [36]. We developed a modified version of the University of Alabama at Birmingham Study of Aging Life-Space Assessment to assess participants' life-space (LSA). The LSA is adjusted to specific limitations of patients with CI to eliminate recall bias and has been successfully validated in geriatric patients with CI (paper submitted).

Additionally, participants' outdoor life-space will be objectively measured using a Global Position System (GPS) tracker. Participants are asked to wear the mobile GPS tracker (QStarz BT1000X, Qstarz International Co., Ltd., Taipei, Taiwan) for 48 consecutive hours. Using a sampling rate of 0.2 Hz, the GPS tracker records participants' outdoor location (i.e., longitude and latitude coordinates) with an accuracy of ±5 m. Outcome measures for a patient's life-space are total LSA score, the maximum distance in meters from the participant home and the mean distance of outdoor walking episodes in meters assessed by GPS using location data [37].

Psycho-social parameters

Health-related quality of life – EuroQol - 5 Dimensions (EQ-5D):

The EQ-5D, including five health-related domains (mobility, self-care, pain/discomfort, usual activities and anxiety/depression) will be used to measure health-related quality of life [38]. Outcome parameters are the EQ-5D total score (5–15 points) and participants' self-rated perceived health status (0–100 points).

Geriatric Depression Scale – Short Form (GDS-SF):

The 15-item GDS-SF will be used to register depressive symptoms [39] by assessing their presence/absence in frail older people (e.g. "Are you basically satisfied with your life?" or "Do you feel happy most of the time?") [40]. A total score of 0–15 points can be achieved with higher scores representing a higher probability of depression (i.e., total score > 5 points indicates mild depressive symptoms, a total score ≥ 10 points indicates moderate to severe depression) [39].

Apathy Evaluation Scale-Clinical version (AES-C):

The 18 item AES-C will be used to evaluate participants' for apathy [41]. The AES-C defines apathy as a psychological dimension based on deficits in behavioral, cognitive, and emotional circumstances of goal-directed behavior. Using the AES-C, the evaluation of apathy is based on clinical observations and subjects' self-reports during a semi-structured interview. A total score of 0 to 54 points can be achieved with higher scores representing a higher probability of apathy.

Fall-related parameters

Fall history:

Falls are defined as an unexpected event where a person comes to rest on the ground, floor or lower level [42]. We will assess the number of falls prospectively during the intervention period using diaries administered by the participants and weekly phone calls conducted by the trainer [43]. Fall history of patients is registered retrospectively at T1, T2 and T3 by asking the participants how often he/she fell during the preceding 4 weeks and 12 months. At T3, participants are additionally asked how often he/she fell during the preceding 12 weeks between T2 and T3.

Short - Falls Efficacy Scale – International (Short-FES-I):

Fall-related self-efficacy will be registered using the 7-item Short-FES-I [44], measuring the level of concern about falling during indoor/outdoor social and physical activities. A total score of 7 (no concern about falling) to 28 (severe concern about falling) can be achieved.

Fear of Falling Avoidance Behavior Questionnaire (FFABQ):

The FFABQ is used to assess activity avoidance behavior due to fear of falling [45]. The FFABQ total score ranges from 0 to 56 points. Higher score indicate greater activity limitations and participation restrictions as a consequence of fear of the falling.

Cognitive Performance

The Digit-Span sub-test of the Wechsler Adult Intelligence Scale (WAIS) [46] is registered to assess participants' short-term working memory. The number of correct repetitions is used for further analyses.

Cost effectiveness

To evaluate cost effectiveness, incremental cost-effectiveness ratios (ICERs) will be calculated [47]. ICERs are calculated by dividing the difference in costs (between the INTV and the CTRL) by the group difference in the outcomes and can be interpreted as the cost to obtain an extra unit of effectiveness, quantifying the trade-offs between patient outcomes gained and resources spend [47]. In our analysis, ICERs will be calculated for primary outcomes (e.g., *motor performance; SPPB total score*) and secondary outcomes (e.g., *health-related quality of life; EQ-5D questionnaire*). Therefore, average costs of the exercise interventions (e.g., training material, visits by trainer, phone calls) as well as overall health care costs (e.g., general practitioner consultations, inpatient and outpatient care, days in hospital, hours of nursing care, hours of professional domestic help or help by family members/friends) will be collected for INTV and CTRL [48]. Overall health care costs will be assessed retrospectively, covering a period of 12 weeks before T1, T2 and T3, using an established questionnaire (FIMA) [49].

Primary outcomes

- *motor performance:* SPPB total score (0–12 points)
- *physical activity:* duration of active episodes (i.e., sum of standing and walking)

Secondary outcomes

- *motor performance:* SPPB sub-test scores (0–4 points each), TuG total time, sensor-based parameters during SPPB sub-tests (e.g. CoP displacements, CoP velocity, sit-to-stand and stand-to-sit duration, maximum angular velocities), and qualitative gait parameters (e.g., mean step duration, step regularity, turning velocity)
- *physical inactivity:* duration of inactive episodes (i.e., sum of lying and sitting), quantitative gait parameters (i.e., cadence as steps per minute, total number of steps, and number of steps per gait episode)
- *life-space:* LSA total score (0–90 points), maximum distance from home and mean walking distances (GPS-based measurements)
- *quality of life:* EQ-5D total score (5–15 points), VAS score (0–100 points)
- *psychosocial status:* GDS-SF total score (0–15 points), AES-C total score (0–54 points), FES-I total score (7–28 points), FFABQ score (0–56 points)
- *falls*: fall history, number of falls during the intervention period
- *short-term working memory:* WAIS-IV test performance (0–9 points)
- *cost evaluation:* ICER for operational as well as health care costs

Intervention

Participants in INTV take part in a standardized 12-week home-based training program. The program is specifically-tailored for geriatric patients with CI after post-ward rehabilitation to improve motor performance and enhance PA. The training intervention was derived from an exercise program developed by our research group, which was feasible and effective to increase strength and functional performances in patients with

CI [24]. Based on results of a successfully conducted home-based exercise pilot RCT, our program includes six exercises to improve static and dynamic postural control (i.e., standing and walking) and strength (i.e., tiptoe stance, stair climbing, sit-to-stand transfers). Exercises are explained and regularly reviewed by a professional trainer and illustrated at the patient's home using a large poster (84.1 × 59.4 cm; Fig. 2). A brief description of key elements for each exercise is provided using a printed manual. Training progress and adherence is supervised by weekly phone calls and regular home visits of the trainer (5 visits in 12 weeks).

One major aim of the intervention is to motivate participants to induce behavioral changes in terms of enhanced PA by incorporating walking trails into their everyday life. Therefore, an individual outdoor walking course is defined next to the patients' homes (i.e., in the respective neighborhoods). Motivational strategies will be used to encourage behavioral changes. Participants are asked to regularly set individual goals, e.g., to extend the individually-defined walking distance. Barriers hampering regular walking sessions and solutions to overcome these barriers are identified in cooperation with the trainer and benefits of regular training/walking sessions are discussed. Variations of the walking trails and physical exercises program are developed to adjust the training protocol to meet the participants' needs (e.g., number of repetitions, handrail support, eyes open/closed, etc.). During the home visits and weekly phone calls, the trainer encourages the participant to conduct the training exercises and the walking trails independently. Furthermore, training descriptions (i.e., training manual; poster), training logs and pedometers are provided to foster participation, to enable self-monitoring of performance, and to define individual goals (e.g., increase number of daily steps). Participation in a local sports club is offered to each participant as an incentive for social participation.

The training program will include a motivational concept that is based on the Theory of Planned Behavior (TPB [50]), Social-Cognitive Theory (SCogT [51]), and Control Theory (CT [52]). The concept will use behavioral change techniques introduced by Abraham & Michie (cf. [53] for a detailed description of the theoretical framework) and integrated into our intervention as followed:

(1) Information about benefits/consequences of regular training and walking sessions are provided (based on TPB);
(2) Encouragement to change daily routines (i.e., integrate training, walk regularly, join a local sport club) (based on TPB);
(3) Barrier identification that hamper training and development of solutions to overcome barriers (based on SCogT);
(4) Set graded tasks (i.e., variations of exercises and walking trails are developed) (based on SCogT);
(5) Provide specific instructions (during home visits using poster and manuals) (based on SCogT);

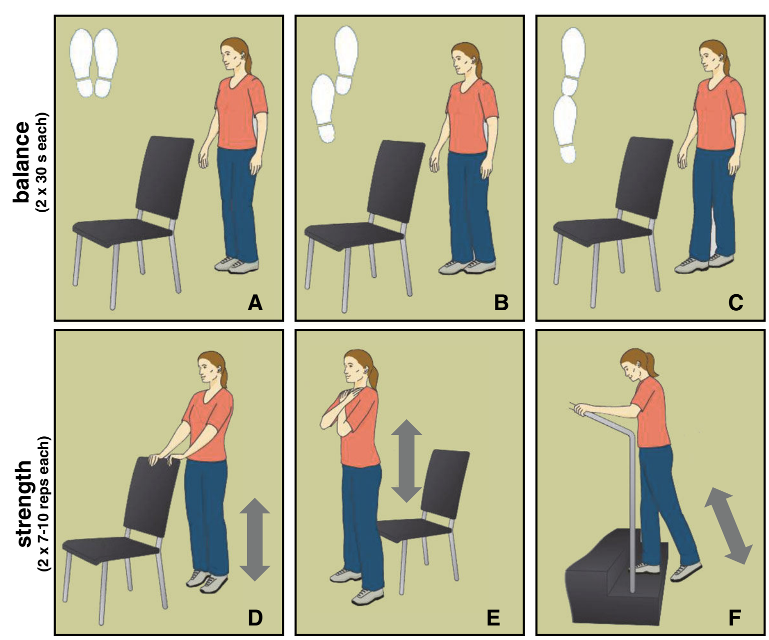

Fig. 2 Illustration of the exercise provided on a poster and used in the intervention. The upper row displays balance exercise (**a**-**c**), the lower row represents strength exercises (**d**-**f**)

(6) Definition of training goals (i.e., frequency, intensity and duration of exercises and walking trails) (based on CT);
(7) Review of behavioral goals (home visits, regular phone calls, pedometer) (based on CT);
(8) Self-monitoring of behavior (training logs, pedometer) (based on CT);
(9) Provide feedback to reinforce behavioral change (home visits, phone calls, pedometer) (based on CT/positive).

These behavioral change techniques are used to encourage patients to translate their intentions into behavioral change. Participants are expected to develop intrinsic motivation and volition to adapt their behavior.

Participants in CTRL receive newsletter-based information about unspecific flexibility and strength training, nutrition and relaxation over a period of 12 weeks. Similar to INTV, participants are called weekly and receive the same amount of home visits as the INTV group to exclude bias effects based on social support. After finishing the project, participants in CTRL will have the opportunity to perform the same exercise program than INTV and also join the local sports club.

Statistical analysis and sample size

An intention to treat analysis will be conducted. We performed an a priori power analysis to determine the sample size necessary to obtain significant effects in PA. Power analysis for PA is difficult to calculate since studies using identical sensor-based physical activity assessments in cognitively-impaired geriatric patients have not been available. Thus, the effect size is based on a study conducting a functional strength training program in 137 institutionalized patients [54]. PA, as assessed by the MTI Actigraph, showed an average increase of PA by 43% in the strength training group compared to a control group (effect size: $eta^2 = 0.18$). A priori power analysis was performed using GPower 3.1 software [55]. A repeated measure analysis of co-variance (ANCOVA) design including two groups and two repeated measurements yielded a total sample size of $N = 101$ ($\alpha = 0.05$; critical $F = 2.69$). Estimating a drop out of 15%, we will recruit a total of 116 participants. For motor performance, as assessed by the SPPB total score, a pilot study conducted by our research group showed that performance improvements can be achieved using relatively small sample sizes ($N = 34$; large effect size: $eta^2 = 0.22$ [56]). Repeated measures ANCOVA will be used to determine effects of the home-based training program on primary and secondary outcomes for effects of intervention (T1-T2) and sustainability of effects (T1-T3). Effect sizes are determined by calculating eta^2 [57]. All data will be analyzed using SPSS 23.0 (SPSS Inc., Chicago, Ill., USA).

Discussion

Our study is among the first RCTs to investigate a specifically-tailored home-based training program with low entry barriers in geriatric patients with CI at the transition from a rehabilitation unit to their home environment. The proposed training program may represent a feasible and effective tool to improve motor performance and increase PA in patients with CI, thus fostering a sustained change in patients' activity behavior. The program requires relatively low supervision and material costs and has the potential to be implemented into existing health care plans. If the program will prove to be effective, it may lower the barrier for post-ward geriatric patients to take up training and exercising. The program may enhance the sustainability of rehabilitation programs by improving medical care of multi-morbid geriatric patients with CI using an innovative therapeutic concept at this vulnerable stage of health care.

Previous home-based training studies showed methodological limitations, e.g., only included sub-groups of patients with CI [27–29] or did not measure key-motor performances as primary endpoints [25, 28] and behavioral aspects in terms of PA have not been investigated in geriatric patients with CI. Only a few studies investigated PA in community-dwelling older adults with CI using questionnaires [17, 18, 21]. Hence, there is a lack of studies in post-ward geriatric patients comprehensively evaluating motor performance and PA. The investigation of training-related effects on motor performance and behavioral changes in terms of enhanced PA requires innovative assessment strategies, including sensor-based as well as questionnaire-based measures. In the presented study we will assess primary outcome measures using well-established, validated tests and complement this approach by additionally registering objective and detailed, sensor-based motor data, a range of psycho-social parameters, such as fear of falling, depression and apathy as well as participants mobility status (life-space), quality of life and cognitive functioning. Applying this comprehensive assessment strategy, we will be able to identify training-related modifications of PA and motor performance based on state-of-the-art sensors and examine their relationship with potentially influencing factors, among others, cognitive status or fear of falling. We regard our assessment as a unique and comprehensive combination of quantitative, qualitative, questionnaire and sensor-based data that - to our knowledge - is not available so far.

One aim of our study is to modify behavior in terms of enhanced PA. Participants need to develop intrinsic motivation and volition to adapt their behavior and to become physically active. So far, only one home-based training study for older adults with CI implemented motivational strategies to increase adherence to physical training, by integrating a goal-oriented and individually-tailored training according to the individual's needs [22]. However, authors did not describe the specific motivational strategy used and did not show data on the feasibility of the motivational support. Our study is going to address this limitation by integrating a specific motivational strategy for patients with CI. Based on various theoretical frameworks (i.e., TPB, SCogT, and CT) [50–52], we will integrate several behavioral change techniques (i.e., information on consequences, barrier identification, proper instructions, goal setting, review of behavioral goals, self-monitoring, and performance-based feedback [53]) into our intervention to ramp up adherence and to increase PA. To the authors knowledge, such a comprehensive interventional approach aiming at behavioral modifications by using individually-tailored motivational instruments not been implemented and evaluated in a home-based training program for patients with CI at the transition from rehabilitation to their home environment before.

In addition, CI represents a high financial burden for the health care systems in western societies [3]. Limited resources in health care require effective interventions that provide high benefits relative to the costs [58]. The presented home-based training program aims to counteract typical health-related limitations in patients with CI and represents a low budget approach. In line with this, our program may encourage the participants to conduct the training sessions independently at their home environments (i.e., no professional monitoring) to minimize costs for supervision by professional trainers. To our knowledge, our study will be the first to also assess economical aspects of a home-based training program for geriatric patients with CI using established instruments (i.e., FIMA [49]) and analyses (i.e. ICER [47, 48]) to objectively yield potential cost effectiveness of the intervention.

In summary, this trial will provide insight into the effect of a specifically-tailored home-based exercise program in patients with CI on motor performance and behavioral change. The program offers several approaches, e.g., a comprehensive and innovative assessment strategy and the integration of individually-tailored motivational strategies to stimulate behavioral change and increase motor performance, may have the potential to enhance the sustainability of geriatric rehabilitation programs in patients with CI.

Abbreviations

ADL: Activities of daily living; AES-C: Apathy evaluation scale-clinical version; CI: Cognitive impairment; CoP: Center of pressure; CT: Control theory; CTRL: Control group; deg.: Degrees; EQ-5D: EuroQol - 5 Dimensions; FFABQ: Fear of falling avoidance behavior questionnaire; GDS-SF: Geriatric Depression Scale – Short Form; GPS: Global position system; ICERs: Incremental cost effectiveness ratios; INTV: Intervention group; LSA: Life-space assessment; MMSE: Mini-Mental-State-Examination; PA: Physical activity; RCT: Randomized-controlled trial; SCogT: Social-cognitive theory; Short-FES-I: Short - Falls Efficacy Scale – International; SPPB: Short-Physical-Performance-Battery; TPB: Theory of planned behavior; TuG: Timed up and go; WAIS: Wechsler adult intelligence scale

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Availability of data and materials

Not applicable.

Authors' contributions

All authors have read and concur with the content in the final manuscript. All authors have made substantial contributions to the manuscript as followed: (1) the conception and design of the study (KH, RK, PU), (2) drafting the article (MB) and/or revising it critically for important intellectual content (MB, RK, PU, TE, JB, KH), (3) final approval of the version to be submitted (MB, RK, PU, TE, JB, KH).

Ethics approval and consent to participate

Ethics approval for the study was received from the internal review board at the Medical Faculty of the University of Heidelberg, Germany (ref: S-252/2015; 26/06/2015). Written informed consent will be requested from subjects and/or their legal representatives (in case those were nominated for persons with severe cognitive impairment) before the onset of the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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- Manuskript III: **Ullrich P**, Werner C, Abel B, Hummel M, Bauer JM, Hauer K. Assessing life-space mobility: A systematic review of questionnaires and their measurement properties.

Under review

Assessing life-space mobility: A systematic review of questionnaires and their psychometric properties

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Assessing life-space mobility: A systematic review of questionnaires and their psychometric properties

ABSTRACT

Background: Life-Space Mobility (LSM) as the ability to move within one's environment is a key for successful aging, and has become a relevant concept in gerontology and geriatric research. Adequate assessment instruments are needed to identify older persons with LSM restrictions, and to initate, adapt, or evaluate intervention strategies.

Objectives: To systematically identify, describe and analyze the psychometric properties of LSM questionnaires, with a special focus on their availability in German language.

Methods: A systematic literature search was conducted in PubMed, PsycINFO, Cochrane Library, CINAHL, and Web of Science. Studies that examined at least one psychometric property of LSM questionnaires published up to August 2021 were included and evaluated based on the COnsensus-based Standards for the selection of health Measurement Instruments (COSMIN) guidelines.

Results: Thirty-seven validation studies describing 13 different LSM questionnaires were included. Methodological quality and comprehensiveness of validations were heterogeneous. Based on comprehensive and high-quality results, four LSM questionnaires stood out:University of Alabama at Birmingham-Life-Space Assessment (UAB-LSA), Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI), interview- and proxy-based versions of the Life-Space Assessment in Institutionalized Settings (LSA-IS), all of them available in German language.

Conclusions: This systematic review provides a quick overview of available LSM questionnaires and their psychometric properties to facilitate the selection for use in clinical practice and research. For questionnaire-based LSM assessment, we recommend the UAB-LSA and LSA-CI for community settings and the interview- or proxy-based LSA-IS for institutionalized settings.

Keywords: Diagnostic Self Evaluation, Systematic Review, Aged, Mobility limitation

GERMAN ABSTRACT

Hintergrund: Life-Space Mobilität (LSM) als die Fähigkeit, sich in seiner Umgebung bewegen zu können, ist ein Schlüssel für erfolgreiches Altern und hat sich als relevantes Konzept in der Gerontologie und Geriatrie entwickelt. Geeignete Assessment-Instrumente werden benötigt, um ältere Personen mit Einschränkungen in der LSM zu identifizieren und Interventionen einzuleiten, anzupassen oder zu evaluieren.

Ziel: Systematische Identifikation, Beschreibung und Analyse psychometrischer Eigenschaften von LSM-Fragebögen und deren Verfügbarkeit in deutscher Sprache.**Methoden**: Eine systematische Literatursuche in PubMed, PsyCINFO, Cochrane Library, CINAHL und Web of Science wurde durchgeführt. Bis August 2021 publizierte Studien zu psychometrischen Eigenschaften von LSM-Fragebögen wurden eingeschlossen und basierend auf den COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) Richtlinien bewertet. **Ergebnisse:** Siebenundreißig Validierungsstudien für 13 verschiedene LSM-Fragebögen wurden identifiziert. Die methodische Qualität und der Umfang der Validierungen waren heterogen. Basierend auf umfassenden und qualitativ hochwertigen Ergebnissen sind vier Fragebögen hervorzuheben: University of Alabama at Birmingham-Life-Space Assessment (UAB-LSA), Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI), interview- und proxy-basierte Versionen des Life-Space Assessment in Institutionalized Settings ´(LSA-IS), die alle in deutschverfügbar sind.

Diskussion: Dieses systematische Review gibt einen schnellen Überblick über LSM-Fragebögen und deren psychometrische Eigenschaften. Als LSM-Fragebögen empfehlen wir den UAB-LSA und den LSA-CI für kommunale Settings und den interview- oder proxy-basierten LSA-IS für institutionalisierte Settings.

Schlagwörter: Diagnostik/Selbstbericht, Systematisches Review, Altern, Mobilitätseinschränkungen

INTRODUCTION

Mobility is a key factor for successful aging. In clinical practice and research, assessing mobility is important for identifying individuals at risk or with mobility limitations, developing and adapting intervention strategies, and evaluating intervention effectiveness. Various mobility instruments have been developed, with a focus on assessing motor capacity [1]. However, as capacity and habitual performance are different concepts [2], assessment instruments on life-space mobility (LSM), defined as the spatial extent of movement in daily life, represents an extention of capacity-oriented mobility instruments by a behavioral perspective of habitual mobility performance in everyday life [3, 4].

LSM has predominantly been assessed via questionnaires, allowing for an easy-to-implement, low-resource, highly-accepted, and valid assessment of combined indoor and outdoor mobility, and contextual aspects of mobility (e.g., mobility aids, personal assistance).

Selecting an appropriate questionnaire for clinical practice and research is challenging as the setting and target population, practical aspects (e.g., interview duration, equipment required), and its methodological quality determined by psychometric properties such as feasibility, validity, reliability, and sensitivity to change must be considered. The use of instruments validated in the appropriate language and cultural setting represents a mandatory methodological criteria, which has so far not been documented for LSM questionnaires in German language. In addition, previous reviews of LSM measurement tools focused only on specific LSM questionnaires [5] or did not provide detailed information on their psychometric properties and did not include the most recent developments [3].

Thus, the primary aim of the present systematic review was to provide an overview on currently available LSM questionnaires and their psychometric properties to facilitate the selection for use in clinical practice and research. A secondary aim was to identify LSM questionnaires validated for use in German language.

METHODS

A systematic literature search was conducted in accordance with recommendations from the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) Protocols [6] and the COnsensus-based Standards for the selection of health Measurement Instruments (COSMIN) guideline for systematic reviews of patient-reported outcome measures [7].

We performed a complete database search with no language restrictions in CINAHL, Cochrane Library, PsycInfo, Pubmed, and Web of Science up to August 2021. Search terms included combinations of variants for the keyword “life-space” along with different terms for assessment, validation, and psychometric properties (see Table S1), as recommended elsewhere [8].

Titles, abstracts and full texts of studies identified by the search were screened for eligibility by two independent reviewers (blinded for review). Any disagreements were solved by a third reviewer (blinded for review). Reference lists of relevant articles and reviews, and grey literature were also screened for additional studies for inclusion.

Studies eligible for inclusion provided empirical evidence for validity, reliability, sensitivity to change, and/or feasibility of a questionnaire designed to assess differentiated spatial aspects of mobility, usually described as "Life-Space Mobility" (LSM). Each version of a LSM questionnaire with relevant changes to the assessment procedure or the information collected were considered as a separate instrument.

Data extraction were performed by two independent reviewers (blinded for review). Information on main features of the identified questionnaires (i.e, mobility construct, target population, test administration, data collection, and scoring) was extracted from the original article of each questionnaire. Information on different aspects of feasibility, validity, reliability, and sensitivity to change were gathered from all included studies. The methodological quality of the included studies was rated by three reviewers (blinded for review) using the COSMIN risk of bias checklist, considering additional references for sample size rating [9, 10]. Disagreements in ratings were resolved by consensus. Where applicable, results on the same questionnaire for the main domains of psychometric properties (feasibility, validity, reliability, sensitivity to change) were summarized from multiple studies (i.e., studies in different populations or different language versions of the same questionnaire) to give an overall recommendation for use. To make the quality rating transparent, notes on the methodological limitations of the studies in the evaluation of the psychometric properties were also provided in the data extraction.

An additional focus of the narrative analysis was given for the availability of LSM questionnaires validated in German language.

RESULTS

The literature search yielded 37 studies eligible for inclusion (see Figure 1), in which 13 unique LSM quesionnaires were identified: Life-Space Diary (LSD) [11], Nursing Home Life-Space Diameter (NHLSD) [12], Life-Space Questionnaire (LSQ) [13], University of Alabama at Birmingham-Life-Space Assessment (UAB-LSA) [14], phone-based (LSA-F) [15] and proxy-based LSA (LSA companion) [16], Homebound Mobility assessment

(HBMA) [17], Indoor life-space mobility at home (LSH) [18], Home-based Life-Space Assessment (Hb-LSA) [19], Life-Space Assessment for Persons with Cognitive Impairment (LSA-CI) [20], interview-based [21] and proxy-reported Life-Space Assessment for Institutionalized Settings (LSA-IS) [22], and Map-based Life-space assessment (MBA) [23].

Characteristics of the LSM questionnaires

A detailed description of these questionnaires is provided in Table S2. The majority of them considers not only spatial (e.g., distance) but also contextual aspects (e.g., mobility aids, personal assistance) of mobility. Nine questionnaires have initially been developed for community-dwelling older persons (LSD, LSQ, UAB-LSA, LSA-F, LSA-CI, MBA) [11, 13-15, 17-20, 23], with three of them specifically focusing on persons having difficulties in going outdoors (HBMA, LSH, Hb-LSA) [17-19], one for power mobility device users (LSA companion) [15], and three for institutionalized older persons (NHLSD, LSA-IS) [12, 21, 22]. The majority of questionnaires are based on self-reports by structured interviews, with one being a web-based survey (MBA) [23]. The NHLSD is the only one specifically designed for proxy documentation of nurses [12]. Four self-report questionaires are available as proxy reports (LSA companion, LSA-IS) [16, 22] or have used proxy reports (HBMA, LSH) [17, 18]). All self-report questionnaires assume full mental abilities of the respondent, except for two (LSA-CI, LSA-IS) [20, 21]. Most questionnaires are conducted via face-to-face interview, two can also be performed via phone (HBMA, LSA-F) [15, 17]. Specific equipment is only needed for the web-based MBA, while all other questionnaires were designed as “paper-and-pencil” tests. The observation period ranges between 24 hours [21, 22] and 4 weeks respectively one month [11, 14-16, 19]. Rating for the different questionnaires varied with total scores ranging from 0-8 points [17] to 0-120 points [14-16, 21, 22], with two questionnaires having an open-ended score (LSH, MBA) [18, 23]. Higher scores consistently indicate higher mobility levels. Some questionnaires provide options to analyze only spatial mobility aspects [14, 15, 20-22], rate specific sub-groups depending on frequency of being outdoors [11], or differentiate between low or high [20], or low, intermediate, and high LSM [17].

Psychometric properties

Table 1 summarizes the results on the psychometric properties and recommendations for each questionnaire based on the 37 included validation studies. Most studies (n = 19) were identified for evaluating the psychometric properties of UAB-LSA [14] in different languages or populations [24-43], additionally the phone-based [15, 44, 45] and proxy reported questionnaires [16] are also based on the UAB-LSA. Detailed information on the individual studies, questionnaires, and COSMIN quality ratings is provided in Table S3.

Sample sizes of the validation studies ranged from 5 [15] to 2.147 [30] participants, with 16 studies having less than 50 participants. Mean age of participants was 75 years, ranging from 43 to 85 years. Studies included community-dwelling older persons without [11, 13, 14, 16-19, 23-26, 29-34, 36, 37, 45, 46] and with cognitive impairment [20], persons with power mobility devices [15], persons with Chronic Obstructive Pulmonary Disease [41-43], persons with stroke [38, 40], persons with vestibular disorders [35], patients with Parkinson Disease [47], persons with spinal cord injury [44], persons with critical illness [27], persons in palliative care [28], geriatric in-patients [21, 22, 48], and nursing home residents [12]. Construct and concurrent validity, and test-retest reliability were the most frequently evaluated psychometric properties.

Feasibility

Floor or ceiling effects were analzed in 16 studies, with all reporting absence of such effects [11, 12, 14, 15, 19-22, 29, 34, 40, 41, 44-46, 48, 49]. Completion rates ranged from 82.6% to 100% but were only rarely reported [11, 15, 20-22, 45, 46]. Completion times were provided even less frequently, averaging between 3 and 9 min across five studies [15, 20, 21, 25, 46], with phone-based questionnaires taking longer.

Validity

Almost all studies included a validity analysis. Construct validity was assessed in 30 studies [11-14, 17-22, 24, 25, 27, 28, 30-36, 38, 40, 41, 43-46, 48, 49], using one to 20 construct variables of different domains (e.g., physical, cognitive, psychosocial, financial, environmental, and/or sociodemographic status). Only four studies used a conceptional framework for mobility [4] to select construct variables [20-22, 46]. Overall, results on construct validity yielded expected directions and magnitudes of correlations, with cut-offs of r >0.5 for similar (e.g., physical variables) and r >0.30-0.50 for related constructs (e.g., financial, psychsocial variables) for evaluation . Concurrent validity was assessed in seven studies [16, 18, 19, 22, 23, 47, 48]. Apart from two studies [18, 23], overall acceptable to good concurrent validity was demonstrated for the questionnaires, depending on the closeness of the comparison instrument to the concept of the LSM questionnaires. Content validity was successfully evaluated in four studies (all for the UAB-LSA) [15, 25, 26, 34], with two focusing on the translation process [15, 26].

Reliability

Reliability results were evaluated in terms of test-retest reliability in 22 studies, showing predominantly acceptable to good results with Intraclass Correlation Coefficients or Kappas of >0.7 [10]. Poor test-retest reliability was reported in only one study for the MBA [23]. Acceptable interrater reliability was observed in three studies [12, 18, 25].

Sensitivity to change

Only eight studies analyzed sensitivity to change of the LSM questionnaires [14, 20-22, 29, 33, 45, 46]. Most of them evaluated the ability to detect intervention-induced changes [20-22, 33, 45, 46]. Changes over time were analyzed in only two studies [14, 29]. For the analysis, most studies used distribution-based methods [20-22, 33, 45, 46], with one of them using also an anchor-based method [29]. Studies calculating standardized response means reported small (<0.5) [22, 33], moderate (>0.5) [20, 45], and large (>0.8) [21, 46] sensitivity to intervention-induces changes.

Risk of bias

The methodological quality for evaluating the different psychometric properties was predominantly moderate to high across studies (Table S3). Overall, methodological quality of validity studies was predominantly negatively affected by low sample sizes that were not statistically justified [11, 16, 18, 38, 40, 48] or low number of construct variables [11, 17, 34, 41, 42, 44, 45], reliability analyses were limited due to very long time period between test and retest (1 year), [13], different test conditions used for test and retest (face-to-face vs. phone) [14], analysis of only relative agreement [12], and small sample sizes [12, 18, 24, 29, 32, 35, 38, 40]. For sensitivity to change, no adequate statistical analysis method was observed in one study [14], and low sample size in another [46]. Five studies could not be rated due to insufficient information as only the abstract was available [19, 27, 30, 33, 43]. A comprehensive validation approach to assess several psychometric properties with consistently high methodological quality was conducted in two studies [20, 21], and in four studies with moderate to high quality [12, 15, 22, 46]. For the UAB-LSA [14] as the most frequent evaluted LSM questionnaire, methodological quality of the studies was heterogeneous and ranged from low to high, with most of them showing, however, higher methodological quality.

Availability in German language

The LSA-CI and both versions of the LSA-IS were comprehensively validated in German language, with overall good results on feasibility, validitiy, reliability, and sensitivitiy to change [20-22, 46]. A German version is also available for the UAB-LSA, whose construct validity has recently been documented in German community-dwelling older adults [31].

DISCUSSION

This systematic review provides a comprehensive overview of currently available questionnaires to assess LSM and their psychometric properties. To the best of our knowledge, this is the first review to systematically analyze such a wide range of LSM questionnaires, with the aim of providing clinicians and researchers with practical knowledge on LSM questionnaires to help them select an instrument appropriate for their purpose.

A high number of different LSM questionnaires were identified. Given the great importance of LSM for successful aging and the increased risk and prevalence of LSM limitations in older age, it was not surprising that a clear focus of these questionnaires was the development and validation for use in older people. According to the different living conditions in older age, LSM questionnaires are available for community-based and institutionalized settings.

Apart from appropriateness of the instrument for the target population, which also covers the availability in the specific language, its feasibility plays an important role in both clinical routine and research. Although feasibility aspects of the LSM questionnaires were rarely or only as marginal notes reported, presented results for the completion rates/times and floor/ceiling effects suggest that they are accepted and not time consuming and cover an adequate range of respondents' LSM.

Most information were provided for the validity of the LSM questionnaires, more specifically for their construct validity showing predominantly hypothesis-confirming associations with physical, cognitive, psychosocial, financial, environmental, and/or sociodemographic variables. Given the overall complexity of real-life mobility [4], it is striking that only a few of the identified studies assessed the construct validity of the LSM questionnaires based on a conceptional framework of mobility including various potential determinants [20-22, 46]. Summarising the results on construct validity of the same questionnaire across several studies, the UAB-LSA, the NHLSD, the LSA-CI and the interview/proxy-based LSA-IS were identified as the most valid questionnaires for the LSM construct. Test-retest reliability of the LSM questionnaires has also been evaluated quite frequently, with overall at least acceptable results. Thus, trained interviewers or proxies can achieve consistent results in stable persons, suggesting that the LSM questionnaires are easy to use and provide clear instructions for administration and scoring.Although it is essential that an assessment instrument can capture changes induced by intervention measures or long-term changes over time, sensitivity of change is clearly understudied, lacking for most LSM questionnaires. A possible reason for this might be the fact that the evaluation of this psychometric property requires a longitudinal study design with a repeated observation of LSM after a period of time in which a change has occurred (e.g., intervention-induced or time-related). The ability to detect such changes has only been demonstrated the UAB-LSA, the LSA-F, the LSA-CI, and the interview-and proxy-based versions of the LSA-IS [14, 15, 20-22].

Among the different LSM questionnaires, the UAB-LSA stands out due to its widespread use and the availability of validated versions in various languages and populations. Potential limitations of the UAB-LSA are its relatively long, retrospective assessment period of four weeks and its focus on the community setting, which may complicate its use in studies focusing on more short-term LSM (changes), in populations with cognitive impairment due to possible recall bias, or institutionalized settings. To promote recall of LSM, the recommended LSA-CI covers a shorter assessment period of 1 week and has shown to be feasible, valid, reliable and sensitivie to intervention-induced changes in community-dwelling older persons with and without cognitive impairment [20, 46]. The two versions of the LSA-IS, which has been specifically developed for use in institutionalized older persons, even cover a shorter assessment period of 1 day, and have also demonstrated overall good psychometric properties in populations with and without cognitive impairment [21, 22]. A potential limitations of such short assessment period could be that it may not fully cover day-to-day variability in LSM, although it can be assumed that variability in LSM tends to decrease in such settings due to institutional routines [50].

Overall, recommendations for use based on comprehensive results on adequate psychometric properties with high methodological quality could only be identified for the UAB-LSA [14] and the LSA-CI (32) for community-dwelling older persons (with cognitive impairment [20]), and the two versions (interview-/proxy-based) of the LSA-IS for older persons staying in institutions [21, 22]. All four recommended LSM questionnaires are available in German language. The German version of the UAB-LSA has been shown to be valid for measuring LSM, but data on other psychometric properties in German populations are still lacking and should be investigated in the future. The LSA-CI and the interview- and proxy-based LSA-IS versions have been comprehensively and successfully validated for use in German speaking older person, and their manuals and assessment forms are provided in the Supplemental Material to facilitate its application in clinical routine and research (Supplemental Documents 4-9).

Future studies on psychometric properties of LSM questionnaires should focus on feasibility aspects, select variables for construct validity analyses based on a conceptional LSM framework, and evaluate the ability to detect changes in LSM.

CONCLUSIONS

Several LSM questionnaires are available for clinicians or researchers to assess spatial aspects of mobility in everyday life. However, only four questionnaires provided a comprehensive validation including good feasibility, validity, reliability and sensitivity to change. Given their comprehensive validation and overall good psychometric properties, the UAB-LSA and LSA-CI can be recommended for use in community-dwelling older persons, and the two versions of the LSA-IS (interview- & proxy-based) for use in institutionalized older persons. Each of these four LSM questionnaires is available in German language.

Practical Conclusions

- Most identified LSM questionnaires showed acceptable to good psychometric properties, although validation strategies were partly limited to single psychometric properties in a number of studies.
- Based on the available evidence, we recommend the most comprehensively validated instruments with overall good psychometric properties: UAB-LSA and LSA-CI for community-dwelling older persons and the LSA-IS as self- or proxy-based version for institutionalized older persons.
- All recommended questionnaires are validated for use in German language.

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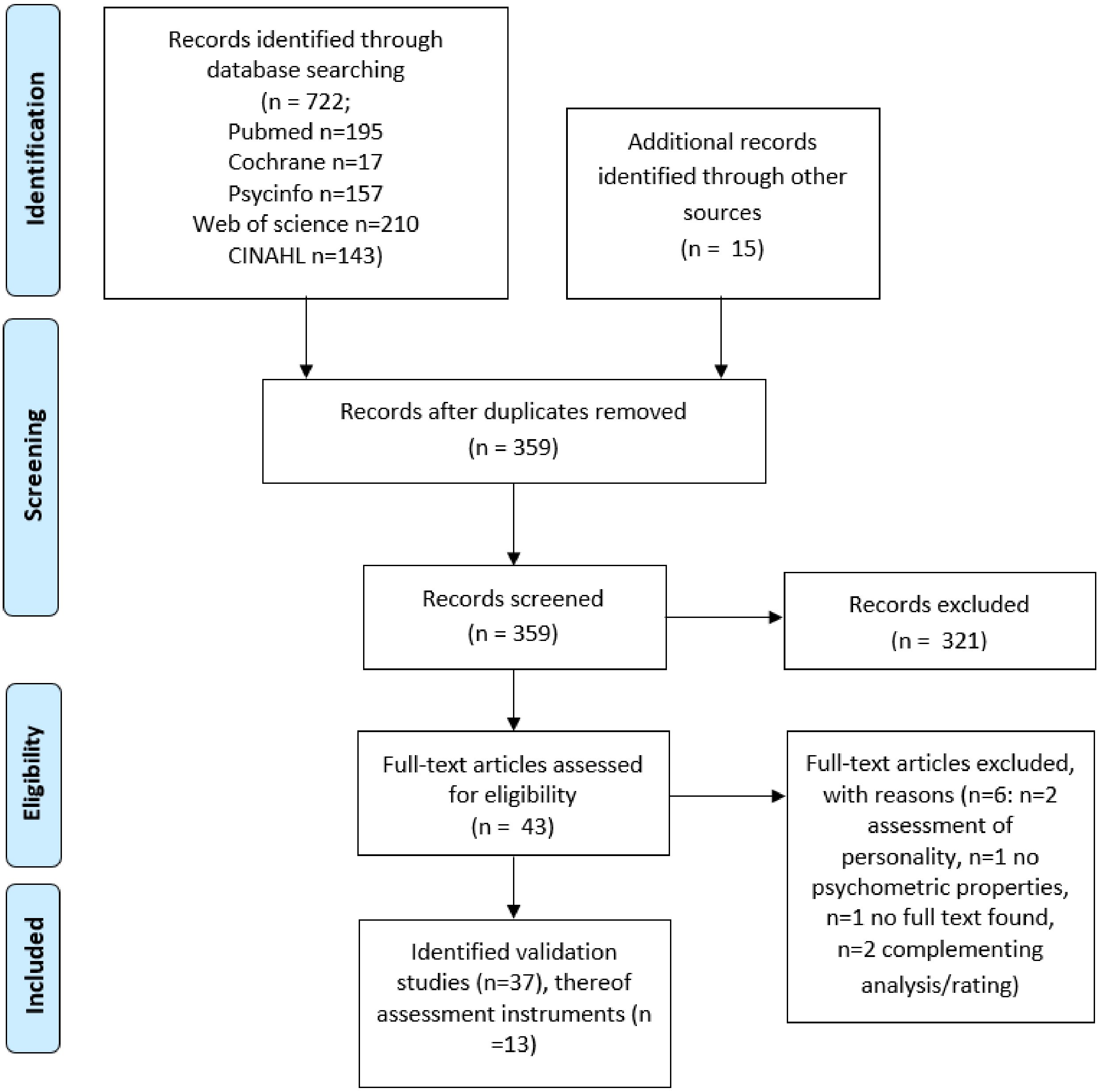
Conflict of interest: All authors state that there are no conflicts of interest.

This article does not contain any studies with human or animals.

Figure

Figure 1: Flowchart for search process



Note: Presented is a flow chart on the search results

Table 1 Overview on included assessment instruments and their psychometric properties

Instrument Name (abbreviation) Original authors (year), references	Psychometric properties*				Recommendation
	Feasibility	Validity	Reliability	Sensitivity to change	
Life-Space Diary (LSD) May et al. (1985), [11]	● (green)	● (yellow)			● (yellow)
Nursing Home Life-Space Diameter (NHLSD) Tinetti & Ginter (1990), [12, 48]	● (yellow)	● (green)	● (yellow)		● (yellow)
Life-Space Questionnaire (LSQ) Stalvey et al. (1999), [13]		● (yellow)	● (yellow)		● (yellow)
University of Alabama at Birmingham Life-Space Assessment (UAB-LSA) Baker et al. (2003), [14, 24-38, 40-43, 47]	● (green)	● (green)	● (green)	● (green)	● (green)
Life-Space Assessment – assessment via phone (LSA-F) Auger et al. (2009), [15, 44, 45]	● (green)	● (yellow)	● (green)	● (yellow)	● (yellow)
Life-Space Assessment – assessment via proxies (LSA) Cavanaugh et al. (2014),[16]		● (yellow)			● (yellow)
Life-Space Assessment in Persons with Cognitive Impairment Ullrich et al. (2019), [20, 46]	● (green)	● (green)	● (green)	● (green)	● (green)
Life-Space Assessment in Institutionalized Settings (LSA-IS, interview-based) Hauer et al. (2020), [21]	● (green)	● (green)	● (green)	● (green)	● (green)
Life-Space Assessment in Institutionalized Settings (LSA-IS, proxy-based) Hauer et al. (2021), [22]	● (green)	● (green)	● (green)	● (yellow)	● (green)
Map-based Life-Space Assessment (MBA) Hinrichs et al. (2020), [23]		● (red)	● (red)		● (red)
Home-Bound Mobility Assessment (HbMA) Allman et al. (2010), [17]		● (yellow)			● (yellow)
Indoor life-space mobility at home (LSH) Hashidate et al. (2013), [18]		● (yellow)	● (yellow)		● (yellow)
Home-based Life-Space Assessment Ohnuma et al. (2014), [19]		● (yellow)	n/a		n/a

*Rating considers quality and results; n/a = not available; green = good, yellow = moderate, red = low

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Supplemental Documents

Table S1: Search Terms

Title	*Title/Abstract/Topic/All text (depending on database)*
#1 Life-space	*#5 psychometr**
#2 Lifespace	*#6 clinimetr**
#3 "Life space"	*#7 clinometr**
#4 OR (#1-#3)	*#8 measure**
	*#9 valid**
	*#10 assess**
	*#11 instrument**
	*#12 tool**
	*#13 evaluat**
	*#14 reproduc**
	*#15 reliab**
	*#16 unreliab**
	#17 coefficient
	*#18 homogen**
	#19 "internal consistency"
	*#20 correlation**
	*#21 selection**
	*#22 reduction**
	#23 test-retest
	*#24 inter**
	*#25 kappa**
	*#26 generali**
	#27 concordance
	#28 discriminative
	*#29 factor**
	*#30 subscale**
	#31 scaling
	*#32 error**
	#33 variability
	*#34 sensitiv**
	*#35 responsive**
	*#36 interpretab**
	#37 "meaningful change"
	#38 ceiling
	#39 floor
	#40 Rasch
	#41 cross-cultural
	*#42 Specific**
	*#43 Feasib**
	#44 agreement
	*#45 precis**
	*#46 imprecis**
	*#47 repeatab**
	*#48 replicab**
	#49 test AND retest
	#50 cronbach AND alpha**

	#51 limit AND detection *#52 (minimal* OR clinical* OR small* OR important OR significant OR detectable OR real) NEAR (change OR difference)* *#53 OR (#5-#52)* *#4 AND #53*

Table S2: Characteristics of the included assessment instruments

Assessment instrument, author (reference), Country	Construct		Persons in…			Administration					Aspects of assessment					Scoring	
						Report			Equipment								
	Life-Space Mobility	Life-Space	… the community	… in institutions	Self-report	Face-to-face	Phone	Proxy-report	Specific requirements	Manual /tutorial	Recall period in days	Nr of Life-Space zones	Frequency (options)	Independence	Other aspects	Range of scores	Additional options
Life-Space Diary (LSD) May et al. 1985 (May, Nayak, & Isaacs, 1985), Great Britain	✓		✓		✓[1]						31	5			weather + falls	0-100	4 groups
Nursing Home Life-Space Diameter (NHLSD) Tinetti & Ginter 1990 (Tinetti & Ginter, 1990), USA	✓			✓				✓			14	4	6	2		0-50 / 0-100	
Life-Space Questionnaire (LSQ) Stalvey et al. 1999 (Stalvey, Owsley, Sloane, & Ball, 1999), USA		✓	✓		✓	✓				✓	3	10				0-9	
University of Alabama at Birmingham-Life-Space Assessment (UAB-LSA) Baker et al. 2003 (Baker, Bodner, & Allman, 2003), USA	✓	✓	✓		✓	✓	✓[2]			✓	28	6	4	3		0-120	4 sub-scores
(Phone-based) Life-Space Assessment (LSA-F) Auger et al. (Auger et al., 2009), Canada	✓	✓	✓		✓						28	6	4	3		0-120	4 sub-scores

Homebound Mobility assessment (HBMA) Allman et al. 2010 (Allman, Sawyer, Ritchie, Locher, & Brown, 2010), USA	✓		✓				✓	✓			1	5		3		0-8	3 groups
Indoor life-space mobility at home (LSH) Hashidate et al. 2013 (Hashidate et al., 2013), Japan	✓		✓		✓	✓		✓			7	5	2	3		0-open end	
Life-Space Assessment (LSA companion) Cavanaugh et al. 2014 (Cavanaugh & Crawford, 2014), USA	✓		✓			✓		✓			28	6	4	3		0-120	
Home-based life-space assessment (Hb-LSA) Ohnuma et al. 2014 (Ohnuma, Hashidate, Yoshimatsu, & Abe, 2014), Japan[3]	✓		✓		✓	✓					31	5	?	?		0-120?	
Life-Space Assessment for persons with cognitive impairment (LSA-CI) Ullrich et al. 2019 (Ullrich et al., 2019), Germany	✓	✓	✓		✓	✓				✓	7	6	3	3		0-90	3 sub-scores
Life-Space Assessment for Institutionalized Settings (LSA-IS) self-report (Hauer et al. 2020 (Hauer et al., 2020)), Germany	✓	✓		✓	✓	✓				✓	1	6	4	3		0-120	3 sub-scores
Map-based Life-space assessment Hinrichs et al. 2020 (Hinrichs et al., 2020), Switzerland		✓	✓		✓	✓			✓	✓	7	3				4 outcomes: 0-open	
Life-Space Assessment for Institutionalized Settings (LSA-IS) proxy report Hauer et al. 2020 (Hauer et al., 2021)), Germany	✓			✓				✓		✓	1	6	4	3		0-120	3 sub-scores

[1]via diary; [2]Retest was conducted via phone; [3]some information was extracted by Tanaka et al. (Tanaka & Yamagami, 2018); [4]two for distance and two for area

Table S3: Psychometric properties for the included assessment instruments

Instrument	Language	Population	Psychometric properties							Rating of methodology based on the COSMIN risk of bias checklist (Mokkink et al., 2018)	Limitations with respect to results
			Feasibility	**Validity** (V): Construct, Concurrent* or Content V, ✓ if >=0.5 for similar, and >=0.3 for related constructs	Methodological limitations	**Reliability** (R): ✓ if ICC/weighed kappa >0.70	Methodological limitations	**Sensitivity to change**	Methodological limitations		
LSD May et al. (1985), (May et al., 1985)	english	Community-dwelling older persons (mean age 77±7 years)	Completion rate 93%, no floor/ ceiling effects	n=30; Construct V: 2 significant out of 2 variables (for function), values✓	n of participants and construct variables					V: moderate	
NHLSD Tinetti & Ginter (1990), (Tinetti & Ginter, 1990)	english	Nursing home residents (mean age 82 years)	No floor/ ceiling effects	n=398; Construct V: 5 significant out of 5 variables (for function + participation), values✓		n=25; Test-Retest + interrater R, results✓	Number of participants, statistical analysis (Pearson)			V: high, R: moderate	
(Tanaka & Yamagami, 2018)	japanese	Patients in geriatric health care facility	No floor/ ceiling effects	n=32; Construct V: 8 significant out of 15 variables (for function, cognition, psychosocial	n of participants					V: moderate	High n of non-significant

		(mena age 87±7 years)		status), values✓; Concurrent V: with Hb-LSA value ✓							correlations (Construct V)
LSQ Stalvey et al. (1999), (Stalvey et al., 1999)		Community-dwelling older persons (age range 55-85 years)		n=242; Construct V: 8 significant out of 12 variables (for psychosocial status, function + environment), values low to ✓	66% concordance with hypotheses	n=242; Test-Retest R: after 1 year, results ✓	Duration between test and retest			V, R: moderate	partially low values (Construct V)
UAB-LSA Baker et al. (2003) (Baker et al., 2003)	english	Community-dwelling older persons (mean age 75±7 years)	No floor/ ceiling effects	n=306; Construct V: 8 significant out of 8 variables (for function, psychosocial + demographic/ biographical status), values low to ✓ Concurrent V in other studies		Test-Retest R: after 14 days, results✓	different test conditions	Changes over time: 10 pts. change	No adequate method / statistical analysis	V: high, R: moderate, S: low	partially low values (Construct V)
(Ji, Zhou, Liao, & Feng, 2015)	Chinese	Community-dwelling older persons (mea nage 72±5 years)		n=100; Construct V: 6 significant out of 6 variables (for function, psychosocial status, cognition), values ✓		n=40, Test-Retest R: after 14 days, results✓	n of participnats, different test conditions			V: high, R: moderate	
(Tseng, Gau, & Lou, 2020)	Chinese	Community-dwelling older persons (mean age	Assessment duration 3-5 minutes	n=225; Construct V: 3 significant out of 3 variables (for function, psychosocial, status), values ✓; Content V:	n of construct variables; no patients included	Test-Retest R: after 14 days, results✓;				V: moderate, R: high	

		73±7 years)		index (I-CVI) and a scale-level content validity index ✓	for Content V	Interrater R: results ✓					
(Pedersen, Kjaer-Sorensen, Midtgaard, Brown, & Bodilsen, 2019)	Danish	Community-dwelling older persons (mean age 79 years)		n=30; Content V: ✓ (focus translation)						V: high	
(Portegijs, Iwarsson, Rantakokko, Viljanen, & Rantanen, 2014)	Finnish	Community-dwelling older persons (mean age 81±4)	No floor/ ceiling effects			n=41; Test-Retest R: after 14 days (winter-spring) ✓	n of participants	n=808, anchor-based method: results✓		R: moderate, S: high	
(Mümken, Gellert, Stollwerck, O'Sullivan, & Kiselev, 2021)	German	Community-dwelling older persons (mea n age 79±5 years)		n=83; Construct V: 6 significant out of 8 variables (for function, psychosocial, status, demographic data/biographical status) values ✓						V: high	
(Harada et al., 2010)	Japanese	Community-dwelling older persons (mean age 79±7 years)		n=2147; Construct V: 4 significant out of 4 variables (for function, demographic data/biographical status) values low to ✓						No rating (only abstract in english language)	partially low values (Construct V)
(Ferreira,	Portugu	Communit		n=520; Construct V: 15		n=103;		n=154;		No rating	Low

Cavalheiro, Fernandes, Goncalves, & Ferreira, 2018)	ese	y-dwelling older persons (mean age 74±7 years)		significant out of 15(?) variables (for function, psychosocial, status, demographic data/biographical status) values low to ✓		Test-Retest R: after 7 days, results ✓		with intervention: SRM 0.40		(only conference abstract)	value (S)
(Simões, Garcia, Costa, & Lunardi, 2018)	Portuguese	Community-dwelling older persons (mean age 70±9 years)	No floor/ ceiling effects	n=80; Construct V: 2 significant out of 2 variables (for function) values ✓; Content V: ✓	n of construct variables	Test-Retest R: after 7 days, results ✓				V: moderate, R: high	
(Curcio et al., 2013)	Portuguese and Spanish	Community-dwelling older persons (age range 65-74)		n=300; Construct V: 10 significant out of 11 variables (for function, cognition, psychosocial + demographic / biographical, financial status) values ✓		n=39; Test-Retest R: after 7-10 days, results ✓	n=39, only spanish version			V: high, R: moderate	
(Fristedt, Kammerlind, Bravell, & Fransson, 2016)	Swedish	Community-dwelling older persons (mean age 80±5 years)		n=327; Construct V: 7 significant out of 7 variables (function) values ✓ (reported as concurrent validity in the article)						V: high	
(Kammerlind, Fristedt, Ernsth Bravell, &	Swedish	Community-dwelling older persons (mean age				n=298; Test-Retest R: after 14 days,	Different test conditions			R: moderate	

Fransson, 2014)		80±5 years)				results ✓					
(Alshebber, Dunlap, & Whitney, 2020)	english	Persons with Vestibular disorders (mea nage 55±17)		n=128; Construct V: 6 significant out of 6 variables (function, psychosocial status) values ✓		n=37; Test-Retest R: after several hours, results ✓	n of participants			V: high, R: moderate	
(Zhu et al., 2020)	english	Persons with Parkinson disease (mean age 68±6 years)		n=54; Concurrent V: GPS-data, values low-moderate	Focus on validation of GPS assessment					V: moderate	low value (Concurrent V)
(Iyer et al., 2017)	english	Persons with Chronic obstructive pulmonary disease (mean age 66±10 years)		n=47: Construct V: 4 significant out of 4 variables (for function, psychosocial status, health) values ✓						No rating (only conference abstract)	
(Petti, Hope, Hsieh, Hurtado-Sbordoni, & Gong,	english	Persons with Critical Illness	Reported without values	n=35 (patients) / 49 (proxys): Construct V: no detailed results reported	No values given					No Rating (only conference abstract)	

2015)											
(Phillips, Lam, Luckett, Agar, & Currow, 2014)	english	Persons in palliative care (mean age 75±10 years)		n=98; Construct V: 9 significant out of 17 variables (for function, psychosocial status) values low to ✓	Part of non-significant correlations high due to consideration of all subscores					V: high	Partially low values for less associated variables
(Yang et al., 2017)	Korean	Persons with stroke (mean age 65±2 years)		n=34; Construct V: 5 significant out of 5 variables (for function, psychosocial status) ✓	n of participants	Test-Retest R: after 14 days, results ✓	n of participnats			V, R: moderate	
(Estima, Dutra, Martins, & Franzoi, 2015)	Portuguese	patients with stroke (mean age 59 years)	No floor/ ceiling effects	n=30; Construct V: 5 significant out of 7 variables (for function, cognition,demographic status) values ✓	n of participants	Test-Retest R: after ? days; Interrater R, results ✓	n of participnats			V, R: moderate	
(I. Garcia, Tiuganji, Simoes, Santoro, & Lunardi, 2016; I. F. F. Garcia, Tiuganji, Simoes, &	Portuguese	Persons with Chronic obstructive pulmonary disease (mean age 65/77±4?	No floor/ ceiling effects	n=62; Construct V: 1 significant out of 1 variable (for function) values✓	n of construct variables	Test-Retest R: after 7 days, results ✓				V: moderate, R: high	

Lunardi, 2018)		years)									
LSA – via phone Auger et al. (Auger et al., 2009)	French (-canadian)	Persons with power mobility devices (age range 45-82)	Completion rate 92%; no floor/ ceiling effects; assessment duration 9 minutes	n=5; Content validity: 86% agreement (not rated), focus translation✓	Only one patient included	n=40, Test-Retest R: after 14 days, results ✓	n of participnats			V, R: moderate	
via phone (Lanzino et al., 2016)	english	Persons with spinal cord injury (mean age 46 ±13 / 43±14 years)	No floor/ ceiling effects	n=50; Construct V: 3 significant out of 3 variables (for function, psychosocial status, participation) values ✓	n of construct variables	Test-Retest R: after 9 days, results ✓				V: moderate, R: high	
via phone (McCrone, Smith, Hooper, Parker, & Peters, 2019)	english	Persons undergoing community-based physical therapy intervention (mean age 81 years; age range 25-99 years)	Completion rate 82.6%; no floor/ ceiling effects	n=276; Construct V: 1 significant out of 1 variable (function) values low	n of construct variables			n=228; with intervention (after 53 days): significant change of 10.5 points; subgroup comparison	No adequate statistical aproach	V: low, S: moderate	Low values

HBMA, Allman et al. (Allman et al., 2010)	english	Community-dwelling older persons (mean age 85±7 years)		n=53; Construct V: 3 significant out of 3 variables (for function) values ✓	n of construct variables					V: moderate	
LSH, Hashidate et al. (Hashidate et al., 2013)	Japanese	Community-dwelling older persons (mean age 77±5 years)		n=20; Construct V: 6 significant out of 7 variables (for function, cognition) values ✓; Concurrent V: with UAB-LSA; ICC=0.33	n of participants	Test-Retest R: after up to 7, results ✓	n of participants			V, R: moderate	low value (concurrent V)
LSA companion, Cavanaugh et al. (Cavanaugh & Crawford, 2014)	english	Community-dwelling older persons (mean age 81±8 years)		n=40; Concurrent V: with UAB-LSA value ✓	n of participants					V: moderate	
Hb-LSA, Ohnuma et al. (Ohnuma et al., 2014)	Japanese	Community-dwelling older persons (mean age 79±7 years)	No ceiling/ floor effects	n=37; Construct V: 5 significant variables out of 7 variables (for function) values ✓ (Concurrent V in (Tanaka & Yamagami, 2018))	n of participants	Test-Retest R: after ? days, results ✓	n of participants			No rating (only abstract in english language)	

LSA-CI, Ullrich et al. (Ullrich et al., 2019)	German	Community-dwelling older adults with CI (mean age 82±6 years)	Completion rate 100%; no floor/ ceiling effects; assessment duration 4 minutes	n=117; Construct V: 16 significant out of 20 variables (based on mobility model**) values ✓		n=102; Test-Retest R: after 1 day, results ✓		n=52; with intervention, SRM 0.80		V, R, S: high***	
(Ullrich, Abel, Bauer, & Hauer, 2021)	German	Community-dwelling older adults without CI (mean age 81±6 years)	Completion rate 100%; no floor/ ceiling effects; assessment duration 4 minutes	n=65; Construct V: 8 significant out of 9 variables (for function, physical activity, psychosocial and demographic status) values ✓		n=55; Test-Retest R: after 1 day, results ✓		n=32; with intervention, SRM 0.70	n of participants	V, R: high, S: moderate ***	
LSA-IS self-report, Hauer et al. (Hauer et al., 2020)	German	Institutionalized older persons (mean age 83±6 years)	Completion rate 100%; no floor/ ceiling effects; assessment duration 3 minutes	n=119; Construct V: 15 significant out of 18 variables (based on mobility model**) values ✓		n=76; Test-Retest R: after 1 day, results ✓		n=69; with intervention, SRM 0.81		V, R, S: high***	
Map-based	German	Communit		n=58 (valid n=37);	n of	N=56/57;				V:	Overall

Life-space assessment, Hinrichs et al. (Hinrichs et al., 2020)	(Suisse)	y-dwelling older adults (mean age 74±6 years)		Concurrent V: with GPS-data, values low to ✓	participants	Test-Retest R: after 22.3 days, results -				moderate, R: high	low values (V,R)
LSA-IS proxy report, Hauer et al. (Hauer et al., 2021)	German	Institutionalized older persons (mean age 83±6 years)	Completion rate 100%; no floor/ ceiling effects	n=94, Construct V: 10 significant out of 14 variables (based on mobility model**) values ✓; Concurrent V: with proxy report values ✓		n= 85; Test-Retest R: after 1 day, results ✓		n=69; with intervention, SRM 0.44	Intervention not adequately described	V, R: high, S: moderate ***	Low value (S)

* Validity studies were only classified as "Concurrent validity" if other assessment instruments including spatial aspects of mobility (LSM or GPS-based assessment) were used for comparison

**Variable selection based on a theory driven mobility model [4], including the domains cognitive, psychosocial, physical, environmental, and financial status and gender/cultural/biographical influences

*** Quality rating by BA and MH

Abbreviations: r=correlation coefficient (Spearman, Pearson or bivariate); ICC= Intraclass Correlation Coefficient; n=number; SRM= standardized response means

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Supplemental Document 4: LSA-CI Assessment Form (in German language)

<u>LSA-CI</u>

Name:		Datum:		
Diese Fragen beziehen sich auf Ihre Aktivitäten innerhalb der **letzten Woche**:				
Lebensraum		**Häufigkeit**	**Selbstständigkeit**	**Punktzahl**
Waren Sie während der letzten Woche…		Wie oft waren Sie dort?	Haben Sie Hilfsmittel benötigt? Haben Sie die Hilfe einer anderen Person benötigt?	Stufe x Häufigkeit x Selbstständigkeit
Stufe 1:…in anderen Räumen bei Ihnen zu Hause außer Ihrem Schlafzimmer?	1 = Ja 0 = Nein	1 = 1-3 Mal/ Woche 2 = 4-6 Mal/ Woche 3 = Täglich	1 = persönliche Hilfe 1,5 = Nur Hilfsmittel 2 = Ohne Hilfe	
Punktzahl (multiplizieren)	____ x	_______x	_______ =	_________ Stufe 1 Punkte
Stufe 2:…außerhalb Ihrer Wohnung, wie z.B. ihrer/m Veranda, Terrasse oder Hof, Hausflur oder Garage, Garten oder Auffahrt?	2 = Ja 0 = Nein	1 = 1-3 Mal/ Woche 2 = 4-6 Mal/ Woche 3 = Täglich	1 = Hilfsperson 1,5 = Nur Hilfsmittel 2 = Ohne Hilfe	
Punktzahl (multiplizieren)	____ x	_______ x	_______ =	_________ Stufe 2 Punkte
Stufe 3:…in Ihrer Nachbarschaft außerhalb Ihres Wohnhauses oder Gartens?	3 = Ja 0 = Nein	1 = 1-3 Mal/ Woche 2 = 4-6 Mal/ Woche 3 = Täglich	1 = Hilfsperson 1,5 = Nur Hilfsmittel 2 = Ohne Hilfe	
Punktzahl (multiplizieren)	____ x	_______ x	_______ =	_________ Stufe 3 Punkte
Stufe 4:…außerhalb Ihrer Nachbarschaft, aber innerhalb Ihres Wohnortes?	4 = Ja 0 = Nein	1 = 1-3 Mal/ Woche 2 = 4-6 Mal/ Woche 3 = Täglich	1 = Hilfsperson 1,5 = Nur Hilfsmittel 2 = Ohne Hilfe	
Punktzahl (multiplizieren)	____ x	_______ x	_______ =	_________ Stufe 4 Punkte
Stufe 5:…außerhalb Ihres Wohnortes?	5 = Ja 0 = Nein	1 = 1-3 Mal/ Woche 2 = 4-6 Mal/ Woche 3 = Täglich	1 = Hilfsperson 1,5 = Nur Hilfsmittel 2 = Ohne Hilfe	
Punktzahl (multiplizieren)	____ x	_______x	_______ =	_________ Stufe 5 Punkte
			Gesamtpunktzahl (Summe Level 1 – Level 5)	_________

Supplemental Document 5: LSA-CI Assessment Manual (in German language)

Life-Space Assessment for Persons with Cognitive Impairment (LSA-CI)

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Manual für Nutzer

Einführung

Das “Life-Space Assessment for Persons with Cognitive Impairment” (LSA-CI) wurde auf Basis des “University of Alabama at Birmingham – Life Space Assessment” (UAB-LSA; Baker et al. 2003) entwickelt, um die “Life-Space Mobilität” auch von älteren Menschen mit kognitiver Einschränkung erfassen zu können. Es wurden Anpassungen und Veränderungen im Hinblick auf das eventuell eingeschränkte Erinnerungsvermögen bei dieser besonders vulnerablen Personengruppe vorgenommen. Aus diesem Grund wurde die Observationsdauer von vier Wochen auf eine Woche reduziert und eine spezielle Interviewtechnik eingeführt, die eine verzerrte Erfassung der Mobilität durch fehlendes Erinnerungsvermögen verhindern soll. Diese wurde auch schon erfolgreich in früheren Projekten (einem Fragebogen zur Erfassung der körperlichen Aktivität bei Personen mit leichter bis moderater kognitiver Einschränkung) eingesetzt (Hauer et al. 2011).

Zielpopulation

Die Zielpopulation umfasst ältere Menschen mit beginnender bis moderater kognitiver Einschränkung (basierend auf dem Mini-Mental Status Examination (MMSE), bei Ergebnissen zwischen 17-26 Punkten). Diese Personen zeigen häufig krankheitsbedingte Symptome wie Verlust des Erinnerungsvermögens, Wortfindungsstörungen, Sprechstörungen, eingeschränkte räumlich-zeitliche Orientierung, Einschränkungen der visuellen Wahrnehmung oder der Aufmerksamkeit (Knopman & Petersen 2014). Dies kann zu Verzerrungen der Erinnerung und Ungenauigkeiten bei dem Berichten zurückliegender Ereignisse (Shephard, 2003) und Schwierigkeiten beim Berichten der eigenen körperlichen Aktivität (Bhandari & Wagner, 2006; Sallis & Saelens, 2000) führen.

Bestandteile des LSA-CI

Der LSA-CI beinhaltet Fragen zum Betreten bzw. Aufenthalt in fünf verschiedenen "Life-Space" Zonen (0 = Schlafzimmer [welches nur indirekt erfasst wird]; 1 = eigene Wohnung oder Haus; 2 = direkte Umgebung des Wohnhauses (Terrasse, Hof, Garten); 3 = Nachbarschaft; 4 = Stadt, 5= außerhalb der Stadt), zur Häufigkeit des Betretens bzw. Aufenthalts in der jeweiligen Zone (täglich, 4-6 x/Woche, 1-3x/Woche), und zum Bedarf an Hilfe oder Hilfsmitteln (ohne Hilfsmittel/-person, mit Hilfsmittel, mit Hilfsperson). Die Konzeption des Fragebogens stimmt mit dem Original UAB-LSA überein, abgesehen von der Einteilung und Bewertung der Häufigkeit, was an der reduzierten Observationsdauer (eine statt vier Wochen) liegt.

Vorbereitungen für die Durchführung des LSA-CI

Für Personen in Gesundheitsberufen ist kein spezielles Training erforderlich um den LSA-CI durchzuführen. Benötigt werden lediglich der Fragebogen und ein Stift.

Vorgehen bei der Durchführung

Der LSA-CI sollte interview-basiert durchgeführt wurden und die speziellen Bedürfnisse von Personen mit kognitiver Einschränkung berücksichtigen. Um die Aufmerksamkeit der zu befragenden Person nicht zu beeinträchtigen, sollte die Erhebung alleine stattfinden. Sollten Angehörige/Pflegekräfte anwesend sein, dürfen diese nicht das Antworten übernehmen oder sich einmischen. Im Anschluss an die Durchführung können die Angehörigen/Pflegekräfte jedoch die Aussagen bestätigen oder falsifizieren.

Das Befragung sollte in einem ruhigen Umfeld durchgeführt werden, am besten in der Wohnung des Befragten, so kann sich der Interviewer sich auf die Wohnsituation beziehen und die Fragen konkret stellen (zum Beispiel bei Life-Space Zone 1 und 2 gezielt Haus / Garten / Terrasse / Garten / Hof / Garage etc. erwähnen, bei Life-Space Zone 3 und 4 gezielt die Örtlichkeiten in der Nachbarschaft oder Stadt ansprechen, wie Supermärkte, Parks, Plätze, Briefkasten, Stationen des öffentlichen Nahverkehrs, Arztbesuche, etc.), oder bei Life-Space Zone 5 berücksichtigen, ob es sich um eine Stadt oder ländliche Region (relevant für Einkaufsmöglichkeiten, Arztbesuche etc.). Das Wissen um die aktuelle Wohnsituation ist auch hilfreich, um die Genauigkeit der Antworten direkt erfassen zu können und gegebenenfalls Rückfragen zu stellen (z.B. steile Treppe am Eingangsbereich, Stellplatz für Hilfsmittel etc.). Es sollte gezielt nach offensichtlichen Einschränkungen in der Beweglichkeit (z.B. Schwierigkeiten beim Aufstehen, Treppengehen etc.) und nach Hilfsmittel (z.B. sichtbarer Gehstock, Rollator etc.) gefragt werden, um einen realistischen Eindruck der aktuellen Fähigkeiten und Tätigkeiten zu erlangen.

Demenzspezifische Interview-Technik:

Die Befragung sollte im persönlichen Gespräch und interviewbasiert erfolgen, um Ungenauigkeiten auszuschließen bzw. zu reduzieren, die Vollständigkeit der Antworten abzusichern und gleichzeitig auf eine mögliche Überförderung des Befragten eingehen zu können (Hauer et al. 2009). Diese Form der Erfassung erlaubt umfassende mündliche Erläuterungen und lässt Raum für Rückfragen, was Ungenauigkeiten oder Mehrdeutigkeit verhindert (Durante & Ainsworth 1996) und Versagensängste in Bezug auf Verständnis und Erinnerungsfähigkeit bei den Befragten verhindern (Hauer et al 2011).

Schritt 1: Die Befragung sollte mit einer kurzen Erläuterung der Ziele und der Dauer der Befragung (insgesamt etwa 3 bis 5 Minuten) starten.

Schritt 2: Wichtig ist, den Beginn und das Ende des Beobachtungszeitraums klar zu benennen (z.B. Dienstag vor einer Woche bis jetzt). Falls während der Befragungen Unklarheiten auftreten, kann es angemessen sein, die Aktivitäten in jeder Zone für jeden Tag einzeln abzufragen.

Schritt 3: Fragen Sie einzeln nach jeder Life-Space Zone, beginnend mit Zone 1 und dann kontinuierlich weitergehend ohne eine Zone auszulassen.

Spezielle Zeitfenster sowie tägliche oder wöchentliche Rituale und Gewohnheiten können dabei als "Anker" genutzt werden, um den Beobachtungszeitraum zu segmentieren oder einzuteilen (z.B. Wochenende und Wochentage, Aufstehen, Mahlzeiten, Körperpflege, kurze Einkäufe, Gang zum Briefkasten/Bäcker, Kiosk, Gartenarbeiten, Fernsehen, Putzen, Wäsche machen, Sportgruppen, Tagespflege, kirchliche Aktivitäten etc.) (Baranowski 1988).

Zusätzlich sollte gezielt nach typischen Aktivitäten gefragt werden, sofern diese nicht selbst erwähnt werden (Einkaufen, Arztbesuche, Therapien), oder besondere Aktivitäten wie Besuche von Freunden /Familie, Feste, Ausflüge etc. um die Vollständigkeit der Erfassung abzusichern. Geschlossene Fragen können dabei besser geeignet sein um eine kognitive Überforderung zu vermeiden ("Waren sie einkaufen" statt "Was haben Sie sonst gemacht?").

Im Fokus der Erfassung steht die aktuelle Mobilität, also das, was die Befragten tatsächlich in der letzten Woche gemacht haben, und nicht das, wozu sie in der Lage gewesen wären.

Ein Anhaltspunkt für die Genauigkeit der Erfassung der einzelnen Zonen ist, dass es nicht möglich ist, eine Zone zu erreichen, ohne sich in den niedrigeren Zonen bewegt zu haben (z.B. ist es nicht möglich, in der Stadt (Zone 4) unterwegs gewesen zu sein, ohne die Nachbarschaft (Zone 3) durchquert zu haben.

Es wird keine exakte Einteilung bzw. Grenze für die Nachbarschaft oder Stadt vorgegeben, die Antworten, die die Befragten geben, werden so akzeptiert.

Schritt 4: Die Befragung schließt mit einer Zusammenfassung des Gesagten für jede Zone einschließlich der Häufigkeit und des Bedarfs an Hilfe, so haben die Befragten Zeit, ihre eigenen Aussagen zu prüfen und zu bestätigen oder zu korrigieren.

Beispiele für die Befragung und die Zusammenfassung:

Zone 1: *Haben Sie sich in der vergangenen Woche in ihrer Wohnung / Ihrem Haus außerhalb Ihres Schlafzimmers aufgehalten? Verlassen Sie nach dem Aufstehen jeden Morgen ihr Bett? Waren Sie in der vergangenen Woche krank und haben einen oder mehrere Tage im Bett verbracht? Benötigen Sie Hilfe, wenn Sie Ihr Bett verlassen, halten Sie sich an Ihrem Rollator/ der Kommode etc. fest? Wenn Sie in das Bett oder die Küche gehen, nutzen Sie dann den Rollator/Gehstock?*

Zusammenfassung Zone 1: *Also, Sie haben in der vergangenen Woche jeden Tag ihr Bett verlassen und dabei keine Hilfsmittel benötigt? Ist das so korrekt?*

Zone 2: *Waren Sie in der vergangenen Woche außerhalb Ihrer Wohnung, zum Beispiel auf Ihrer/m Veranda, Terrasse, Hof, öffentlichem Hausflur, Garage, Garten, Auffahrt? Wie oft haben Sie ihre Wohnung/Haus verlassen und sind rund um das Haus unterwegs? Nutzen Sie Ihren Rollator/Rollstuhl? Muss Ihnen dabei jemand helfen?*

Zusammenfassung Zone 2: *Lassen Sie mich das zusammenfassen: Sie haben Ihre Wohnung jeden Tag genau ein Mal verlassen, um zum Briefkasten zu gehen und die Zeitung zu holen und dabei ihren Gehstock benutzt? Ist das richtig?*

Zone 3: *Waren Sie in der vergangenen Woche auch in Ihrer Nachbarschaft außerhalb Ihres Wohnhauses, Hofs oder Gartens unterwegs? Waren Sie zum Beispiel Nachbarn besuchen, beim Bäcker oder haben einen Spaziergang in Ihrer Straße gemacht? Wie oft waren Sie in ihrer Nachbarschaft unterwegs? Ich habe auf dem Hinweg einen Supermarkt/Park gesehen, waren Sie dort mal in der vergangenen Woche? Als Sie dorthin gegangen sind, waren Sie mit dem Auto oder zu Fuß unterwegs? Haben Sie jemanden gebraucht, der Ihnen geholfen hat?*

Zusammenfassung Zone 3: *Sie gehen also ein Mal in der Woche zur Tagespflege in der Nachbarschaft und haben wie jeden Dienstag einen Spaziergang mit ihrem Bekannten in der*

Nachbarschaft hier gemacht. Dann waren Sie zwei Mal beim Bäcker, und ein Mal mit ihrer Tochter einkaufen mit dem Auto. Insgesamt waren Sie also fünf Mal letzte Woche in Ihrer Nachbarschaft unterwegs, stimmt das so? Sie können diese Aktivitäten ohne Hilfspersonen durchführen, brauchen aber Ihren Rollator?

Zone 4: *Waren Sie in der vergangenen Woche außerhalb Ihrer Nachbarschaft, aber noch innerhalb Ihres Wohnortes/Name der Stadt unterwegs? Waren Sie letzte Woche bei Ihrem Arzt, Einkaufszentrum, Sportgruppe, Tagespflege? Wie oft waren Sie da? Gab es letzte Woche ein besonderes Ereignis, wie ein Fest, eine Familienfeier, oder ein Besuch von Freunden? Gehen Sie dort zu Fuß/selbst hin, oder ist es zu weit weg? Haben Sie ein Fahrrad/Auto/Bus/Taxi genutzt? Nutzen Sie Hilfsmittel wie den Gehstock/Rollator? Gibt es auch eine Person, die Ihnen hilft?*

Zusammenfassung Zone 4: *Lassen Sie mich das wiederholen, Sie waren also letzte Woche zwei Mal außerhalb Ihrer Nachbarschaft unterwegs, ein Mal waren Sie mit dem Taxi Freunde besuchen und ein Mal waren Sie mit Ihrer Tochter mit dem Auto einkaufen, Sie haben Ihren Gehstock und die Hilfe einer Person beim Ein-und Aussteigen in das Auto benötigt? Habe ich das richtig verstanden?*

Zone 5: *Haben Sie in der vergangenen Woche ihre Stadt verlassen? Waren Sie zum Beispiel in (Name der Nachbarstadt/nächstgrößeren Stadt)? Wie oft waren Sie dort? Wie sind Sie dorthin gekommen, selbstständig oder mit Hilfe?*

Zusammenfassung Zone 5: *Sie waren also letzte Woche nicht außerhalb von Ihrer Heimatstadt (Name) unterwegs? Ist das richtig?*

Bewertung

Zunächst werden die Ergebnisse auf der Zoneneben multipliziert: Zone (1-5) x (Häufigkeit 1-3) x Selbstständigkeit (1, 1,5 oder 2). Bei Selbstständigkeit wird die selbstständigste Variante bewertet, hat ein Befragter in einer bestimmten Zone beispielsweise ein Mal einen Rollator zum Fortbewegen benutzt und war einmal selbstständig ohne Hilfsmittel unterwegs, wird dies als "selbstständig" (=2) bewertet. Anschließen werden die Ergebnisse für jede Zone addiert.

Ungültige Aussagen oder Ausschluss von Ergebnissen:

Bei ganz offensichtlich falschen Angaben oder nicht plausiblen Aussagen sollten die Ergebnisse nicht berücksichtigt werden. Es sollten jedoch Versuche unternommen werden, realistische Angaben zu erhalten (Hinweise zur Mobilität während des Assessments geben, gezielte Fragen zu Hilfsmittel stellen).

Beispiele:

- Der Befragte berichtet, ohne Hilfsmittel außerhalb der Wohnung unterwegs zu sein, ist aber offensichtlich auf Hilfsmittel (sitzt beispielsweise im Rollstuhl und kann nicht selbstständig aufstehen).
- Der Befragte behauptet sein Bett nicht verlassen zu haben, hat jedoch selbstständig die Tür geöffnet.
- Eine Pflegekraft oder Angehörige bestätigen im Anschluss, dass die Angaben nicht korrekt sind.

Informationen sind erhältlich bei:

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Supplemental Document 6: LSA-IS Interview-Version Assessment Form (in German language)

Life-Space Assessment in Institutionalized Settings (LSA-IS)

<table>
<tr><td colspan="3">Name:</td><td colspan="3">Datum:</td></tr>
<tr><td colspan="6">Diese Fragen beziehen sich auf Ihre Aktivitäten innerhalb des gestrigen Tages.</td></tr>
<tr><th colspan="2">LEBENSRAUM-STUFE</th><th>HÄUFIGKEIT</th><th colspan="2">SELBSTSTÄNDIGKEIT</th><th>PUNKTE</th></tr>
<tr><td colspan="2">Waren Sie während des gestrigen Tages…</td><td>Wie oft?</td><td colspan="2">Haben Sie Hilfsmittel verwendet?
Haben Sie die Hilfe einer anderen Person benötigt?</td><td>Stufe
×
Häufigkeit
×
Selbstständigkeit</td></tr>
<tr><td>Stufe 1…
innerhalb Ihres Zimmers unterwegs?</td><td>1 = Ja
0 = Nein</td><td>1 = 1 × pro Tag
2 = 2-3 × pro Tag
3 = >3 × pro Tag</td><td colspan="2">1 = persönliche Hilfe
1.5 = nur Hilfsmittel
2 = ohne Hilfsmittel oder persönliche Hilfe</td><td rowspan="2">________________
Stufe 1 Punkte</td></tr>
<tr><td>Punkte</td><td>_____ ×</td><td>_____ ×</td><td colspan="2">_____ =</td></tr>
<tr><td>Stufe 2…
außerhalb Ihres Zimmers, aber innerhalb Ihrer Station unterwegs?</td><td>2 = Ja
0 = Nein</td><td>1 = 1 × pro Tag
2 = 2-3 × pro Tag
3 = >3 × pro Tag</td><td colspan="2">1 = persönliche Hilfe
1.5 = nur Hilfsmittel
2 = ohne Hilfsmittel oder persönliche Hilfe</td><td rowspan="2">________________
Stufe 2 Punkte</td></tr>
<tr><td>Punkte</td><td>_____ ×</td><td>_____ ×</td><td colspan="2">_____ =</td></tr>
<tr><td>Stufe 3…
außerhalb Ihrer Station, aber innerhalb der Einrichtung unterwegs (z.B. andere Station, Cafeteria, Kapelle)?</td><td>3 = Ja
0 = Nein</td><td>1 = 1 × pro Tag
2 = 2-3 × pro Tag
3 = >3 × pro Tag</td><td colspan="2">1 = persönliche Hilfe
1.5 = nur Hilfsmittel
2 = ohne Hilfsmittel oder persönliche Hilfe</td><td rowspan="2">________________
Stufe 3 Punkte</td></tr>
<tr><td>Punkte</td><td>_____ ×</td><td>_____ ×</td><td colspan="2">_____ =</td></tr>
<tr><td>Stufe 4…
außerhalb der Einrichtung, aber innerhalb des dazugehörigen Geländes
(z.B. Terrasse, Park)?</td><td>4 = Ja
0 = Nein</td><td>1 = 1 × pro Tag
2 = 2-3 × pro Tag
3 = >3 × pro Tag</td><td colspan="2">1 = persönliche Hilfe
1.5 = nur Hilfsmittel
2 = ohne Hilfsmittel oder persönliche Hilfe</td><td rowspan="2">________________
Stufe 4 Punkte</td></tr>
<tr><td>Punkte</td><td>_____ ×</td><td>_____ ×</td><td colspan="2">_____ =</td></tr>
</table>

Stufe 5… **außerhalb des zur Einrichtung dazugehörigen Geländes?**	5 = Ja 0 = Nein	1 = 1 × pro Tag 2 = 2-3 × pro Tag 3 = >3 × pro Tag	1 = persönliche Hilfe 1.5 = nur Hilfsmittel 2 = ohne Hilfsmittel oder persönliche Hilfe	
Punkte	_____ **×**	_____ **×**	_____ **=**	____________ *Stufe 5 Punkte*
Gesamtpunktzahl **(LSA-IS-T)**				____________ *Summe der Stufen*
Max. Stufe (LSA-IS-M)				________
Max. Stufe ohne Hilfemittel und ohne persönliche Hilfe (LSA-IS-I)				________
Max. Stufe nur mit Hilfsmittel, aber ohne persönliche Hilfe (LSA-IS-E)				________
Max. Stufe mit persönlicher Hilfe (LSA-IS-P)				________

Supplemental Document 7: LSA-IS Assessment Manual (in German language)

Life-Space Assessment für Personen in Institutionen

(LSA-IS)

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Manual für Nutzer für die interviewbasierte Version

Einführung

Das “Life-Space Assessment für Personen in Institutionen” (LSA-IS) gibt es als interviewbasierte und als fremdberichtete (Angehörige, Pflegekräfte) Version. Dieses ist das Manual für die interviewbasierte Version. Das LSA-IS wurde auf Basis des “Nursing Home Life-Space Diameters (Tinetti & Ginter 1990) und des “University of Alabama at Birmingham – Life Space Assessment” (UAB-LSA; Baker et al. 2003) entwickelt, um die “Life-Space Mobilität” auch von älteren Menschen, die sich in Einrichtungen wie Krankenhaus, Rehabilitationsklinik oder Pflegeheim befinden, erfassen zu können. Es wurden Anpassungen und Veränderungen im Hinblick auf das Setting und eventuelle Einschränkungen durch fehlendes Erinnerungsvermögen durch akute medizinische Ereignisse, kognitive Einschränkungen, Delir/Narkosefolgen, oder die Ortswechsel bei diesen Personen vorgenommen. Unter anderem aus diesem Grund wurde die Observationsdauer von zwei bzw. vier Wochen auf einen Tag reduziert und eine spezielle Interviewtechnik für die Version des Selbstberichts eingeführt, die eine verzerrte Erfassung der Mobilität durch fehlendes Erinnerungsvermögen verhindern soll. Diese wurde auch schon erfolgreich in früheren Projekten (einem Fragebogen zur Erfassung der körperlichen Aktivität bei Personen mit leichter bis moderater kognitiver Einschränkung) eingesetzt (Hauer et al. 2011).

Das LSA-IS erfasst die Mobilität innerhalb von klar definierten Bereichen (eigener Raum, Station, Einrichtung, und darüber hinausgehende Bereiche), die typisch für eine Einrichtung wie Krankenhaus, Rehabilitationsklinik oder Pflegeheim sind, und erfasst zusätzlich die Häufigkeit dieser Bewegungen und den Bedarf an Hilfsmittel oder Hilfspersonen.

Zielpopulation

Die Zielpopulation umfasst ältere Menschen, die sich in einer Institution wie Krankenhaus, Rehabilitationsklinik oder Pflegeheim befinden. Diese Personen weisen häufig

Multimorbidität, akute medizinische Probleme, kognitive Einschränkungen, oder eine eingeschränkte Orientierung auf.

Vorbereitungen für die Durchführung des LSA-CI

Für Personen in Gesundheitsberufen ist kein spezielles Training erforderlich um den LSA-CI durchzuführen. Benötigt werden lediglich der Fragebogen und ein Stift.

Vorgehen bei der Durchführung

Der LSA-CI kann als Interview (oder als Bericht durch Angehörige oder Pflegekräfte siehe LSA-IS proxy-version und Manual) durchgeführt wurden und berücksichtigt die speziellen Bedürfnisse von älteren, multi-morbiden Personen mit möglicher körperlicher oder kognitiver Einschränkung. Bei der interview-basierten Variante sollte die Erhebung alleine stattfinden, um die Aufmerksamkeit der zu befragenden Person nicht zu beeinträchtigen. Sollten Zimmernachbarn, Angehörige, oder Pflegekräfte anwesend sein, dürfen diese nicht das Antworten übernehmen oder sich einmischen. Im Anschluss an die Durchführung können die Angehörigen oder Pflegekräfte jedoch die Aussagen bestätigen oder falsifizieren.

Das Befragung sollte in einem ruhigen Umfeld durchgeführt werden, am besten im Zimmer des Befragten, so kann sich der Interviewer sich auf die aktuelle Situation beziehen und die Fragen konkret stellen. Das Wissen um die aktuelle Situation ist auch hilfreich, um die Genauigkeit der Antworten direkt erfassen zu können und gegebenenfalls Rückfragen zu stellen (z.B. steile Treppe am Eingangsbereich, Stellplatz für Hilfsmittel etc.). Es sollte gezielt nach offensichtlichen Einschränkungen in der Beweglichkeit (z.B. Schwierigkeiten beim Aufstehen, Treppengehen etc.) und nach Hilfsmittel (z.B. sichtbarer Gehstock, Rollator etc.) gefragt werden, um einen realistischen Eindruck der aktuellen Fähigkeiten und Tätigkeiten zu erlangen.

Dermenzspezifische Interview-Technik:

Die Befragung sollte im persönlichen Gespräch und interviewbasiert erfolgen, um Ungenauigkeiten auszuschließen bzw. zu reduzieren, die Vollständigkeit der Antworten abzusichern und gleichzeitig auf eine mögliche Überförderung des Befragten eingehen zu können (Hauer et al. 2010). Diese Form der Erfassung erlaubt umfassende mündliche Erläuterungen und lässt Raum für Rückfragen, was Ungenauigkeiten oder Mehrdeutigkeit verhindert (Durante & Ainsworth 1996) und Versagensängste in Bezug auf Verständnis und Erinnerungsfähigkeit bei den Befragten verhindern (Hauer et al 2011).

Schritt 1: Die Befragung sollte mit einer kurzen Erläuterung der Ziele und der Dauer der Befragung (3 bis 5 Minuten) starten.

Schritt 2: Wichtig ist, den Beginn und das Ende des Beobachtungszeitraums klar zu benennen (den gestrigen Tag). Falls während der Befragungen Unklarheiten auftreten, kann es angemessen sein, die Aktivitäten in jeder Zone in Abschnitten abzufragen und den Tag zu segmentieren mit Hilfe von typischen Aktivitäten (nach dem Aufstehen, vor dem Frühstück, bis zum Mittagessen, vor der Therapie/Arztbesuch/Gruppe etc.).

Schritt 3: Fragen Sie einzeln nach jeder Life-Space Zone, beginnend mit Zone 1 und dann kontinuierlich weitergehend ohne eine Zone auszulassen.

Spezielle Zeitfenster sowie tägliche Rituale und Gewohnheiten können dabei als "Anker" genutzt werden, um den Beobachtungszeitraum zu segmentieren oder einzuteilen (z.B. Wochenende und Wochentage, Aufstehen, Mahlzeiten, Körperpflege, Gang zu Cafeteria/Shop/Kiosk, Fernsehen, etc.).

Zusätzlich sollte gezielt nach typischen Aktivitäten gefragt werden, sofern diese nicht selbst erwähnt werden (Besuche von Freunden und Verwandten, Arztbesuche, Therapien) um die Vollständigkeit der Erfassung abzusichern. Geschlossene Fragen können dabei besser geeignet sein, um eine kognitive Überforderung zu vermeiden ("Waren sie einkaufen" statt "Was haben Sie sonst gemacht?").

Im Fokus der Erfassung steht die aktuelle Mobilität, also das, was die Befragten tatsächlich am vorigen Tag gemacht haben, und nicht das, wozu sie in der Lage gewesen wären.

Ein Anhaltspunkt für die Genauigkeit der Erfassung der einzelnen Zonen ist, dass es nicht möglich ist, eine Zone zu erreichen, ohne sich in den niedrigeren Zonen bewegt zu haben (z.B. ist es nicht möglich, in außerhalb der Institution unterwegs gewesen zu sein, ohne die Institution durchquert zu haben).

Schritt 4: Die Befragung schließt mit einer Zusammenfassung des Gesagten für jede jeweilige Zone einschließlich der Häufigkeit und des Bedarfs an Hilfe, so haben die Befragten Zeit, ihre eigenen Aussagen zu prüfen und zu bestätigen oder korrigieren.

Beispiele für die Befragung und die Zusammenfassung:

Zone 1: *Haben Sie sich gestern außerhalb Ihres Zimmers aufgehalten? Haben Sie nach dem Aufstehen ihr Bett verlassen? Haben Sie sich gestern krank gefühlt und den Tag im Bett verbracht? Haben Sie Hilfe benötigt, als Sie Ihr Bett verlassen, halten Sie sich an Ihrem Rollator/ Nachttisch etc. fest? Wenn Sie in das Bad/zum Fernseher/Schrank gehen, nutzen Sie dann den Rollator/Gehstock?*

Zusammenfassung Zone 1: *Also, Sie haben gestern ihr Bett verlassen und sich mindestens zehn Mal in Ihrem Raum bewegt und dabei keine Hilfsmittel benötigt? Ist das so korrekt?*

Zone 2: *Waren Sie gestern außerhalb Ihres Zimmers und auf Ihrer Station unterwegs? Wie oft haben Sie Ihr Zimmer verlassen und sind im Flur oder in der Teeküche auf der Station unterwegs? Nutzen Sie Ihren Rollator/Rollstuhl? Muss Ihnen dabei jemand helfen?*

Zusammenfassung Zone 2: *Lassen Sie mich das zusammenfassen: Sie haben gestern ihr Zimmer 4 Mal verlassen, 3 Mal zu den Mahlzeiten im Gemeinschaftsraum und ein Mal, um zur Teeküche zu gehen? Dabei haben Sie Ihren Rollator benutzt? Ist das richtig?*

Zone 3: *Waren Sie gestern auch außerhalb Ihrer Station unterwegs? Waren Sie zum Beispiel eine andere Station besuchen, in der Cafeteria oder haben Sie den Therapieraum/Gruppenraum genutzt? Wie oft waren Sie außerhalb Ihrer Station unterwegs? Kennen Sie die Cafeteria / Kapelle / Kiosk, waren Sie gestern dort? Als Sie dorthin gegangen sind, waren Sie mit alleine unterwegs? Haben Sie hierbei ein Hilfsmittel oder die Hilfe einer Person benötigt?*

Zusammenfassung Zone 3: *Sie waren gestern also zwei Mal außerhalb der Station, ein Mal vormittags in der Cafeteria im Erdgeschoss, und noch ein Mal am Nachmittag um in den Park zu gelangen? Sie konnten diese Aktivitäten ohne Hilfspersonen durchführen, brauchten aber Ihren Rollator?*

Zone 4: *Waren Sie gestern außerhalb des Krankenhauses/Pflegeheims (Name)aber auf dem Krankenhaus/Heimgelände unterwegs? Wie oft waren Sie da? Gehen Sie dort zu Fuß/selbst hin, oder ist es zu weit weg? Nutzen Sie Hilfsmittel wie den Gehstock/Rollator? Gibt es auch eine Person, die Ihnen hilft?*

Zusammenfassung Zone 4: *Lassen Sie mich das wiederholen, Sie waren gestern also zwei Mal außerhalb Ihrer Pflegeheims unterwegs, und zwar waren Sie ein Mal beim Arzt, und ein Mal haben Sie sich in den Park gesetzt. Sie haben für den Weg in den Park Ihren Rollator benötigt und nur für die Taxifahrt die Hilfe einer Person beim Ein-und Aussteigen in das Auto? Habe ich das richtig verstanden?*

Zone 5: *Haben Sie gestern die Einrichtung verlassen und waren in der Stadt unterwegs? Wie oft waren Sie dort? Gab es gestern ein besonderes Ereignis, wie einen Arztbesuch, oder einen Ausflug? Wie sind Sie dorthin gekommen, selbstständig oder mit Hilfe?*

Zusammenfassung Zone 5: *Sie waren also gestern nicht außerhalb des Krankenhausgeländes unterwegs? Ist das richtig?*

Bewertung

Zunächst werden die Ergebnisse auf der Zoneneben multipliziert: Zone (1-5) x (Häufigkeit 1-3) x Selbstständigkeit (1, 1,5 oder 2). Bei Selbstständigkeit wird die selbstständigste Variante bewertet, hat ein Befragter in einer bestimmten Zone beispielsweise ein Mal einen Rollator zum Fortbewegen benutzt und war einmal selbstständig ohne Hilfsmittel unterwegs, wird dies als "selbstständig" (=2) bewertet. Anschließen werden die Ergebnisse für jede Zone addiert.

Ungültige Aussagen oder Ausschluss von Ergebnissen:

Bei ganz offensichtlich falschen Angaben oder nicht plausiblen Aussagen sollten die Ergebnisse nicht berücksichtigt werden. Es sollten jedoch Versuche unternommen werden, um realistische Angaben zu bekommen (Hinweise auf Mobilität während Assessment, gezielte Fragen zu Hilfsmittel).

Beispiele:

- Der Befragte berichtet, ohne Hilfsmittel außerhalb der Einrichtung unterwegs zu sein, ist aber offensichtlich auf Hilfsmittel angewiesen (sitzt beispielsweise im Rollstuhl und kann nicht selbstständig aufstehen).
- Der Befragte behauptet sein Bett nicht verlassen zu haben, sitzt jedoch während der Befragung am Tisch.
- Eine Pflegekraft oder Angehörige bestätigen im Anschluss, dass die Angaben nicht korrekt sind.

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Supplemental Document 8: LSA-IS Proxy Report Assessment Form (in German language)

Life-Space Assessment in Institutionalized Settings (LSA-IS)

Name:		Datum:		
Diese Fragen beziehen sich auf die Aktivitäten innerhalb des gestrigen Tages.				
LEBENSRAUM-STUFE		**HÄUFIGKEIT**	**SELBSTSTÄNDIGKEIT**	**PUNKTE**
War der Patient/Bewohner/Gast während des gestrigen Tages…		**Wie oft?**	**Hat er/sie Hilfsmittel verwendet?** **Hat er/sie die Hilfe einer anderen Person benötigt?**	Stufe × Häufigkeit × Selbstständigkeit
Stufe 1… **innerhalb des eigenen Zimmers unterwegs?**	1 = Ja 0 = Nein	1 = 1 × pro Tag 2 = 2-3 × pro Tag 3 = >3 × pro Tag	1 = persönliche Hilfe 1.5 = nur Hilfsmittel 2 = ohne Hilfsmittel oder persönliche Hilfe	
Punkte	_____ ×	_____ ×	_____ =	_______________ *Stufe 1 Punkte*
Stufe 2… **außerhalb desZimmers, aber innerhalb der Station unterwegs?**	2 = Ja 0 = Nein	1 = 1 × pro Tag 2 = 2-3 × pro Tag 3 = >3 × pro Tag	1 = persönliche Hilfe 1.5 = nur Hilfsmittel 2 = ohne Hilfsmittel oder persönliche Hilfe	
Punkte	_____ ×	_____ ×	_____ =	_______________ *Stufe 2 Punkte*
Stufe 3… **außerhalb der Station, aber innerhalb der Einrichtung unterwegs (z.B. andere Station, Cafeteria, Kapelle)?**	3 = Ja 0 = Nein	1 = 1 × pro Tag 2 = 2-3 × pro Tag 3 = >3 × pro Tag	1 = persönliche Hilfe 1.5 = nur Hilfsmittel 2 = ohne Hilfsmittel oder persönliche Hilfe	
Punkte	_____ ×	_____ ×	_____ =	_______________ *Stufe 3 Punkte*
Stufe 4… **außerhalb der Einrichtung, aber innerhalb des dazugehörigen Geländes** **(z.B. Terrasse, Park)?**	4 = Ja 0 = Nein	1 = 1 × pro Tag 2 = 2-3 × pro Tag 3 = >3 × pro Tag	1 = persönliche Hilfe 1.5 = nur Hilfsmittel 2 = ohne Hilfsmittel oder persönliche Hilfe	
Punkte	_____ ×	_____ ×	_____ =	_______________ *Stufe 4 Punkte*

Stufe 5… **außerhalb des zur Einrichtung dazugehörigen Geländes?**	5 = Ja 0 = Nein	1 = 1 × pro Tag 2 = 2-3 × pro Tag 3 = >3 × pro Tag	1 = persönliche Hilfe 1.5 = nur Hilfsmittel 2 = ohne Hilfsmittel oder persönliche Hilfe	
Punkte	_____ **×**	_____ **×**	_____ **=**	________________ *Stufe 5 Punkte*
Gesamtpunktzahl **(LSA-IS-T)**				________________ *Summe der Stufen*
Max. Stufe (LSA-IS-M)				__________
Max. Stufe ohne Hilfemittel und ohne persönliche Hilfe (LSA-IS-I)				__________
Max. Stufe nur mit Hilfsmittel, aber ohne persönliche Hilfe (LSA-IS-E)				__________
Max. Stufe mit persönlicher Hilfe (LSA-IS-P)				__________

Supplemental document 9: LSA-IS Proxy Report Assessment Manual (in German language)

Life-Space Assessment für Personen in Institutionen

(LSA-IS)

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Manual für Nutzer für die proxy-Version (Erfassung durch Angehörige oder Pflegekräfte)

Einführung

Das “Life-Space Assessment für Personen in Institutionen” (LSA-IS) gibt es als interviewbasierte und als proxy-report Version, hierzu dokumentieren Angehörige oder Pflegekräfte die Mobilität des zu Beobachtenden innerhalb des gestrigen Tages. Das LSA-IS wurde auf Basis des “Nursing Home Life-Space Diameters (Tinetti & Ginter 1990) und des “University of Alabama at Birmingham – Life Space Assessment” (UAB-LSA; Baker et al. 2003) entwickelt, um die “Life-Space Mobilität” auch von älteren Menschen, die sich in Einrichtungen wie Krankenhaus, Rehabilitationsklinik oder Pflegeheim befinden, erfassen zu können. Es wurden Anpassungen und Veränderungen im Hinblick auf das Setting vorgenommen. Aus verschiedenen Gründen wurde die Observationsdauer von zwei bzw. vier Wochen auf einen Tag reduziert.

Das LSA-IS erfasst die Mobilität innerhalb von klar definierten Bereichen (eigener Raum, Station, Einrichtung, und darüber hinausgehende Bereiche), die typisch für eine Einrichtung wie Krankenhaus, Rehabilitationsklinik oder Pflegeheim sind, und erfasst zusätzlich die Häufigkeit dieser Bewegungen und den Bedarf an Hilfsmittel oder Hilfspersonen.

Zielpopulation

Die Zielpopulation umfasst ältere Menschen, die sich in einer Institution wie Krankenhaus, Rehabilitationsklinik oder Pflegeheim befinden. Diese Personen weisen häufig Multimorbidität, akute medizinische Probleme, kognitive Einschränkungen, oder eine eingeschränkte Orientierung auf.

Vorbereitungen für die Durchführung des LSA-CI

Für Personen in Gesundheitsberufen ist kein spezielles Training erforderlich um den LSA-CI durchzuführen. Benötigt werden lediglich der Fragebogen und ein Stift.

Vorgehen bei der Durchführung

Der LSA-CI sollte nur von einer Person durchgeführt hat, die Einblick in das aktuelle Bewegungsverhalten des zu Beobachtenden hat (Bedarf an Hilfsmittel oder Hilfspersonen, Gewohnheiten), die Abläufe in der Einrichtung (Therapien, Gruppenangebote, Mahlzeiten) und die die räumliche Umgebung (Garten- oder Parkanlagen, Einkaufsmöglichkeiten in der Umgebung) kennt. Der Beobachter sollte die Gelegenheit haben, den zu Beobachtenden mehrfach am Tag zu sehen, ohne dabei in dessen Mobilitätsverhalten einzugreifen.

Im Fokus der Erfassung steht die aktuelle Mobilität, also das, was die Befragten tatsächlich am vorigen Tag gemacht haben, und nicht das, wozu sie in der Lage gewesen wären.

Ein Anhaltspunkt für die Genauigkeit der Erfassung der einzelnen Zonen ist, dass es nicht möglich ist, eine Zone zu erreichen, ohne sich in den niedrigeren Zonen bewegt zu haben (z.B. ist es nicht möglich, in außerhalb der Institution unterwegs gewesen zu sein, ohne die Institution durchquert zu haben).

Bewertung

Zunächst werden die Ergebnisse auf der Zoneneben multipliziert: Zone (1-5) x (Häufigkeit 1-3) x Selbstständigkeit (1, 1,5 oder 2). Bei Selbstständigkeit wird die selbstständigste Variante bewertet, hat ein Befragter in einer bestimmten Zone beispielsweise ein Mal einen Rollator zum Fortbewegen benutzt und war einmal selbstständig ohne Hilfsmittel unterwegs, wird dies als "selbstständig" (=2) bewertet. Anschließen werden die Ergebnisse für jede Zone addiert.

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Measurement Article

Validation of a Modified Life-Space Assessment in Multimorbid Older Persons With Cognitive Impairment

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Abstract

Background and Objectives: To investigate the validity, reliability, sensitivity to change, and feasibility of a modified University of Alabama at Birmingham Study of Aging Life-Space Assessment (UAB-LSA) in older persons with cognitive impairment (CI).

Research Design and Methods: The UAB-LSA was modified for use in persons with CI Life-Space Assessment for Persons with Cognitive Impairment (LSA-CI). Measurement properties of the LSA-CI were investigated using data of 118 multimorbid older participants with CI [mean age (*SD*): 82.3 (6.0) years, mean Mini-Mental State Examination score: 23.3 (2.4) points] from a randomized controlled trial (RCT) to improve motor performance and physical activity. Construct validity was asessed by Spearman's rank (r_s) and point-biseral correlations (r_{pb}) with age, gender, motor, and cognitive status, psychosocial factors, and sensor-derived (outdoor) physical activity variables. Test–retest reliability was analyzed using intra-class correlation coefficients (ICCs). Sensitivity to change was determined by standardized response means (SRMs) calculated for the RCT intervention group.

Results: The LSA-CI demonstrated moderate to high construct validity, with significant correlations of the LSA-CI scores with (outdoor) physical activity (r_s = .23–.63), motor status (r_s = .27–.56), fear of falling-related psychosocial variables (r_s = |.24–.44|), and demographic characteristics (r_{pb} = |.27–.32|). Test–retest reliability was good to excellent (ICC = .65–.91). Sensitivity to change was excellent for the LSA-CI composite score (SRM = .80) and small to moderate for the LSA-CI subscores (SRM = .35–.60). A completion rate of 100% and a mean completion time of 4.1 min) documented good feasibility.

Discussion and Implications: The LSA-CI represents a valid, reliable, sensitive, and feasible interview-based life-space assessment tool in multimorbid older persons with CI.

Keywords: Assessment of Conditions/People, Clinical Trial Methods, Quantitative research methods, Measurement, Exercise/Physical Activity, Cognitive Impairment, Validation

Introduction

Community mobility has been conceptualized and measured in terms of life-space (Webber, Porter, & Menec, 2010), a concept which encompasses a concentric pattern of mobility zones from own bedroom to regions beyond city limits.

Life-space measures quantify activity and location of mobility influenced by interaction between functional, cognitive, and psychosocial ability with social, economic and cultural aspects (Parker, Baker, & Allman, 2002). Restricted life-space mobility is associated with higher mortality

(Kennedy et al., 2017), institutionalization (Sheppard, Sawyer, Ritchie, Allman, & Brown, 2013), lower quality of life (Bentley et al., 2013), and social engagement (Rosso, Taylor, Tabb, & Michael, 2013). Moreover, it has been identified as a predictor of cognitive decline (Crowe et al., 2008; Silberschmidt et al., 2017).

Cognitive impairment (CI) in older persons increases the risk for mobility limitations (Pedersen et al., 2014), and is associated with loss of functional independence (Wadley et al., 2007) and reduced time spent out-of-home (Wettstein et al., 2015).

The assessment of life space via questionnaires has been introduced in 1985 (May, Nayak, & Isaacs, 1985). Since then several questionnaires have been developed with the University of Alabama at Birmingham Study of Aging Life-Space Assessment (UAB-LSA) representing one of the most frequently used life-space mobility assessment tools in older adults (Chung, Demiris, & Thompson, 2015). The UAB-LSA was initially developed and validated for use in older community-dwelling persons without CI (Baker, Bodner, & Allman, 2003; Peel et al., 2005). In this population, the UAB-LSA was translated and validated in several languages (Auger et al., 2009; Curcio et al., 2013; Fristedt, Kammerlind, Bravell, & Fransson, 2016; Harada et al., 2010; Ji, Zhou, Liao, & Feng, 2015), proved for good to excellent test–retest reliability (Auger et al., 2009; Baker et al., 2003; Curcio et al., 2013; Ji et al., 2015; Kammerlind, Fristedt, Ernsth Bravell, & Fransson, 2014; Portegijs, Iwarsson, Rantakokko, Viljanen, & Rantanen, 2014), and demonstrated to be feasible (Auger et al., 2009; Peel et al., 2005; Portegijs et al., 2014). Sensitivity to change of the UAB-LSA has so far only been documented over time by natural course without statistical analysis (Baker et al., 2003).

The UAB-LSA has already been used to assess life-space mobility in mixed populations including some persons with CI (Al Snih et al., 2012; Crowe et al., 2008; Fairhall et al., 2012; Silberschmidt et al., 2017; Tsutsumimoto et al., 2014); however, it has not yet been validated in, nor has it been adjusted to this population, which have shown recall bias and inaccuracy in retrospective self-reports (Shephard, 2003) as well as difficulties in self-reporting physical activity (PA) (Bhandari & Wagner, 2006; Sallis & Saelens, 2000). In addition, previous UAB-LSA validation studies have not yet conducted in multimorbid older persons with acute motor impairment, although this population represents a high-risk group for life-space restrictions (Baker et al., 2003; Brown et al., 2009; Crowe et al., 2008; Portegijs, Rantakokko, Viljanen, Sipila, & Rantanen, 2016). The aim of this study was therefore to validate a modified version of the UAB-LSA (Life-Space Assessment in Persons with Cognitive Impairment, LSA-CI) specifically developed for use in multimorbid persons with CI.

Methods

Study Design

The present validation study was part of a double-blinded, randomized, placebo-controlled intervention trial (RCT) to improve motor performance and PA in older persons with mild to moderate CI recently discharged from geriatric rehabilitation (ISRCTN82378327). The RCT was performed according to the Helsinki declaration and was approved by the ethics committee of the Medical Department of the University of Heidelberg.

Study Sample

Participants were consequently recruited from rehabilitation wards of a German geriatric hospital. Individuals with Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975) scores of 17–26 indicating mild to moderate CI were included in the study (Monsch et al., 1995; O'Bryant et al., 2008; Thalmann et al., 2002). Further inclusion criteria were: age ≥65 years; ability to walk at least 4 m without a walking aid; residence within 30 kilometers of the study center; discharge to the patients' home (i.e., no nursing home residents); no terminal disease; no delirium; German-speaking, and written informed consent.

Descriptive Measures

Demographic and clinical characteristics including age, gender, and comorbidity (number of diagnoses, medications) were documented at baseline from patient charts. A trained interviewer assessed falls in the previous year, cognitive status (MMSE) (Folstein et al., 1975), professional education (school education only vs. additional vocational training or academic studies), and psychosocial status for depression (Geriatric Depression Scale, 15-item version, GDS, Yesavage et al., 1982) and fear of falling (Falls Efficacy Scale-International, 7-item version, FES-I, Kempen et al., 2008; Fear of Falling Avoidance Behavior Questionnaire, FFABQ, Landers, Durand, Powell, Dibble, & Young, 2011). Motor status was assessed by the Short Physical Performance Battery (SPPB, Guralnik et al., 1994) and the Timed "Up & Go" (TUG, Podsiadlo & Richardson, 1991).

Life-space Assessment

University of Alabama at Birmingham Study of Aging Life-Space Assessment

The UAB-LSA is an instrument to assess life-space mobility of the previous 4 weeks by the frequency of movements and assistance needed to travel via face-to-face or telephone interview. The activity area is classified into six hierarchically structured, concentric zones ranging from activity locations including a person's bedroom (level 0), to a person`s home (level 1), area outside the house (level 2), the neighborhood (level 3), the home town (level 4), and beyond the person's home town (level 5). A composite score of life-space mobility (LSA-C) is calculated by multiplying the levels reached (levels 0–5), with the frequency of activity within a level (1 = "less than 1 time per week", 2 = "1–3 times per week", 3 = "4–6 times per week", 4 = "daily") and the assistance needed to travel to the level (1 = "help of another person", 1.5 = "use of assistive device only", 2 = "no assistance"). The lowest LSA-C score of 0 indicates total immobility (bed-bound) and the maximum LSA-C score of 120 indicates daily independent out-of-town mobility. In addition, three LSA subscores can be calculated for (a) the maximum life-space level reached allowing equipment or personal assistance (LSA-M; range 0–5), (b) the maximum life-space level reached with equipment if needed but without personal assistance (LSA-E; range 0–5), and (c) the maximum life-space level reached independently without any assistance (LSA-I; range 0–5) (Baker et al., 2003).

Modifications for Life-Space Assessment in Persons with Cognitive Impairment

The assessment period covered by the UAB-LSA was reduced from 4 weeks to 1 week to prevent recall bias in persons with CI, thus the LSA-CI has a different scoring range for frequency (1 point: 1–3 times per week, 2 points: 4–6 times per week, and 3 points: daily), and consequently the composite score ranges from 0 ("totally bed-bound") to 90 points ("traveled out of town every day without assistance"). The LSA-CI constitutes an interview-based and strictly standardized questionnaire, which was conducted face-to-face without participation of proxies or caregivers. A dementia-specific interview technique, originally developed for the assessment of PA in patients with CI, was implemented to prevent recall problems (Hauer et al., 2011). The strategy included an informal conversational approach to prevent fear of failure in comprehension and recall and to improve the completeness of reports, fostering memory by precise questions and response options, structuring the observation period by referring to daily routines and highlighting landmark events such as meals, daily/weekly habits, special events as visits, celebration, and summarizing the information (Bhandari & Wagner, 2006; Shephard, 2003) (the LSA-CI questionnaire form and a manual for assessment instruction and rationale are provided as supplementary material).

Translation Process

The translation from English into German language was performed according to a structured proceeding suggested by Beaton, Bombardier, Guillemin, and Ferraz (2000) (stages I–IV), including forward- and backward-translation by bilingual translators and tests in the target population in terms of comprehensibility.

Assessment of Measurement Properties

Construct Validity

To analyze construct validity, correlations between the LSA-CI scores at baseline (LSA-CI-C, -M, -E, and -I) with demographic variables (age, gender), motor status (SPPB, gait speed from the SPPB, TUG), cognitive status (MMSE), and psychological status (GDS, FES-I, FFABQ) were calculated. These correlates were selected according to previous validation studies of the UAB-LSA, demonstrating construct validity by associations with age and gender (Harada et al., 2010; Peel et al., 2005), physical performance (Baker et al., 2003; Curcio et al., 2013; Fristedt et al., 2016; Ji et al., 2015; Peel et al., 2005), cognitive status (Curcio et al., 2013; Ji et al., 2015) and multiple psychosocial factors (Baker et al., 2003; Curcio et al., 2013; Ji et al., 2015; Peel et al., 2005). As previous observational studies in community-dwelling people reported that life-space mobility is associated with objectively measured PA (Portegijs, Tsai, Rantanen, & Rantakokko, 2015; Tsai et al., 2015), we additionally used sensor-derived PA and outdoor PA data (OPA) captured for 48 hours during the baseline assessment for validity testing.

PA was measured by a small (5.1 × 3 × 1.6 cm), light (24 g), body-fixed motion sensor (PAMSys™, BioSensics, Cambridge, MA) attached to the participant's sternum. The PAMSys™ is able to identify posture durations (i.e., minutes of lying, sitting, standing, and walking) and locomotion outcomes (i.e., number of walking steps and walking episodes) based on established and validated algorithms (Najafi et al., 2003).

OPA variables were calculated based on PA data and data derived from a mobile Global Positioning System (GPS). In our study, we used a QStarz GPS-tracker (QStarz BT1000X, Qstarz International Co., Ltd., Taipei, Taiwan), an established device to assess spatial location of physical activity (Wu et al., 2010). The Software Personal Activity Location Measurement System (PALMS; available from: http://ucsd-palms-project.wikispaces.com/.) was used to merge the GPS and PA data. PALMS is valid for processing GPS data to objectively measured PA data (Carlson et al., 2015). OPA variables included being active outdoors (yes or no), mean outdoor walking duration and distance, number of outdoor walking episodes, and maximum distance from home.

Test–retest Reliability

To test for test–retest reliability, the LSA-CI assessment was conducted twice within two days for all participants at post-intervention by the same trained interviewer to exclude interrater variability.

Sensitivity to Change

Sensitivity to change was examined for the participants randomly assigned to the intervention group of a 12-week home-based interventional trial to improve motor performance and physical activity in geriatric patients with CI following rehabilitation. The intervention included exercises to promote functional balance and strength performance as well as various motivational strategies to promote physical activity (Bongartz et al., 2017).

Feasibility

Completion rate and completion time to fill out the questionnaire were documented at baseline to determine feasibility. In case of unrealistic self-reports and implausible participant statements data was not analyzed. In addition, LSA-CI scores at baseline were checked for floor and ceiling effects, which were considered present when more than 15% of the individuals achieve the highest or lowest score (McHorney & Tarlov, 1995).

Statistical Analysis

Descriptive data were presented as frequencies and percentages for categorical variables, and means and standard deviations or medians and ranges for continuous variables as appropriate. Spearman and point-biserial correlation coefficients were calculated to assess construct validity. Correlation coefficients (r) were interpreted as low ($r < 0.2$), moderate ($r = 0.2–0.5$), or high ($r > 0.5$) (Cohen, 1988). Intra-class correlation coefficients (ICC3,1 for absolute agreement) with 95% confidence intervals for the LSA-CI composite score and each subscore were used to analyze test–retest reliability. ICCs were interpreted as poor (<0.4), fair to good (≥ 0.4 ≤ 0.75), and excellent (>0.75) (Fleiss, 1986). Sensitivity to change was assessed using paired t-tests to test for significant within-group differences between baseline and post intervention assessment and standardized response means (SRMs) to quantify the magnitude of changes. SRMs were calculated as the difference in mean change scores divided by the *SD* of the change score (Katz, Larson, Phillips, Fossel, & Liang, 1992). SRMs were adjusted for the size of correlation coefficients between the baseline and post-intervention scores (Middel & van Sonderen, 2002) to use Cohen's thresholds for effect sizes (trivial < 0.2, small ≥ 0.2 < 0.5, moderate ≥ 0.5 < 0.8, and large ≥ 0.8) (Cohen, 1988). A two-sided p-value of < 0.05 indicated statistical significance. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 23 for Windows (IBM Corp., NY).

Results

Participants' Characteristics

Out of 1,981 persons screened for eligibility, 1,863 did not meet inclusion criteria due to MMSE criteria ($n = 553$; MMSE >26: $n = 382$, MMSE <17: $n = 102$, MMSE not feasible: $n = 69$), residence >30 km from study center ($n = 241$), medical contraindications ($n = 217$), being recruited for another trial ($n = 211$), inability to walk at least 4 m without a walking aid ($n = 196$), refusal to participate ($n = 123$), nursing home resident or admission ($n = 113$), or other reasons ($n = 209$; e.g., <65 years, lack of German language skills, transfer to another hospital). Thus, the total sample included 118 multimorbid, older, community-dwelling persons with mild to moderate CI with at least two chronic diseases, and predominantly orthopedic and cardiovascular diseases. Detailed participant characteristics are summarized in Table 1.

Construct Validity

The LSA-CI scores showed consistently moderate to high correlations with all OPA variables ($r = .30–.63$), with the lowest correlations for the Life-Space Assessment for Persons with Cognitive Impairment for the maximal life-space score (LSA-CI-M) ($r = .30–.34$) (Table 2). Moderate to high correlations of the LSA-CI scores were also found with almost all (15 of 16) PA variables addressing physical active behavior (i.e., standing, walking, number of walking episodes and steps) ($r = .23–.60$), whereas correlations with PA variables addressing sedentary behavior (i.e., lying, sitting) were consistently lower ($r = −.06$ to $−.40$). Overall, the lowest correlations with PA variables were found for the LSA-CI-M ($r = −.06$ to $−.29$). Except for the LSA-CI-M ($r = |.05–.13|$), LSA-CI scores showed moderate to high correlations with motor status ($r = |.27–.56|$) and fear of falling-related psychosocial variables ($r = −.24$ to $−.44$). For depressive symptoms, only low correlations were

Table 1. Participant Characteristics

Characteristics	Total sample $n = 118$
Age, years, mean (*SD*)	82.3 (6.0)
Gender, female, *n* (%)	90 (76.3)
Professional education, *n* (%)	
School education only	37 (31.4)
Vocational training or academic studies	81 (68.6)
Diagnoses, number, mean (*SD*)	11.4 (4.4)
Medications, number, mean (*SD*)	9.5 (3.5)
MMSE, score, mean (*SD*)	23.3 (2.4)
SPPB, total score, mean (*SD*)	5.2 (2.3)
Gait speed, m/s, mean (*SD*)[a]	0.45 (0.20)
TUG, s, median (range)[b]	20.5 (8.8–91.0)
At least one fall in the previous year, *n* (%)	79 (66.9)
FES-I, score, median (range)	11 (7–25)
FFABQ, score, mean (*SD*)	18.7 (12.6)
GDS, score, mean (*SD*)	5.3 (3.0)

Note: GDS = Geriatric Depression Scale; FES-I = Falls Efficacy Scale-International, seven-item version; FFABQ = Fear of Falling Avoidance Behavior Questionnaire; MMSE = Mini-Mental State Examination; SPPB = Short-Physical-Performance-Battery; TUG = Timed "Up & Go".

[a]Calculated based on the SPPB gait speed test.

[b]Based on data $n = 113$ as five participants were not able to complete the TUG due to physical limitations.

found (r = −.02 to −.16). The LSA-CI scores predominantly (3 out of 4) correlated only weakly with cognitive status (r = .02–.18). Except for the LSA-CI-M (r = |.13–.15|), demographic characteristics showed moderate correlations with the LSA-CI scores (r = |.27–.32|) with older and female participants demonstrating lower life-space mobility. Subgroup analyses for different cognitive status groups (i.e., MMSE >24 vs. ≤24 and >21 vs. ≤21) revealed no significant differences for any LSA-CI score (unpaired t-test: p = .137–.810).

Test–Retest Reliability

Correlations between the two LSA-CI assessments performed by the same interviewer within 2 days indicated good to excellent test–retest reliability for all LSA-CI scores, with ICCs ranging from 0.65 to 0.91 (Table 3).

Sensitivity to Change

LSA-CI scores were significantly different between baseline and post-intervention assessment (p ≤ .001). Small to large SRMs (range 0.35–0.80) over the intervention were found across the LSA-CI scores, with the highest SRM for the LSA-CI-C (0.80) while LSA-CI subscores reached lower SRMs (0.35–0.60) (Table 4).

Feasibility

No participant objected to the assessment procedure, and data documentation was comprehensive, with no missing responses for any LSA-CI item (i.e., 100% completion rate). We excluded 1 of 118 participants (0.8%) from the analysis, because of unrealistic statements, advanced disorientation, and confabulation. Mean completion time (*SD*) to assess the LSA-CI was 4.1 (2.2) min.

No participant obtained the minimum or maximum LSA-CI-C score, with values ranging from 4.5 to 70.0 points, indicating no ceiling or floor effects for this score. No ceiling or floor effects were documented also for the LSA-CI-E, with no participant obtaining the minimum and only 12 participants (10.3%) obtaining the maximum score. For the LSA-CI-M, we found no floor effect (no participant with the minimum score) but a ceiling effect, with 35 participants (29.9%) obtaining the maximum score. For the LSA-CI-I, no ceiling (n = 5 [4.3%] with the maximum score) but a floor effect was identified, with 58 participants (49.6%) obtaining the minimum score.

Discussion

Although older persons with CI represent a high-risk group for life-space restrictions, established interview-based life-space assessment instruments have not yet been adjusted or validated for use in this population. The presented study is the first to modify one of the most frequently used life-space assessment tools (UAB-LSA) for persons with CI and to evaluate its measurement properties in multimorbid older persons with mild to moderate CI.

Construct Validity

Our results indicated moderate to high construct validity of the LSA-CI with measures of demographic characteristics, motor status, fear of falling-related psychosocial factors, and PA and OPA. Lower life-space mobility was associated with female sex, higher age, lower motor status, pronounced fear of falling-related variables, and higher levels of physical active behavior, which is consistent with previous UAB-LSA validation studies (Baker et al., 2003; Curcio et al., 2013; Fristedt et al., 2016; Harada et al., 2010; Ji et al., 2015; Peel et al., 2005) or cohort studies investigating life-space mobility (Portegijs et al., 2015; Tsai et al., 2015) in community-dwelling older people without CI.

We found that motor status was one of the strongest variables associated with LSA-CI scores, confirming results of previous UAB-LSA validation studies, which also reported higher correlations for measures of motor status compared to demographic variables, psychosocial status, and cognitive status (Baker et al., 2003; Curcio et al., 2013; Peel et al., 2005). As previously described for older people without CI (May et al., 1985; Peel et al., 2005), our results documented that physical functioning represents a main determinant of life space mobility also in multimorbid older people with CI.

High correlations were also found among the variables documenting physical active behavior. As expected from previous cohort studies (Portegijs et al., 2015; Tsai et al., 2015), higher life-space mobility was associated with being more physically active (higher PA and OPA) in our study (e.g., higher number of steps, longer outdoor walking distance, being active outdoors). These results might be explained by the facts that (1) for reaching higher levels of the concentric zones within the life-space concept (e.g., outside bedroom, neighborhood) a certain level of (outdoor) PA is necessary and (2) the OPA variables also addressed activity and location of mobility as made by the LSA-CI. Sedentary behavior was not associated with life-space mobility, which was previously shown by (Tsai et al., 2015), indicating that sedentary persons may use more motorized transportation to reach comparable life-space levels or physical active persons organize their daily life within the immediate surrounding. A number of papers have found out similar results for physical activity. Sedentary behavior and low physical activity seem to be independent predictors of worse health outcomes (DiPietro, Jin, Talegawkar, & Matthews, 2017; Klenk et al., 2016; Patel et al., 2010). To the best of our knowledge, our study was the first that successfully demonstrated construct validity of an interview-based life-space assessment instrument based on objectively, sensor-derived PA and OPA behavior.

Table 2. Construct Validity for the Different Scores of the LSA-CI

Variables (n = 117)	LSA-CI-C	LSA-CI-M	LSA-CI-E	LSA-CI-I
Demographic characteristics				
Age, years	**−.32****	−.15	**−.31****	**−.27****
Gender (0 = female, 1 = male)[a]	**.28****	.13	**.32****	**.31****
Cognitive status				
MMSE score	.18	.15	**.21***	.02
Psychological status				
GDS	−.11	−.16	−.11	−.02
FES-I	**−.24****	−.12	−.12	**−.25****
FFABQ	**−.38****	−.15	**−.35****	**−.44****
Motor status				
SPPB total score	**.39****	.05	**.30***	**.52****
Gait speed	**.41****	.13	**.27****	**.56****
TUG	**−.40****	−.08	**−.38****	**−.52****
Physical activity				
Lying (min)	−.13	−.07	**−.25****	−.14
Sitting (min)	−.12	−.06	−.04	−.07
Standing (min)	**.41****	**.28****	**.53****	**.23***
Walking (min)	**.55****	**.27****	**.58****	**.51****
Walking episodes (n)	**.40****	.16	**.42****	**.42****
Steps (n)	**.59****	**.29****	**.60****	**.53****
Outdoor physical activity				
Being active outdoors? (0 = no, 1 = yes)[a]	**.53****	**.30****	**.63****	**.33****
Mean outdoor walking duration (s)	**.54****	**.31****	**.62****	**.37****
Mean walking distance outdoors (m)	**.54****	**.34****	**.63****	**.33****
Outdoor walking episodes (n)	**.54****	**.31****	**.62****	**.32****
Maximum distance from home (m)	**.52****	**.32****	**.63****	**.32****

Note: Presented are Spearman rank correlation coefficients (r_s), except for gender and being active outdoors. FFABQ = Fear of Falling Activity Avoidance Questionnaire; GDS = Geriatric Depression Scale; LSA-CI = Life-Space Assessment for Persons with Cognitive Impairment; LSA-CI = Life-Space Assessment for Persons with Cognitive Impairment; LSA-CI-C = composite life-space; LSA-CI-M = maximum life-space; LSA-CI-E = maximum life-space with equipment; LSA-CI-I = maximum independent life-space; MMSE = Mini-Mental State Examination; SPPB = Short-Physical Performance Battery; TUG = Timed "Up & Go"; FES-I = short Falls-Efficacy-Scale. Correlations coefficients (r): < .20 = low, .20–.50 = moderate, > .50 = high.

[a]Point-biserial correlation coefficients (r_{pb}).

*p < .05. **p < .01.

Table 3. Test–Retest Reliability of the LSA-CI Scores

	Mean (SD)			
Variable (n[a] = 102)	First test session	Second test session	ICC(3,1)	95% CI
LSA-CI-C	29.7 (15.4)	29.0 (15.0)	0.91	0.87–0.94
LSA-CI-M	4.1 (1.1)	3.9 (1.1)	0.80	0.71–0.86
LSA-CI-E	2.8 (1.4)	2.6 (1.3)	0.65	0.53–0.75
LSA-CI-I	1.4 (1.6)	1.4 (1.5)	0.91	0.86–0.94

Note: CI = confidence interval; LSA-CI = Life-Space Assessment for Persons with Cognitive Impairment; LSA-CI-C = composite life-space; LSA-CI-M = maximum life-space; LSA-CI-E = maximum life-space with equipment; LSA-CI-I = maximum independent life-space; ICC = intra-class correlation coefficient (<0.4 = poor, 0.4–0.74 = fair to good, >0.75 = excellent).

[a]Sample size was reduced due to the organization of the study and the timing of the assessment.

Previous UAB-LSA validation studies in community-dwelling elderly reported moderate correlations of life-space mobility with participants' cognitive status (Ji et al., 2015; Peel et al., 2005). In contrast to these studies, these correlations were considerably lower in our cognitively impaired participants. The lower correlations may be related to the relatively small range of cognitive status in our sample, as we included solely persons with mild to moderate CI and excluded those with more severe or without CI. Previous UAB-LSA validation studies included a large number of community-dwelling elderly (n = 100–998; >65 years) without taking into account the cognitive status for an inclusion criterion, which may have resulted in wide-ranging cognitive performance levels among their

Table 4. Sensitivity to Change of the LSA-CI Scores

Variable (n^a = 53)	Mean (*SD*) Baseline	Mean (*SD*) Post-intervention	*p*-Value	SRM
LSA-CI-C	28.4 (14.0)	37.6 (14.5)	<.001	0.80
LSA-CI-M	3.9 (1.1)	4.5 (0.9)	.001	0.60
LSA-CI-E	3.0 (1.2)	3.3 (1.2)	<.001	0.35
LSA-CI-I	1.3 (1.5)	1.8 (1.6)	.001	0.43

Note: LSA-CI = Life-Space Assessment for Persons with Cognitive Impairment; LSA-CI-C = composite life-space; LSA-CI-M = maximum life-space; LSA-CI-E = maximum life-space with equipment; LSA-CI-I = maximum independent life-space; SRM = standardized response mean (<0.2 = trivial, ≥0.2 < 0.5 = small, ≥0.5 <0.8 = moderate, ≥0.8 = large).

[a]Only participants randomly assigned to the intervention group and completing the intervention were included in the analyses.

samples and potentially also in the higher correlations found in these studies.

We found lowest correlations of life-space mobility with depressive symptoms. Previous findings for associations of life-space mobility and depressive symptoms in older people without CI have been ambiguous (Baker et al., 2003; Curcio et al., 2013; Ji et al., 2015; Peel et al., 2005; Polku et al., 2015; Umstattd Meyer, Janke, & Beaujean, 2014). Our results suggest that there seems to be no association of life-space mobility and despressive symptoms in community-dwelling older people with CI.

Across all correlates used for testing construct validity, we found the lowest correlations for the maximal life-space score (LSA-CI-M), which is in line with the results reported in previous UAB-LSA validation studies (Baker et al., 2003; Fristedt et al., 2016). This can be explained by the fact that the LSA-CI-M does not consider a person's own ability to independently reach the maximum life-space (i.e., without personal assistance or equipment). Thus, this score documents a different aspect of life-space mobility which may rather be determined by the availability and the use of assistance from persons or equipment than by personal characteristics such as age, gender, or motor, cognitive and psychological status, or by PA behavior, which may explain the lower correlations (Baker et al., 2003; Fristedt et al., 2016).

Test–Retest Reliability

The LSA-CI demonstrated good to excellent test–retest reliability (ICC = 0.65–0.91) in our sample of multimorbid older people with CI. These reliability results are similar (ICC = 0.72–0.96) (Auger et al., 2009; Baker et al., 2003; Ji et al., 2015; Kammerlind et al., 2014; Portegijs et al., 2014) or even better (ICC = 0.37–0.70) (Curcio et al., 2013) compared to those reported for the UAB-LSA in older persons without CI. The overall good reliability of the LSA-CI might be particularly related to the specific strategy to prevent recall bias as used for the LSA-CI (i.e., shorter assessment period; highly-standardized interview technique), which is highly relevant in older persons with CI.

Sensitivity to Change

For use in clinical settings, it is essential that assessment instruments are able to detect changes over time or effects of intervention studies. To our knowledge, this is the first study that evaluated sensitivity to change of a life-space mobility assessment instrument within an interventional trial including a statistical analysis as suggested for evaluation of responsiveness (Terwee, Dekker, Wiersinga, Prummel, & Bossuyt, 2003).

The significant improvements with a large effect size for the LSA-CI-C score demonstrated the high potential of the LSA-CI to adequately reproduce changes in life-space mobility induced by an intervention on motor performance and physical activity. The LSA-CI subscores seemed to be less sensitive, as documented by the lower effect sizes. This may be related to the smaller scoring range of these scores (range 0–5) compared to the LSA-CI-C (range 0–90) and to the ceiling and floor effects observed for the subscores LSA-CI-M and -I, which generally limit the ability to detect changes over time (Beaton, Bombardier, Katz, & Wright, 2001).

Feasibility

Feasibility of the LSA-CI was excellent in our sample of multimorbid older persons with CI. No participant refused the assessment and life-space mobility could be documented adequately. Although cognitively impaired persons show a variety of limitations regarding the recall of behavior, participants' statements were plausible, except for only one person. These excellent results may be related to the modifications made on the recall period covered by the LSA-CI (only 1 week instead of 4 weeks) and to the use of specific, highly structured face-to-face interview technique, which has been previously demonstrated to be effective in promoting recall and assessing physical activity in older persons with CI (Hauer et al., 2011). Despite the potential challenges of cognitively impaired persons to recall retrospective information, the completion time for the LSA-CI was brief and similar to that reported for the UAB-LSA in older persons without CI (about 5 min) (Peel et al., 2005).

The LSA-CI showed excellent instrument coverage with no floor and ceiling effects for the LSA-CI-C score, indicating that this score covers a wide range of life-space mobility levels without being limited in upper and lower levels even in this vulnerable study sample with relevant motor and CIs. The floor and ceiling effects observed for the subscores LSA-CI-M and LSA-CI-E were consistent with those reported in cognitive intact persons (Auger et al., 2009). The floor effect found for the LSA-CI-I documented the vulnerable status of our study sample as most of the participants were not able to leave the bed without equipment or personal assistance. The ceiling effects for the LSA-CI-M may be explained by its relation to social support (Baker et al., 2003; Fristedt et al., 2016). In this study, community-dwelling persons post-hospitalization were analyzed, discharged to their homes and thus adequately supplied with assistance to remain in their homes, which could explain the large life-space.

Limitations

Results may be marginally influenced by preceding hospitalization of the subjects which is associated with decreasing life-space and varying recovery rates (Brown et al., 2009). The participants were selected according to the inclusion criteria of the intervention study in which the participants were recruited representing former geriatric patients discharged from ward-based rehabilitation to their homes. Although severely impaired persons were excluded in this intervention study, the recruitment of former rehab patients may have influenced results of the presented validation.

Conclusions

The presented study demonstrated good to excellent measurement properties of the LSA-CI representing a modified version of the established UAB-LSA specifically adjusted to older persons with CI. Despite the potential challenges in the assessment of retrospective information in this population, the LSA-CI has shown to be a valid, reliable, sensitive, and feasible questionnaire to assess life-space mobility in multimorbid older people with mild to moderate CI.

Supplementary Material

Supplementary data are available at *The Gerontologist* online.

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Conflict of interest

None reported.

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BRIEF REPORT

Validation of the Life-Space Assessment (LSA-CI) in multi-morbid, older persons without cognitive impairment

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Key summary points

Aim To validate the "Life-Space Assessment in Persons with Cognitive Impairment" (LSA-CI) to assess mobility within the environment including contextual factors in older persons without cognitive impairment.

Findings Excellent feasibility with 100% completion rate and average assessment duration of 4 min in 65 older persons. The LSA-CI composite score stood out with moderate to high construct validity, excellent test–retest reliability and moderate sensitivity to change. Analysis of sub-scores confirmed most of the composite score results.

Message The LSA-CI represents a valid, reliable, responsive, and highly feasible assessment method in multi-morbid, older persons without cognitive impairment, and can be recommended for use in clinical practice and research.

Abstract

Purpose The "Life-Space Assessment in Persons with Cognitive Impairment" (LSA-CI) to assess mobility within the environment including frequency and independence in 1 week has been developed for and successfully validated in older persons with mild to moderate cognitive impairment. However, its psychometric properties in persons without cognitive impairment are unknown. This study aims to validate the LSA-CI in older persons without cognitive impairment.

Methods Comprehensive validation with construct validity, test–retest reliability and sensitivity to change of the LSA-CI including the main composite score and three sub-scores in community-dwelling older persons recruited during geriatric rehabilitation.

Results Excellent feasibility with 100% completion rate and an average assessment duration of 4 min in 65 older, multimorbid persons (mean age: 81.4 ± 5.9 years; 72.3% female; average number of diagnoses: 11.1 ± 4.4). The LSA-CI composite score stood out with moderate to high construct validity (Spearman correlation coefficients |0.26|–|0.60|), excellent test–retest reliability (intraclass correlation coefficient 0.890) and moderate sensitivity to change (adjusted standardized response mean 0.70). Analysis of sub-scores confirmed most of the composite score results.

Conclusions The LSA-CI represents a valid, reliable, responsive, and highly feasible assessment method in multi-morbid, older persons without cognitive impairment, supporting the use of the LSA-CI in clinical practice and research.

Keywords Life-space · Mobility · Aged · Assessment · Validation · LSA-CI

Introduction

Life-space mobility reflects mobility within the environment including contextual factors [1], and contributes to independent living and social participation in community-dwelling older persons [2]. However, mobility becomes increasingly challenging during the ageing process [3]. To prevent mobility impairment, or to adjust and evaluate interventions, appropriate and validated assessment tools with minimized burden are needed [4].

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Recently, the Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI) [5] has been developed and successfully been validated to facilitate assessment of mobility in the home and the surrounding area, divided in concentric zones around the home, the frequency of zone visits, and the independence while being mobile in older persons with cognitive impairment, with a short observation period of 1 week to facilitate recall and a structured participant-centered conversational assessment approach to increase accuracy of results [5, 6].

However, for a broad applicability of the LSA-CI in mixed populations, validity for different levels of cognitive status will be required. It is hypothesized that the assessment approach as developed for the LSA-CI also supports assessment in multi-morbid, older persons without cognitive impairment.

Thus, the aim of this study was to demonstrate the feasibility, construct validity, test–retest reliability and sensitivity to change of the LSA-CI in older persons without cognitive impairment.

Methods

This study reports the psychometric properties of the LSA-CI in a subgroup of participants of a randomized controlled 12-week intervention trial to improve motor performance and physical activity after discharge from geriatric rehabilitation (ISRCTN82378327). Procedures were in accordance with the Declaration of Helsinki and approved by the ethics committee of the Medical Department of the University of Heidelberg (S-252/2015). All participants provided written informed consent. Details of the study were previously described [7]. For this secondary analysis, the validated German version of the Mini-Mental State Examination (MMSE) was used [8, 9], and a score of ≥ 24 was set to define intact cognition [10].

The LSA-CI is conducted via comprehensive interview in a personal conversation by a structured approach, including hints to foster memory and a summarizing feedback. It covers activities within 1 week in six concentric life-space zones (ranging from 0 = person's bedroom, to 1 = a person's home, 2 = area outside the house, 3 = neighborhood, 4 = home town, and 5 = beyond the person's home town), including independence (1 = help of another person, 1.5 = use of equipment, 2 = no assistance), and frequency (1 = 1 – 3*x*/week, 2 = 4 – 6*x*/week, 3 = daily). A composite score can be calculated by multiplying the zone score with scores for frequency and the assistance needed to travel within a zone, and then adding the scores for each zone. Total immobility is indicated by 0 and 90 indicates daily independent out-of-town mobility. Additional sub-scores, ranging from 0 to 5 and taking only the zones into account, document the maximal, equipment-assisted and independent life-space [5].

Feasibility

Completion rate and time to fill out the LSA-CI were documented. Floor and ceiling effects were considered present when more than 15% of the individuals achieve the highest or lowest score [11].

Construct validity

Correlations between all LSA-CI scores were calculated with variables that showed moderate to high associations with life-space mobility in previous studies [1, 4, 5], such as demographic variables (age, gender), motor status (short physical performance battery (SPPB) [12], with scores below 9 indicating frailty [13] and below 6 predicting disability [14]), psychological status related to fear of falling activity avoidance behavior [15], physical activity (walking episodes and steps during 48 h; assessed via PAMSys, BioSensics, Cambridge, MA, USA), and outdoor activity (mean outdoor walking duration and distance, and outdoor walking episodes; assessed via combination of PAMSys and a body-worn GPS-tracking device over 48 h; QStarz BT1000X, QStarz International Co., Ltd., Taipei, Taiwan).

Test–retest reliability

The LSA-CI was assessed twice at post-intervention within 3 days by the same trained interviewer in all available persons.

Sensitivity to change

Sensitivity to change was examined in a subgroup of participants assigned to the intervention group by urn randomization [16] within the 12-week home-based trial to improve physical performance and activity using the pre- and post-intervention assessment [7].

Statistical analysis

Descriptive data were presented as means and standard deviations and percentages for categorical variables. Construct validity was tested via Spearman rank and point-biserial correlation coefficients with low ($r < 0.2$), moderate ($r = 0.2$–0.5), or high correlations ($r > 0.5$) [17]. Test–retest reliability was calculated by intra-class correlation coefficients (ICCs) with 95% confidence intervals (95% CI), interpreted as poor (< 0.4), fair to good (≥ 0.4 ≤ 0.75), and excellent (> 0.75) [18]. Sensitivity to change was assessed using standardized response means (SRMs) [19], adjusted for the size of correlation coefficients between pre- and post-assessment and rated by Cohen's thresholds for effect sizes: trivial < 0.2, small ≥ 0.2 < 0.5, moderate ≥ 0.5 < 0.8, and large ≥ 0.8 [17]. A two-sided p value of < 0.05 indicated statistical significance. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 23 for Windows (IBM Corp., NY).

Results

The sample included 65 older (age: 81.4 ± 5.9 years), multimorbid (average number of diagnoses: 11.1 ± 4.4, with at least two chronic diseases) persons without cognitive impairment (according to a cut-off of 24; MMSE score: 25.1 ± 0.8). Motor status was low (SPPB score: 5.2 ± 2.4), indicating a frail and disabled group [13, 14], and 72.3% of participants were female.

Feasibility

The completion rate was 100% and the mean duration was 4.1 ± 2.1 min (range 1–10 min). The LSA-CI composite score ranged between 4.5 and 70, indicating no ceiling or floor effects. A ceiling effect was documented for the maximal life-space sub-score with 35.4% of participants reaching the maximal level, and a floor effect was documented for the independent life-space with 47.7% of participants reaching the lowest possible score.

Construct validity

Significant moderate to high correlations were found for the LSA-CI composite score and physical capacity, physical activity and outdoor activity variables.

The sub-scores confirmed the results for the composite score, but tended to show lower correlations. For age, fear of falling avoidance behavior, and age only partially significant correlations were shown (Table 1).

Test–retest-reliability

Retests were conducted in a subgroup of 55 participants, with excellent results for the LSA-CI composite score, the sub-scores equipment-assisted, and independent life-space, as well as fair to good results for the maximal life-space (Table 2).

Sensitivity to change

For the 32 persons allocated to the intervention group, sensitivity to change was shown to be moderate for the LSA-CI composite score, and small to moderate for the sub-scores (Table 3).

Table 1 Construct validity for the LSA-CI composite score and sub-scores in persons without cognitive impairment (n = 65)

Correlation coefficients	LSA-CI scores			
Construct variables	Composite score	Maximal score	Equipment-assisted score	Independent score
Age, years	−0.31*	−0.0	−0.24*	−0.35**
Gender (0 = female, 1 = male)[a]	0.26	0.06	0.18	0.41**
Fear of falling activity avoidance behavior questionnaire	−0.38**	−0.19	−0.28*	−0.54**
Physical function (SPPB score)	0.55**	0.28*	0.41**	0.55**
Physical activity				
Walking episodes (n)	0.38**	0.17	0.39**	0.29*
Number of steps (n)	0.60**	0.33**	0.56**	0.41**
Outdoor activity				
Mean walking duration (s)	0.49**	0.32**	0.53**	0.32*
Mean walking distance (m)	0.49**	0.36**	0.53**	0.23
Walking episodes (n)	0.49**	0.31*	0.54**	0.21

Presented are Spearman's rank correlation coefficients, except for [a]Point-biserial correlation coefficients. Correlations coefficients (r): < 0.20 = low, 0.20–0.50 = moderate, > 0.50 = high

LSA-CI Life-Space Assessment for Persons with Cognitive Impairment, *SPPB* short-physical-performance-battery

*p < 0.05; **p < 0.01

Table 2 Test–retest reliability of the LSA-CI scores in persons without cognitive impairment ($n = 55$)

LSA-CI scores	ICC[3, 1]	(95% Confidence interval)
Composite score	0.890	0.819–0.934
Maximal score	0.642	0.456–0.774
Equipment-assisted score	0.777	0.645–0.863
Independent score	0.814	0.700–0.887

Sample size was reduced due to the organization of the study and the timing of the assessment

LSA-CI Life-Space Assessment for Persons with Cognitive Impairment, *ICC* intra-class correlation coefficient (< 0.4 = poor, 0.4–0.74 = fair to good, > 0.75 = excellent)

Table 3 Sensitivity to change of the LSA-CI scores ($n = 32$)

LSA-CI scores	Adjusted SRM
Composite score	0.70
Maximal score	0.48
Equipment-assisted score	0.33
Independent score	0.46

Only participants randomly assigned to the intervention group and completing the intervention were included in the analyses

LSA-CI Life-Space Assessment for Persons with Cognitive Impairment, *SRM* standardized response mean < 0.2 = trivial, ≥ 0.2 < 0.5 = small, ≥ 0.5 < 0.8 = moderate, ≥ 0.8 = large)

Discussion

The results for the LSA-CI validation confirmed an excellent feasibility by a 100% completion rate and short assessment duration in multi-morbid, older persons without cognitive impairment which encourages the application in clinical practice or research settings to measure mobility within the environment, thereby covering diverse health-related domains [2]. Assessment of life-space mobility allows insights into habitual physical activity range in contrast to typical performance oriented tests [1, 4, 20], and has shown to be associated with highly relevant factors participation [21] and quality of life [22]. The full continuum of mobility could be assessed using the LSA-CI main composite score with gathering in-depth information on contextual factors of mobility, while the sub-scores provided additional information, valuable depending on aim and interest. The ceiling effect for the sub-score maximal life-space indicated a high external support by carers/proxies in the study population, which might be explained by the high need for assistance which matches the low mobility status in the study population. The floor effect for the independent sub-score also documented the study participants' low functional status and therefore high need for supportive devices rather than methodological limitations of the method.

Study results confirmed the LSA-CI's construct validity as documented by moderate to high associations of selected constructs which were in line with a theoretical framework for life-space mobility [2] and previous research [1, 4, 5]. The high associations with motor capacity and physical activity variables stood out, documenting a common and highly associated motor domain of the life-space mobility model [2].

Test–retest reliability was conducted in a reduced number of participants due to organizational aspects and the timing of the retest, and was excellent for the composite score and two sub-scores, demonstrating the stability of participants' behavior and the consistency of responses over short time periods as assessed in the present study. The lower results for the sub-score maximal life-space may be due to the high dependency on external support. This support by carers/proxies allows a more extended life-space, however, its random nature may lead to a greater intra-individual day-to-day variability, rather pointing out the real-life situation than a methodological insufficiency of the assessment.

Results further suggest the LSA-CI composite score to be sensitive to changes, which is important for the use in clinical research to reflect changes over time or effects of interventions. Sub-score results were lower, but acceptable, which might be caused by the lower range of the scores, but also the restricted number of subjects included in the present analyses.

Overall, the results obtained were consistent with theoretical considerations on life-space mobility [2], previous literature [1, 4], and findings for the LSA-CI validation in persons with cognitive impairment [5]. The findings underline the applicability of the LSA-CI to assess mobility status or measure changes in the general older population with a wide range of cognitive status levels from moderate to no cognitive impairment. The results gained might provide information on the ability of a person to live independently in the community, or facilitate prognoses. In contrast to other life-space assessment instruments, the relatively short observation period facilitates capturing changes over time or induced by interventions.

The large part of women in the study population might reflect the higher life expectancy, but also the worse health in older women as enrollment took place in a rehabilitation setting [23].

A limitation of the study was the lack of assessment of inter-rater variability.

Conclusions

The LSA-CI represents a valid, reliable, responsive, and highly feasible assessment method and can be recommended for use in clinical practice and research for community-dwelling multi-morbid, older mixed populations with mild to moderate or without cognitive impairment.

Author contributions PU participated in data collection, conducted data analyses and drafted the manuscript. BA, JMB, and KH made critical revision of the article. KH was responsible for the conception of this study and study design. All authors read and approved the final manuscript.

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Data availability The datasets generated and/or analyzed during the current study are not publicly available as the ethical vote did not include open data access, but are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study has been approved by the Ethics Committee of the Medical Departmwnt of Heidelberg University (Ref. S-252/2015).

Informed consent Informed consent was obtained from all individual participants included in the study.

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SHORT COMMUNICATION

Cut-off for the Life-Space Assessment in persons with cognitive impairment

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Abstract

Background A version of the Life-Space Assessment in persons with cognitive impairment (LSA-CI) has recently been developed.

Aims To establish a cut-off value for the newly developed Life-Space Assessment in persons with cognitive impairment (LSA-CI).

Methods In a cross-sectional study including 118 multimorbid, older persons with cognitive impairment, life-space mobility (LSM) was documented by the LSA-CI. The analysis was rationalized by Global Positioning System (GPS)-based measures of spatial distance from home. A receiver-operating characteristic (ROC) curve was created and the cut-off point for the LSA-CI was identified with the Youden's Index.

Results ROC curve analysis indicated a critical value of 26.75 (within a range of 0–90) to differentiate between low and high LSM with a sensitivity of 78.1% and specificity of 84.2%.

Discussion Diagnostic interpretation of the ROC curves revealed that low and high LSM groups can be differentiated with the proposed cut-off.

Conclusions The proposed LSA-CI cut-off score can be recommended to tailor clinical interventions and evaluate change over time.

Keywords Life-Space · Cut-off · Mobility · Cognitive impairment

Background

Life-space reflects the area a person moves through during activities of daily living and is known to be constricted in people with cognitive impairment. The University of Alabama at Birmingham-Life Space Assessment (UAB-LSA) [1] was recently modified and validated for people with cognitive impairment (Life-Space Assessment in persons with cognitive impairment; LSA-CI) [2]. Cut-off values have been proposed for the original UAB-LSA including a theoretically derived cut-off [3], as well as data-driven cut-offs identified by ROC curves to classify older people based on disability in basic [4] and instrumental activities of daily living [5]. However, there is no cut-off value available for people with cognitive impairment and for the LSA-CI.

Life-space has been conceptualized as a measure of mobility. Finding a data-driven cut-off value can assist clinical decision making by confirming the presence or absence of a mobility problem and establishing norms for life-space

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mobility (LSM). Identification of people with low LSM can, in turn, assist with tailoring clinical interventions and evaluating change over time. Receiver operating characteristic (ROC) curves represent an appropriate tool to calculate cut-offs in the presence of a gold standard criterion. However, for LSM a gold standard is not available. For life-space analyses, objective Global Positioning System (GPS)—based measures have been used to assess the geographical area a person covers in daily life [6].

The study aim was to propose a data-driven cut-off value for the LSA-CI to differentiate between low and high LSM in older people with cognitive impairment (CI) using GPS measures. With respect to the methodological perspective, such a measure represents a valuable external criterion in the absence of a gold standard [7] as dichotomous criterion to objectively distinguish between persons that were house-bound and persons that were active outdoors with no report bias in this vulnerable patient sample with CI. Outdoor activity represents a hallmark of adequate mobility status in people with CI, as it is highly associated with reduced function and health status [8] and risk of losing autonomy [9].

In terms of the clinical or rehabilitative perspective being active outdoors provides a multitude of health benefits such as maintenance of physical function in frail elderly people [10], and facilitates social involvement [11] and quality of life [12].

Methods

Study design

The present study used cross-sectional data from a double-blinded, randomized, placebo-controlled trial (RCT) to improve motor performance and physical activity in older people with mild–moderate CI recently discharged from geriatric rehabilitation. Older participants (age > 65 years) with mild–moderate CI as indicated by a Mini-Mental State Examination score of 17–26 [13] were consecutively recruited from rehabilitation wards of a German geriatric hospital. Further inclusion criteria has been previously been described [2]. The RCT was performed according to the Helsinki declaration and was approved by the ethics committee of the Medical Department of the Heidelberg University.

Descriptive measurements

Age, gender and number of diagnoses were documented from patient charts. Physical performance was assessed with the Short Physical Performance Battery (SPPB) [14]. Physical activity levels were estimated by measuring the number of steps using an activity monitor for 48 h (PAMSys, BioSensics, Cambridge, MA, USA). History of falls in the past 12 months was assessed retrospectively and fall-related avoidance behavior by the Fear of Falling Avoidance Behavior Questionnaire (FFABQ) [15].

Life-Space Assessment in persons with cognitive impairment

The LSA-CI [2] assessed life-space mobility in six hierarchically structured, concentric life-space zones ranging from activity locations including a person's bedroom (level 0), to a person's home (level 1), area outside the house (level 2), the neighborhood (level 3), the hometown (level 4), and beyond the person's hometown (level 5) within the previous week. A composite score can be calculated by multiplying the zone score with scores for frequency of mobility for each zone and the assistance needed to travel within a zone and adding the scores for each zone, with 0 indicating total immobility and 90 indicating daily independent out-of-town mobility. Additional scores of subscales document the maximal life-space achieved independently or with the assistance of equipment or personal support.

GPS-based Life-Space Assessment

Spatial location of mobility was assessed by an established body-worn GPS-tracking device over 48 h (QStarz BT1000X, Qstarz International Co., Ltd., Taipei, Taiwan). Levels of indoor activity were used as the external criterion for low LSM while outdoor activity was used for high LSM.

Data analysis

A ROC analysis was constructed and the area under the curve (AUC) was calculated to identify the optimal cut-off that discriminates between low and high LSM [16]. Results were interpreted according to their AUC and classified as non-informative (AUC < 0.5), less accurate ($0.5 <$ AUC ≤ 0.7), moderately accurate ($0.7 <$ AUC ≤ 0.9), highly accurate ($0.9 <$ AUC < 1.0), and perfect discriminatory tests (AUC $= 1.0$); [17]. The Youden Index was used to determine the cut-off point with the highest combination of sensitivity and specificity [18]. The stability of the cut-off was studied with 100,000 bootstrap replications. Plausibility analyses of the cut-off were performed using a physical performance measure (habitual gait speed below vs. above 0.6 m/s); and a LSA-CI subscore (dichotomous measure of restricted life-space according to the definition by the original authors [1], adjusted to the vulnerable population by allowing use of equipment) as external criterion. Subsequently, the discriminatory performance of the derived cut-off was tested using unpaired *t* tests, Mann–Whitney *U* tests (continuous variables), and Chi-square tests (dichotomous variables) according to the distribution of the data to compare the groups dichotomized based on the proposed cut-off with respect to descriptive variables that have been shown to be associated with LSM (sociodemographic variables, cognition, physical and emotional health) [1–3]. A p value < 0.05 was considered statistically significant. All statistical analyses were performed using the Software IBM SPSS Statistics Version 23 for Windows (IBM Corp., NY, USA).

Results

The sample included 118 older people (82.3 ± 6.0 years), with multiple comorbidities (11.4 ± 4.4 medical diagnoses) and cognitive impairment (MMSE: 23.3 ± 2.4 points). Poor mobility was reflected by low scores on the SPPB (5.2 ± 2.3 points) and a limited LSM (LSA-CI: 23.9 ± 13.2; Table 1).

The cut-off calculation was based on data of 108 participants. Ten participants were excluded due to invalid GPS (n = 5, unwilling to wear the device; n = 4 erroneous data records) and LSA-CI (n = 1, unrealistic statements) data; sensitivity analyses showed no significant differences between included and excluded participants for descriptive variables except age. According to the GPS measurements, 76 people stayed only indoors and 32 people were active outdoors. The optimal cut-off point for the LSA-CI was 26.75, with a sensitivity of 78.1% and specificity of 84.2%, and a moderately accurate diagnostic validity (AUC: 0.81; Fig. 1). The bootstrap analysis confirmed our proposed cut-off value of 26.75 (Bootstrap-median: 26.75; 59.15% of all values revealed the proposed cut-off; mean ± SD of the bootstrap cut-off: 27.30 ± 1.23). Plausibility analyses revealed LSA-CI cut-offs of 25.75 (AUC = 0.704) using habitual gait speed and 28.25 (AUC = 0.940) using the LSA-CI subscore. The discriminatory performance of the cut-off was excellent,

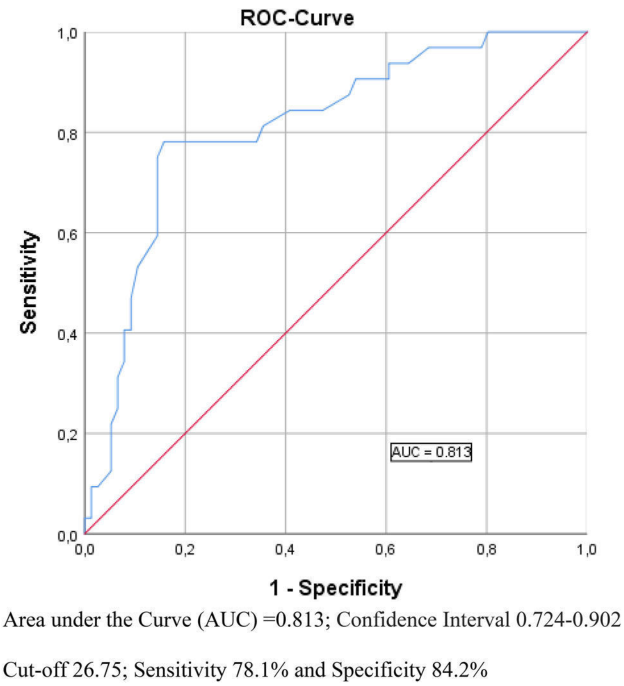

Fig. 1 ROC curve for the LSA-CI

with significant between-group differences for low and high LSM based on age, gender, cognitive function, physical performance (SPPB, gait speed), physical activity, and fall-related avoidance behavior (FFABQ; Table 2).

Table 1 Sample characteristics

Characteristics	n = 118
Age (years), mean (SD)	82.3 (6.0)
Gender (female/male), n (%)	90 (76)/28 (24)
Number of diagnoses, mean (SD)	11.4 (4.4)
MMSE (0–30), mean (SD)	23.3 (2.4)
SPPB (0–12), mean (SD)	5.2 (2.3)
Gait speed (m/s), mean (SD)	0.45 (0.20)
PA (number of steps per day), median (IQR)	2467 (1121–4054)
Faller (no falls/at least one fall), n (%)	39 (33)/ 79 (67)
FFABQ (0–56), median (IQR)	17 (8–30)
LSA-CI (0–90), mean (SD)	23.9 (13.2)

FFABQ Fear of Falling Avoidance Behavior Questionnaire, *IQR* Interquartile Range, *MMSE* Mini-Mental Score Examination, *PA* Physical Activity, *SPPB* Short Physical Performance Battery

Discussion

The present study provides a data-driven cut-off point and interpretation for LSM in older persons with CI.

The cut-off differentiates between people with low (confined to the home; LSA-CI score < 26.75) and high (active outdoors; LSA-CI score: ≥ 26.75) LSM. The cut-off was tested for plausibility by additional ROC analyses using physical performance and restricted life-space independently or with equipment as external criteria. The analyses resulted in comparable cut-off values (range 25.75–28.25), supporting the plausibility of the proposed cut-off value.

The cut-off discriminates significantly between groups in terms of relevant characteristics that have been shown to be associated with LSM, suggesting its validity for the study group. The proposed cut-off value was substantially lower compared to cut-offs found for the UAB-LSA in healthy older adults (between 52.3 and 60) [3–5], which confirms the need for a separate cut-off for older, multimorbid people with motor and cognitive impairment representing a high-risk group for life-space restriction [1, 4].

The strength of our study relates to the systematic and comprehensive methodological approach to set a cut-off

Table 2 Differences between groups of different life-space mobility levels

Life-space mobility levels	Low LSM group ($n=76$, 65%)	High LSM group ($n=41$, 35%)	Difference between groups (p)
Age, mean (SD)	84.0 ± 5.2	79.1 ± 6.1	< 0.001
Gender (female/male), *n*	65/11	25/16	0.003
MMSE, mean (SD)	22.9 ± 2.5	24.0 ± 2.2	0.018
SPPB, mean (SD)	4.6 ± 2.1	6.3 ± 2.2	< 0.001
Gait speed (m/s), mean (SD)	0.39 ± 0.18	0.56 ± 0.19	< 0.001
PA (number of steps), median (IQR)	1515 (635–2778)	4074 (2874–5550)	< 0.001
FFABQ, median (IQR)	20 (13–31)	10 (4–21)	0.002

FFABQ Fear of Falling Avoidance Behavior Questionnaire, *IQR* Interquartile Range, *MMSE* Mini-Mental Score Examination, *PA* Physical Activity, *SPPB* Short Physical Performance Battery

score including extensive sensitivity and plausibility testing. We do acknowledge that the lack of a gold standard for life-space mobility is a limitation of the study, however, we feel confident that the use of GPS as the next best available practicable method was appropriate as a reference standard to determine LSM.

Conclusion

Our cut-off value, validated for use in people with CI, will allow clinicians and researchers to monitor and evaluate status, change or response to treatment and enable categorization and comparison between individuals and tracking of improvements over time. The proposed cut-off further allows the much needed identification of persons with restricted LSM and documentation of the natural course of LSM in this vulnerable target population.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki declaration and its later amendments.

Informed consent Written informed consent was obtained from all individual participants included in the study.

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BMC Geriatrics

RESEARCH ARTICLE Open Access

Validation of the interview-based life-space assessment in institutionalized settings (LSA-IS) for older persons with and without cognitive impairment

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Abstract

Background: Self-reported life-space assessment methods so far focus on community-dwelling persons, with a lack of validated assessment methods for institutionalized settings. This study evaluated construct validity, test-retest reliability, sensitivity to change, and feasibility of a new Life-Space Assessment for Institutionalized Settings (LSA-IS) in geriatric patients.

Methods: Psychometric properties of the LSA-IS in 119 hospitalized geriatric patients (83.0 ± 6.2 years) with and without cognitive impairment (CI) [Mini-Mental State Examination: 22.4 ± 4.9 scores] were evaluated within a comprehensive validation design. For the total group and subgroups according to cognitive status, construct validity was assessed by calculating Spearman's rank correlation coefficients (rho) with established construct variables, test–retest reliability by intra-class correlation coefficients (ICCs), sensitivity to change by standardized response means (SRMs) calculated for effects of early ward-based rehabilitation during hospital stay.

Results: The LSA-IS (total score) demonstrated good test–retest reliability (ICC = .704), and large sensitivity to change (SRM = .806), while construct validity was small to high indicated by significant correlations of the LSA-IS to construct variables (rho = .208–716), depending on relative construct association. On average results of LSA-IS sub-scores confirmed results of the total score. Subgroups according to cognitive status did not differ for most analyzed variables. A completion rate of 100% and a completion time of 3.2 ± 1.2 min documented excellent feasibility.

Conclusions: The interview-based LSA-IS has proven to be valid, reliable, sensitive, and feasible in hospitalized, multi-morbid, geriatric patients with and without CI documenting good psychometric properties for institutionalized settings.

Trial registration: DRKS00016028

Keywords: Assessment, Clinical trial methods, Cognitive impairment, Life-space mobility, Measurement, Exercise, Physical activity, Validation

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Background

Mobility in institutionalized settings is severely restricted with the consequence of a highly sedentary behavior of older patients during hospital stay or nursing home residents spending most of their time lying or sitting [1, 2]. This immobility is associated with relevant, negative consequences such as drastic functional decline and muscle loss [3, 4], and higher risk for nursing home placement and mortality following hospitalization [5]. While mobility in community-dwelling older persons is influenced by a large number of individual as well as societal factors [6, 7], in institutionalized persons some additional factors become specifically relevant [8]. Such factors with influence on mobility status during hospitalization cover patient-related (illness severity, comorbid conditions), treatment-related (bed-rest required, hospital devices such as catheters, restraints), attitudinal (attitudes towards mobility, expectations of hospital stay), and institutional aspects (nursing to patient ratio, availability of equipment) [9]. Institutions such as hospitals or nursing homes also have an overwhelming organizational influence by their treatment routines or social activities (e.g. timing/ location of meals) [10].

Among the vulnerable, multi-morbid persons in institutionalized settings, persons with CI stand out, as they show a decreased health status compared to their non-impaired peers [11, 12], relevant for their health prognosis but also for health assessments. To address the specific limitations and resources of this vulnerable group, it is mandatory to specifically develop and validate assessment methods in this population [13–15].

To better understand health trajectories while being institutionalized, a large number of established assessments and diagnostic procedures have been established also including functional status or motor performance. Surprisingly the concept of life-space mobility (LSM) has not made it yet into these diagnostic routines despite its' unique ability to cover mobility-related quality of life and its' potential role as a "biomarker" of health status, documenting the individual habitual physical activity range in contrast to highly standardized testing routines. For assessment purposes the LSM concept offers chances as well as challenges as it is determined by various domains related to the individual status as well as social interaction to others [7, 16].

A number of life-space assessment methods have been developed and validated for use in community dwelling persons such as the "Life-Space Diary" [17], the "Life-Space Questionnaire" [18], the "University of Alabama at Birmingham – Life-Space Assessment" (UAB-LSA) [16], the "Life-Space Assessment in Persons with cognitive impairment" (LSA-CI) [14], and the "Life-Space mobility at home assessment" [19]. However, different validation approaches have been used for these life-space measures. Construct validity was analyzed in all validation studies, but the comprehensiveness of constructs used differed substantially. Only one study selected variables based on a comprehensive theoretical, multi-domain framework on mobility [14], while literature-based constructs including variables of two or three domains as identified in previous comparable research [16, 18] or measures with strict focus on one domain (physical function) [17, 19] have been used in other studies. Reliability was tested in terms of intra-rater reliability [19], and test-retest reliability [14, 16, 18]. Feasibility was analyzed in only few studies, with one study presenting a comprehensive documentation of duration of assessment, completeness of reports, and floor/ceiling effects [14] and other studies reporting on potential ceiling effects [16] or completeness [17]. Sensitivity to change has been the least analyzed psychometric property performed in two studies [14, 16].

The only LSM assessment (The "Nursing Home Life-Space Diameter", NHLSD) which could be identified for an institutionalized setting [20], performed a validation with reliability and restricted construct validity with functional-social variables, but not an evaluation of comprehensive construct validity, feasibility, or sensitivity to change. Level of personal support represents an option for data assessment but was not included in presented data of the validation. The NHSLD was designed to be nurse-administered which may differ from a patient perspective with additional burden to nurses. As with other established mobility assessment methods, the evaluation tool was not specifically tailored and validated for use in multi-morbid, vulnerable populations such as persons with cognitive impairment (CI), with relevant potential limitations for self-report, although such vulnerable persons represent the majority in a large number of institutionalized settings. The fixed time frame of 2 weeks of the NHLSD is not feasible at least in hospital settings with varying duration of hospital stay, most often less than 2 weeks.

The objective of the present study therefore was to comprehensively validate a new, detailed, interview-based LSM assessment, specifically developed for institutionalized persons with and without CI including construct validity, test-retest reliability, sensitivity to change, and feasibility in hospitalized geriatric patients including subsamples according to cognitive status.

Methods

Study design

The present study follows a comprehensive validation design (see Additional file 3) using secondary data from a prospective, longitudinal cohort study examining physical activity behaviour and mobility of geriatric patients with and without CI during hospitalization (trial registration number: DRKS00016028). The study was performed according to the Helsinki Declaration and was approved by the ethics committee of the Medical Department of the University of Heidelberg (S-709/2018).

Study sample

Participants were consecutively recruited from acute medical wards of a geriatric hospital. Individuals receiving complex early geriatric rehabilitation treatment according to the German hospital payment system (German Diagnosis-Related Groups) were included by the following inclusion criteria: age ≥ 65 years, Mini-Mental State Examination (MMSE [21]) score ≥ 10, ability to walk at least 4 m with or without walking aid, no terminal illness, no severe functional, sensorial or behavioral restrictions, which did not allow study participation or assessment, no delirium (Confusion Assessment Method [22]), no uncontrolled infection, adequate language level, and written informed consent (obtained from patients or their legal representatives) within 72 h after admission.

Descriptive measures

Descriptive data were collected at baseline from patient charts after hospital admission to describe the sample and to analyze construct validity. Trained interviewers assessed measures for health status (weight and height to calculate Body Mass Index (BMI), number of medication, frailty status (Clinical Frailty Scale, CFS [23], falls in the previous year [24], pain (Present Pain Intensity scale, 6 points, PPI [25]), cognitive status (MMSE), and psychological status (health-related quality of life (EuroQol-questionnaire, EQ-5D-3L [26]), apathetic symptoms (Apathy Evaluation Scale- Clinical version, AES-C [27]), and concerns about falling (Short Falls Efficacy Scale-International, 7-item version, Short-FES-I [28, 29]). Motor–functional status was assessed by the Activities of Daily Living (ADL, Barthel-Index [30]), the Short Physical Performance Battery (SPPB [31]), and gait speed from the SPPB. Physical activity (reported as number of steps) was assessed for a 48 h period using the uSense sensor, which has been validated in multi-morbid, geriatric patients [32].

Clinical intervention

The "complex early geriatric rehabilitation" as analyzed in the present study represents an established rehabilitation routine/pathway to prevent loss of function during in-hospital, acute medical treatment. It was developed as a multidisciplinary, geriatric rehabilitation program including at least two of the following four domains: physiotherapy, occupational therapy, speech and language therapy, and psychology (Operation and Procedure Code version 2018, German Institute of Medical Documentation and Information), (https://www.dimdi.de/static/de/klassifikationen/ops/kode-suche/opshtml2020/).

Life-space assessment

The Life-Space Assessment in Institutionalized Settings (LSA-IS) is a newly developed, interview-based instrument tailored for the specific target setting to assess LSM by the spatial extent of movement, the frequency of movement, and the level of assistance for movement within institutions during the previous day. The short time frame allows to evaluate trajectories of LSM in institutionalized settings, considering the special needs of persons with acute or chronic medical events and/or CI as well as institution−/organization-based restrictions in LSM. The LSA-IS' basic structure is defined by life-space zones within a typical institutionalized setting ranging from a person's own room to outside the facility (e.g. garden of nursing home and beyond the outdoor area of the facility (e.g., public area, neighborhood) to document also higher functioning mobility levels (outdoor), which are still preserved in a minority of institutionalized persons.

The LSA-IS also documents the independence of mobility (i.e., without any support, with equipment or personal support) by a detailed qualitative and quantitative approach. Such a semi-qualitative approach seems mandatory given the low functional status, the extraordinary high risk of falling, and the high implementation level of equipment-, or staff- supported mobility in institutionalized settings such as geriatric hospitals or nursing homes.

The interview procedure of the LSA-IS includes an interview-based and strictly standardized face-to-face questionnaire with a clear focus on the subjective self-report of participants rather than proxy reports. Assessment strategies of the LSA-IS were thus optimized to gain correct and complete information including multi-morbid persons with and without CI. The interview is based on an informal conversational approach to prevent fear of failure in comprehension and recall by precise and structured questions and response options, reduction of recall period, clear structure of the observation period by referring to daily routines and landmark events such as meals, doctoral visits, or therapies, or special events such as external visits, and a summary of the given information for immediate review of reports. This approach is based on previous research to validly assess LSM [14] and physical activity for a short recall period (24 h) in older persons with CI [13, 33, 34].

The LSA-IS is structured by three criteria: A) spatial extent of movement, classified into five hierarchically structured, concentric zones (level 1 = own room, level 2 = within the ward, level 3 = within the facility, level 4 = immediate outdoor area of the facility, level 5 = beyond the area of the facility); B) frequency of movement (1 = 1 × per day, 2 = 2–3 × per day, 3 = 4–5 × per day, 4 = > 5 × per day); and C): independence of movement (1 =

with personal support, 1.5 = with equipment, 2 = without any support).

A score for each life-space zone is calculated by multiplying values for the zone, frequency and independence. Each life-space zone is added to a LSA-IS-T total score, with the lowest score of 0 indicating total immobility (bed-bound) and the maximum score of 120 indicating independent mobility beyond the area of the facility at least six times at the relevant day. In addition, three LSA sub-scores can be determined for the maximal life-space zone achieved (1) with equipment or personal assistance if needed (LSA-IS-M, range 0–5), (2) with equipment, if needed, but without personal assistance (LSA-IS-E, range 0–5), and (3) independently without any assistance (LSA-IS-I, range 0–5) [14, 16]. For details of the test proceeding see manual attached in supplements (Additional files 1 and 2).

Assessment of measurement properties

The analysis of construct validity, test-retest reliability, and sensitivity to change was performed for the total group and subgroups according to cognitive status as a most relevant criteria for rehab prognosis also considering the high incidence of CI in institutionalized settings. Study participants with MMSE scores < 24 (range: 10–23) were considered cognitively impaired and participants with scores ≥24 (range: 24–30) cognitively intact [21].

Construct validity

Assessment of construct validity was conducted after hospital admission. Items for construct validity were selected according to previous, directly comparable validation studies for life-space assessment for the UAB-LSA [16], the LSA-CI [14] and the NHLSD [20], guided by and categorized according to the comprehensive and well-established mobility model by Webber [6]. Correlations between the LSA-IS scores at baseline with demographic variables (age, gender), measures for health status (BMI, number of medication, frailty status (CFS, falls, pain), cognitive status (MMSE), psychological status (EQ-5D, AES-C, FES-I,), motor - functional status (ADL Barthel Index, SPPB, gait speed), and physical activity (assessed by uSense and reported as number of steps, duration of lying, activity, and gait) were calculated.

Test-retest-reliability

The LSA-IS assessment was conducted on two consecutive days with general assessments being performed by the same trained interviewer to exclude inter-rater variability.

Sensitivity to change

Sensitivity to change was examined in all participants tested at admission and at the end of the hospital stay immediately before discharge for effects of the complex early geriatric rehabilitation on LSM.

Feasibility

Completion rate and completion time for the questionnaire were documented at baseline to determine feasibility. In addition, LSA-IS scores at baseline were checked for floor and ceiling effects, which were considered present when more than 15% of the individuals achieve the lowest or highest score [35].

Statistical analysis

Descriptive data were presented as frequencies and percentages for categorical variables, and means and standard deviations or medians and ranges for continuous variables as appropriate. Comparison with respect to descriptive characteristics between groups according to cognitive status was conducted using *t*-tests and Mann-Whitney-*U* tests as appropriate.

Spearman's rank-order and point-biserial correlation coefficients between LSA-IS scores and a comprehensive set of associated factors selected in accordance with a theoretical framework and existing research evidence were calculated to assess construct validity. Correlation coefficients (r) were interpreted as small ($r = 0.1–0.3$), moderate ($r = 0.3–0.5$), or high ($r > 0.5$) [36].

Independent from formal cut-off criteria, we hypothesized a priori low to moderate associations of the LSA-IS scores with health-related, psychological and cognitive variables and moderate to high correlations with motor-functional variables and variables documenting physical activity behavior.

Intra-class correlation coefficients (ICC) with 95% confidence intervals for the LSA-IS total score and each subscore were used to analyze test–retest reliability. ICCs were interpreted as poor (< 0.4), fair to good (≥ 0.4 ≤ 0.75), and excellent (> 0.75) [37]. Sensitivity to change was assessed using paired *t*-tests to test for significant within-group differences between assessments at admission and immediately before discharge and standardized response means (SRMs) to quantify the magnitude of changes. SRMs were calculated as the difference in mean change scores divided by the *SD* of the change score [38]. SRMs were adjusted for the size of correlation coefficients between the baseline and post-intervention scores [39] to use Cohen's thresholds for effect sizes (trivial < 0.2, small ≥0.2 < 0.5, moderate ≥0.5 < 0.8, and large ≥0.8) [36]. The level of significance was set to $p < 0.05$. All statistical analyses were performed using the Software IBM SPSS Statistics Version 23 for Windows (IBM Corp., NY, USA).

Results

Participants' characteristics

The study sample included 119 multi-morbid (10.2 ± 4.3 medications at admission), older (mean age 83.0 ± 6.2

years) persons with CI (MMSE score: 23 (10–30) points) and motor impairment (SPPB score: 4 (0–11) points). Apart from the classification criteria (MMSE score < 24 vs. ≥24), subsamples with and without CI differed with respect to frailty-, functional-, motor-, and psychological status (CFS, ADL, SPPB AES-C) indicating a reduced status in persons with CI but more apathetic symptoms in the group without CI (Table 1).

Description of life-space mobility

The mean total score for the LSA-IS of 12.7 ± 9.0 (range: 0–48 points) indicated a largely restricted LSM for the total group. Restriction of life-space was also confirmed for all sub-scores such as the LSA-IS-M for maximal life-space with technical and personal support: (2.2 ± 1.0), the LSA-IS-E as achieved with supportive devices (1.7 ± 1.2), and the independent life-space (LSA-IS-I), achieved without human or technical assistance (0.4 ± 1.0). Results differed significantly between persons with and without CI for the total score and the LSA-IS-E, but not for the LSA-IS-M and the LSA-IS-I (Table 2).

Construct validity

In the total sample, the LSA-IS-T (total score) showed significant moderate associations to most variables documenting demographic and health status (age, BMI, number of medication, frailty status), cognitive status (MMSE), or psychosocial status (FES-I, EQ-5D, AES-C). Other variables such as gender, history of falls, and pain were not associated with LSA-IS (Table 3). Motor-functional status and activity behavior stood out with significant associations in all parameters especially so for variables related to activity behavior indicated by higher associations to LSM.

On average a trend for lower associations is visible for the sub-score LSA-IS-I (independent score) as compared to the total score and other sub-scores throughout all samples.

When classified into persons with intact and impaired cognition, results of the total group were confirmed for most associations, while descriptive variables and

Table 1 Participant characteristics for the total study sample (*n* = 119), and subgroups according to cognitive status

Characteristics	(Mean (SD)/ n (%) / Median (range) Total group *n* = 119)	Non-CI (MMSE ≥24) *n* = 57	CI (MMSE< 24) *n* = 62	*P*-value*
Demographic factors				
Age, years	82.95 (6.20)	82.49 (6.54)	83.37 (5.89)	.488
Gender, female, n (%)	73 (63.5%)	38 (66.7%)	38 (61.3%)	.546
Health status				
BMI[a]	26.24 (13–48)	26.33 (16.98–48.04)	25.87 (13.77–37.42)	.480
Medications, number	10.22 (4.28)	10.07 (4.29)	10.40 (4.26)	.773
CFS, score[c]	6 (3–8)	6 (3–7)	6 (3–8)	**.012**
PPI, score	0 (0–5)	0 (0–5)	0 (0–4)	.501
No. of falls in the previous year[b]	1 (0–4)	1 (0–2)	1 (0–4)	.463
Cognitive status				
MMSE, score	23 (10–30)	27 (24–30)	19 (10–23)	**<.001**
Psychosocial status				
Short FES-I, score[b]	11(6–26)	11.5 (6–25)	10.5 (7–26)	.514
EQ-5D score	0.70 (0.96–1.00)	0.79 (0.06–1.00)	0.64 (0.06–1.00)	.237
AES-C, score[b]	25 (5–35)	26 (6–35)	22 (5–35)	**.017**
Motor-functional status				
ADL Barthel score[c]	75 (5–100)	80 (25–100)	65 (5–100)	**.009**
SPPB, score[a]	4 (0–11)	5 (0–11)	3 (0–10)	**.026**
Gait velocity (s)[d]	7.63 (4.75)	7.13 (4.74)	8.15 (4.76)	.300
Physical activity				
PA (mean number of steps per day)	704 (0–7095)	813 (1.5–6772)	690 (0–7095)	.293

Presented are patient characteristics for the study sample description for the total group and according to cognitive status. Total sample included 119 participants, however, single measures are lacking for some individuals, including [a] *n* = 110 participants, [b] *n* = 112 participants, [c] *n* = 113 participants, [d] *n* = 94 participants. **p*-values are given for Mann-Whitney *U* tests and *t*-tests as appropriate

Abbreviations: *AES-C* Apathy Evaluation Scale – Clinical version, *BMI* Body Mass Index, *CFS* Clinical Frailty Scale, *MMSE* Mini-Mental State Examination, *PPI* Present Pain Intensity Scale, *SPPB* Short-Physical-Performance-Battery, *Short FES-I* Short Falls Efficacy Scale-International, 7-item version, *VRS* Verbal rating scale, *EQ-5D* European health-related quality of life questionnaire (EuroQol-questionnaire, EQ-5D-3L), *n* Numbers, *CI* Cognitive impairment, *SD* Standard deviation, *m/s* Meters per second, *PA* Physical activity

Table 2 Baseline LSA status for the LSA-IS composite score and sub-scores

LSA-Variables	Total group $n = 117^{a}$ Mean (SD)	Non-CI $n = 57$ Mean (SD)	CI $n = 60$ Mean (SD)	*P*-value **
LSA-IS-T total score	12.72 (9.00)	14.94 (10.34)	10.62 (6.96)	**.035**
LSA-IS-M maximal score	2.17 (.096)	2.35 (1.04)	2.00 (0.84)	.084
LSA-IS-E equipment-assisted score	1.74 (1.16)	2.05 (1.16)	1.45 (1.10)	**.008**
LSA-IS-I independent score	0.44 (1.99)	0.51 (1.14)	0.37 (0.86)	.546

Presented are results for the total group and sub-groups according to cognitive status

Abbreviations: *LSA-IS* Life-space assessment for institutionalized settings, *−T* Total score, *−M* Maximal life-space, *E* Equipment assisted life-space, *I* Independent life-space

***p*-values are given for Mann Whitney U tests for differences between persons without cognitive impairment (Non-CI; $n = 57$), and persons with cognitive impairment (CI; $n = 60$) at baseline. [a]$n = 2$ were excluded, as these persons were transferred for diagnostic reasons during the relevant time period

variables related to health status were less associated. Some variables differed as age, cognitive status, and duration of lying were only significantly associated to LSM in the group of cognitively intact persons, while the number of medications was only significantly correlated in the group of persons with CI (Table 3).

Test–retest reliability

ICCs between the two LSA-IS assessments indicated fair to excellent test–retest reliability for all LSA-IS scores, with ICCs ranging from .412–.799 except for 1 result (LSA-IS-M, .285, subgroup with CI). Results for test-retest reliability were comparable in both groups according to cognitive status. Within LSA-IS scores, the LSA-IS-M (maximal) score presents with an on average lower reliability as compared to all other scores while the LSA-IS-I (independent) stood out with excellent results in all samples (Table 4).

Sensitivity to change

All LSA-IS scores differed over the treatment period ($p \leq .001$), indicating a global sensitivity to change of the assessment method. Improvements of LSM as documented by SRMs during the hospital stay were found across all LSA-IS scores for the total group, with the highest SRM for the LSA-IS-T (.806), while LSA-IS-I sub-scores reached lower SRMs (.326–.667). The two groups according to cognitive status achieved comparable results with the highest value for the total score (cognitively intact persons: .812, persons with CI: .833), and values for sub-scores ranging from .383–.812 for persons with intact cognition and .269–.833 for persons with CI. Across all samples, the LSA-IS-I (independent score) showed the least responsiveness during hospital stay, while results of the total score achieved SRMs >.800 in all samples indicating large responsiveness (Table 5).

Feasibility

No participant objected to the assessment procedure and data documentation was comprehensive, with no missing responses for any LSA-IS item (100% completion rate). Mean completion time to assess the LSA-IS was brief with 3.2 ± 1.2 min (range 1–11) and not significantly different between subgroups by cognitive status (CI: 3.0 ± 0.9 vs. non-CI: 3.4 ± 1.5). For the total score no relevant ceiling (no participant) or floor effects ($n = 3$ (2.6%) occurred [35]. None of the sub-scores presented ceiling effects, however, the sub-scores LSA-IS-E and the LSA-IS-I showed relevant floor effects (LSA-IS-E: 19.3%; LSA-IS-I: 79.0%) in this population of vulnerable patients during hospital stay.

Discussion

The LSA-IS (total score) demonstrated good test–retest reliability, high sensitivity to change, while construct validity was appropriate depending on relative construct association as hypothesized. Results of LSA-IS sub-scores confirmed most results of the total score, while results of persons with and without CI did not differ for most analyzed variables. A very high completion rate and a brief completion time indicated excellent feasibility for use in research or clinical routines.

Construct validity

For construct validation we used construct variables out of different domains to allow a validation within a comprehensive Life Space Mobility model. We assumed different levels of associations for different domains based on their content association to LSM based on results of previous comparable studies [14, 16, 32] and in line with the comprehensive and well-established mobility model by Webber [6]. Present results of the construct validation fitted well with these a priori assumptions, indicating good construct validity of the assessment. The LSA-IS total score showed significant, moderate associations to most variables documenting demographic-, health-, cognitive-, and psychosocial status representing more “distant” domains to the LSA representing a behavioral activity measure As hypothesized, motor-functional status and activity behavior stood out with significant,

Table 3 Construct validity for the LSA-IS total score and sub-scores

	Total group				Non-CI				CI			
	LSA-IS-T total score	Subscores			LSA-IS-T total score	Subscores			LSA-IS-T total score	subscores		
		LSA-IS-M maximal	LSA-IS-E equipment-assisted	LSA-IS-I independent		LSA-IS-M maximal	LSA-IS-E equipment-assisted	LSA-IS-I independent		LSA-IS-M maximal	LSA-IS-E equipment-assisted	LSA-IS-I independent
Demographic factors												
Age	**–.295****	**–.291****	**–.194***	**–.195***	**–.415****	**–.434****	**–.320***	**–.282***	–.164	–.137	–.055	–.103
Gender[a]	.000	–.009	.105	–.027	–.009	.002	.045	–.022	.032	.016	.209	–.026
Health status												
BMI	**–.210***	–.189	–.136	–.139	–.233	–.115	–.076	–.046	–.217	–.248	–.191	–.241
No. of medication	**–.302****	**–.302****	**–.292****	**–.239****	–.213	–.256	–.164	–.127	**–.382****	**–.344****	**–.421****	**–.350****
CFS	**–.387****	**–.281****	**–.391****	–.139	**–.350***	**–.282***	**–.394****	–0.184	**–.369****	–.249	**–.314***	–.042
No of falls in the previous year	–.144	–.111	–.120	–.120	–.023	–.116	.036	.015	–.244	–.087	–.259	–.263
PPI	–.055	–.056	–.034	.077	.023	.002	.064	.103	–.170	–.172	–.187	.022
Cognitive status												
MMSE	**.213***	**.202***	**.267****	–.003	**.262***	**.315***	.177	.015	–.078	–.053	.066	–.221
Psychosocial status												
EQ-5D score	**.403****	**.268****	**.408****	.182	.186	.135	.094	**.307***	.154	.189	.144	–.113
AES-C score	**.225***	**.219***	**.256****	–.069	.244	.199	**.276***	–.192	.167	.219	.161	–.048
Short-FESI score	**–.299****	**–.208***	**–.259****	–.113	**–.277***	–.178	–.214	–.016	**–.357****	–.250	**–.363****	–.245
Motor-functional status												
ADL Barthel, score	**.579****	**.389****	**.650****	**.231***	**.527****	**.365****	**.574****	.181	**.588****	**.374****	**.683****	.207
SPPB, score	**.575****	**.330****	**.591****	**.454****	**.590****	**.374****	**.566****	**.433****	**.513****	.248	**.583****	**.428****
Gait Velocity, s	**–.518****	**–.359****	**–.481****	**–.371****	**–.493****	**–.299***	**–.435***	**–.355***	**–.495****	**–.406****	**–.459***	**–.332***
Physical activity												
Duration of lying	**–.381****	**–.450****	**–.372****	.043	**–.513****	**–.589****	**–.560****	–.019	–.052	–.073	–.063	.152
Duration of activity	**.538****	**.399****	**.600****	**.327****	**.448****	.307	**.494****	**.471****	**.565****	.309	**.575****	**.416***
Duration of gait	**.716****	**.555****	**.598****	**.468****	**.677****	**.519****	**.552****	**.460****	**.776****	**.549****	**.675****	**.586****
Number of steps	**.713****	**.567****	**.588****	**.457****	**.665****	**.522****	**.543****	**.439****	**.756****	**.553****	**.650****	**.575****

Presented are Spearman rank correlation coefficients (r_s), except for gender [a] point-biserial correlation coefficients (r_{pb})

Abbreviations: *ADL* Activities of daily living, *AES-C* Apathy Evaluation Scale – Clinical version, *BMI* Body mass Index, *CFS* Clinical Frailty Scale, *EQ-5D score* EuroQol-questionnaire score EQ-5D-3L version, *LSA-IS* Life-Space Assessment for institutionalized settings, *LSA-IS-C* Composite life-space mobility, *LSA-IS-M* Maximum life-space, *LSA-IS-E* Maximum life-space with equipment, *LSA-IS-I* Maximum independent life-space, *MMSE* Mini-Mental State Examination, *PPI* Present Pain Intensity Scale, *SPPB* Short-Physical Performance Battery, *Short FES-I* Short Falls-Efficacy-Scale. Correlations coefficients (r): small ($r = 0.1–0.3$), moderate ($r = 0.3–0.5$), or high ($r > 0.5$). *$p < .05$. **$p < .01$; b point-biserial correlation coefficients (rpb)

Table 4 Test – retest reliability for total group and subgroups

Variable	First test Mean (SD)	Retest	ICC	95% CI
Total group (*n* = 76)				
LSA-IS-T	18.42 (10.21)	19.20 (10.91)	.704	.570–.801
Subscores				
LSA-IS-M	2.74 (0.93)	2.79 (0.94)	.412	.208–.582
LSA-IS-E	2.32 (1.16)	2.34 (1.23)	.741	.620–.827
LSA-IS-I	0.64 (1.10)	0.80 (1.34)	.799	.701–.868
Non-CI/Subsample with intact cognition (*n* = 36)				
LSA-IS-T	19.29 (11.29)	21.72 (12.50)	.715	.511–.843
Subscores				
LSA-IS-M	2.81 (0.92)	2.86 (0.96)	.558	.288–.747
LSA-IS-E	2.56 (1.06)	2.67 (1.04)	.671	.445–.817
LSA-IS-I	0.69 (1.17)	0.83 (1.34)	.798	.641–.891
CI/Subsample with impaired cognition (*n* = 40)				
LSA-IS-T	17.64 (9.19)	16.93 (8.80)	.676	.467–.814
Subscores				
LSA-IS-M	2.68 (0.94)	2.73 (0.93)	.285	−.023–.544
LSA-IS-E	2.10 (1.22)	2.05 (1.32)	.766	.602–.869
LSA-IS-I	0.60 (1.06)	0.78 (1.35)	.805	.662–.892

Presented are results of test-re test reliability for the total group and sub-scores according to cognitive status
Abbreviations: *CI* Confidence interval, *LSA-IS* Life-Space Assessment for institutionalized settings, *LSA-IS-T* Total life-space mobility, *LSA-IS-M* Maximum life-space, *LSA-IS-E* Maximum life-space with equipment, *LSA-IS-I* Maximum independent life-space; ICCs were interpreted as poor (< 0.4), fair to good (≥ 0.4 ≤ 0.75), and excellent (> 0.75)

higher associations for all construct parameters with all of them representing a common motor domain.

Two out of three sub-scores (LSA-IS-M, LSA-IS-E) followed the results for the total score, while a trend for lower associations was visible for the sub-score LSA-IS-I (independent score). We assume the weaker association to be caused by the lower incidence of independent, non-supported mobility in this multi-morbid, vulnerable sample during acute, ward-based medical care with a higher number of participants with low levels of LSA-IS-I.

Results of the construct validation also indicate that achieved good results were not different between sub-groups according to cognitive status for most variables, indicating good validity also for persons with moderate to more advanced stages of CI, representing the majority of patients in geriatric hospitals as well as other institutionalized settings.

Test-retest reliability

Test–retest reliability was good to excellent in the total score as well as two out of three sub-scores, indicating highly stable results for the LSA-IS in general. Results are in line with a trend for lower reliability as compared to previous validation studies for community dwelling older persons documented by ICCs [14, 16]. The lower test-re-test reliability for the sub-score maximal life-space is in line with a trend for lower reliability as compared to a previous validation study for community dwelling older persons documented by ICCs [16] and may be caused by the fact that maximal life-space, including outer ranges of mobility such as cafeteria visits or even outdoor visits beyond into the neighboring surrounding (e.g. hospital garden), are more infrequent and random in vulnerable, institutionalized persons. Occurrence of such events heavily depend on external support and are therefore less reliable when tested in a short period of time, but do not necessarily indicate a lower biometrical quality of the evaluation method. However, the low reliability of this sub-score may indicate a limitation for this specific hospital setting.

Sensitivity to change

All LSA-IS scores significantly increased during the relatively short assessment period within an intervention (early ward-based rehab) which was not specifically tailored to achieve LSM changes, indicating a global sensitivity to change of the assessment method. Specific modification of the LSA-IS, such as framing of the observation period, supported the good responsibility. Apart from supporting recall in persons with memory deficits, relevant for all institutional settings, the short observation period as used for the LSA-IS, represented a precondition to document sensitivity to change in hospital or rehab settings within the given limited time frame of therapeutic interventions.

Other life-space assessment validation did predominantly not include this biometrical measure which is highly relevant to document efficacy of interventions in research or clinical routines. The two comparable studies used different statistical strategies. While Baker used a dichotomized descriptive analysis without statistical analysis and a longitudinal, observational design demonstrating adequate responsiveness [16], Ullrich reported comparable results to the present study for effects of an RCT on activity promotion to document good sensitivity to change [14].

In the present study sensitivity to change as documented by SRMs was large for the main total score summarizing all changes for all independence levels and areas of mobility. Moderate effects for the sub-scores LSA-IS-M and LSA-IS-E documented effects of routine hospital-based rehab, leading to relevant changes to extent mobility by using technical or personal support. The sub-score with the least responsiveness (LSA-IS-I) was relevant for only a minority of high functioning persons not using such support, which is almost mandatory for ambulation of multi-morbid persons within hospitals [40]. The somewhat lesser responsiveness may therefore

Table 5 Sensitivity to change of the LSA-IS total score and sub-scores

Variables	Test at admission Mean (SD)	Test at discharge	P-value*	SRM	Adjusted SRM
Total sample (*n* = 69)					
LSA-IS-T	12.43 (8.82)	19.17 (11.12)	<.001	0.696	0.806
Subscores					
LSA-IS-M	2.22 (1.00)	2.80 (1.01)	<.001	0.545	0.667
LSA-IS-E	1.68 (1.14)	2.29 (1.21)	<.001	0.574	0.647
LSA-IS-I	0.46 (1.11)	0.78 (1.33)	<.001	0.292	0.326
Subsample with intact cognition (*n* = 33)					
LSA-IS-T	14.20 (9.62)	21.89 (12.77)	<.001	0.700	0.812
Subscores					
LSA-IS-M	2.30 (0.98)	2.91 (1.01)	<.001	0.572	0.701
LSA-IS-E	1.97 (1.08)	2.67 (0.99)	<.001	0.648	0.786
LSA-IS-I	0.55 (1.23)	0.94 (1.41)	<.001	0.353	0.383
Subsample with cognitive impairment (*n* = 36)					
LSA-IS-T	10.82 (7.81)	16.67 (8.82)	<.001	0.701	0.833
Subscores					
LSA-IS-M	2.14 (1.02)	2.69 (1.01)	<.001	0.514	0.631
LSA-IS-E	1.42 (1.16)	1.94 (1.31)	<.001	0.500	0.548
LSA-IS-I	0.39 (0.96)	0.64 (1.25)	.004	0.232	0.269

Presented are results for sensitivity to change for effects of early rehabilitation during hospital stay
Abbreviations: *SD* Standard deviation, *SRM* Standardized response mean, *LSA-IS* Life-Space Assessment for institutionalized settings, *LSA-IS-T* Total life-space mobility, *LSA-IS-M* Maximum life-space, *LSA-IS-E* Maximum life-space with equipment, *LSA-IS-I* Maximum independent life-space; Adjusted SRMs are classified as < 0.2 = trivial, ≥0.2 < 0.5 = small, ≥0.5 < 0.8 = moderate, ≥0.8 = large
*difference between admission and discharge

rather be an indicator of the very low functional status of the study sample than a methodological limitation of the evaluation method. As with other biometrical domains in this study, no relevant differences were documented between subgroups according to cognitive status, indicating good responsiveness of the LSA-IS also in persons with CI. Results, as achieved in this study may mirror the special focus of the development of the LSA-IS on persons with CI, that require a specific approach due to their special needs [13, 14, 41].

Feasibility

The 100% completion rate with no missing responses documented an excellent feasibility of the LSA-IS even in multi-morbid, vulnerable persons during acute medical, ward-based treatment. The specific component of the questionnaire such as the interview-based interrogation, the interview technique tailored to the study sample including persons with moderate to more advanced stages of CI, as in previous successful validation studies [13, 14] and the highly organized setting with restricted degrees of freedom for mobility following standardized routines, which are easy to recall and structure by interview, may have helped to achieve this extraordinary result. The LSA-IS completion time of 3.2 min is very brief allowing its use in research as well as clinical routines with only very little resources and no risk of overtaxation of interviewed persons.

As in comparable questionnaires [20] or sensor-based LSA [10], the LSA-IS includes categories extending beyond the institutions covering the clinically relevant transition from protected indoor to demanding outdoor activity.

In the present study floor effects occurred in two subscores with focus on equipment-assisted or independent life-space. In a clinical acute setting with multi-morbid, vulnerable persons, most of those not able to independently move without technical or personal support and with institutional activity restrictions to stay indoors, such a result is to be expected. On the other hand, as a logical consequence, the main total score and the sub-score including technical or personal support did not have such floor effects and none of the scores showed ceiling effects as documented in other LSM assessment validation studies which reported on this issue [14, 16]. It is noteworthy that good feasibility could be achieved also in the group with moderate to more advanced stages of CI, with specific limitations for a questionnaire-based assessment.

Limitations

Although the LSA-IS has been developed for generic use in comparable institutional settings, formally the present validation is focused on ward-based acute geriatric care and generalizability of its' psychometric properties will have to be additionally confirmed for other settings.

Conclusions

The results of this study demonstrate good validity, reliability, sensitivity to change, and feasibility of the newly developed LSA-IS in geriatric patients without and with moderate to advanced stages of CI during acute, in-hospital medical treatment. Based on the high comparability of organizational structures and populations, we consider the use of the instrument feasible in other comparable institutionalized settings such as other in-house medical care, rehabilitation centers, or in nursing homes settings.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-020-01927-8.

Additional file 1. Life-Space Assessment in Institutionalized Settings (LSA-IS). (documentation form)

Additional file 2. Life-Space Assessment for Persons in institutionalized settings (LSA-IS) – User Manual.

Additional file 3. COSMIN Study Design checklist for Patient-reported outcome measurement instruments.

Abbreviations

AES-C: Apathy Evaluation Scale – Clinical version; BMI: Body Mass Index; CFS: Clinical Frailty Scale; CI: Cognitive impairment; EQ-5D: European health-related quality of life questionnaire (EQ-5D-3L); LSA-CI: Life-Space Assessment in Persons with cognitive impairment; LSA-IS: Life-Space Mobility in Institutionalized Settings; LSM: Life-space mobility; n: Numbers; NHLS D: Nursing Home Life-Space Diameter; MMSE: Mini-Mental State Examination; PA: Physical activity; PPI: Present Pain Intensity Scale; SD: Standard deviation; SPPB : Short-Physical-Performance-Battery; Short FES-I: Short Falls Efficacy Scale-International, 7-item version; UAB-LSA: University of Alabama at Birmingham – Life-Space Assessment; VRS: Verbal rating scale

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Authors' contributions

KH drafted the manuscript. Analyses of the data were carried out by KH and PU. PU and CW made critical revision of the article. KH, JMB and CW were responsible for the conception of this study and study design. PH and SH participated in data collection. All authors read and approved the final manuscript.

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Availability of data and materials

Availability was only given to participants (for their own information) and specific members of the study. The datasets generated and/or analysed during the current study are not publicly available as the ethical vote did not include open data access, but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was performed according to the Helsinki Declaration and was approved by the ethics committee of the Medical Department of the University of Heidelberg (S-709/2018). Written-informed consent has been part of the mandatory participants' agreement which also included consent to publish data. In case participants would decide to withdraw their consent it was guaranteed that individual data was not used in data analysis and deleted.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Article

Psychometric Properties of the Proxy-Reported Life-Space Assessment in Institutionalized Settings (LSA-IS-Proxy) for Older Persons with and without Cognitive Impairment

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Abstract: (1) Background: Life-space mobility assessments for institutionalized settings are scarce and there is a lack of comprehensive validation and focus on persons with cognitive impairment (CI). This study aims to evaluate the psychometric properties of the Life-Space Assessment for Institutionalized Settings by proxy informants (LSA-IS-proxy) for institutionalized, older persons, with and without CI. (2) Methods: Concurrent validity against the self-reported version of the LSA-IS, construct validity with established construct variables, test-retest reliability, sensitivity to change during early multidisciplinary geriatric rehabilitation treatment, and feasibility (completion rate, floor/ceiling effects) of the LSA-IS-proxy, were assessed in 94 hospitalized geriatric patients (83.3 ± 6.1 years), with and without CI. (3) Results: The LSA-IS-proxy total score showed good-to-excellent agreement with the self-reported LSA-IS (Intraclass Correlations Coefficient, $ICC_{3,1}$ = 0.77), predominantly expected small-to-high correlations with construct variables (r = 0.21–0.59), good test–retest reliability ($ICC_{3,1}$ = 0.74), significant sensitivity to change over the treatment period (18.5 ± 7.9 days; $p < 0.001$, standardized response mean = 0.44), and excellent completion rates (100%) with no floor/ceiling effects. These results were predominantly confirmed for the sub-scores of the LSA-IS-proxy and were comparable between the sub-groups with different cognitive status. (4) Conclusions: The LSA-IS-proxy has proven to be feasible, valid, reliable, and sensitive to change in hospitalized, geriatric patients with and without CI.

Keywords: clinical trial methods; cognitive impairment; life-space mobility; assessment; exercise; physical activity; validation; hospitalization

1. Introduction

The assessment of life-space mobility (LSM) is used to document an individual's mobility in the environment considering contextual factors [1,2]. As LSM captures the habitual mobility range, it also reflects functional, environmental, and social factors that affect mobility. Independent mobility represents a prerequisite to master challenges in everyday life [3], quality of life [4], and participation in society and the natural environment [5,6]. However, during hospitalization or institutionalization, older patients have a highly sedentary behavior and spend most of their time in a lying or sitting position [7,8], with negative consequences such as a higher risk of decline in activities of daily living, new institutionalization, or death [9], underlining the need for assessment of mobility and interventions to reduce the risk of adverse outcomes. Since the concept of LSM was introduced in 1985 by May [10], it is increasingly being used to characterize the status or time course of LSM impairment, or to initiate, adjust and evaluate therapies or interventions. Several instruments have been developed to measure LSM in older adults [11]; however, with a focus on community-dwelling older persons [12].

While the mobility of community-dwelling older persons and the mobility of older persons in institutions (e.g., hospitals, rehabilitation clinics, or nursing homes) have some similarities (both depend on the physical, cognitive, psychosocial, and personal capacities of an individual [1]), they also have major differences. Life-space is commonly structured into different life-space zones within and around the home and typically includes areas such as the garden, neighborhood, hometown, etc. However, these areas are not transferable to institutionalized persons, as the type of mobility area differs substantially (home vs. ward and common areas, garden, neighborhood vs. hospital, or nursing home outdoor area). Additionally, during hospitalization, aspects related to medical status such as the severity of disease or comorbidity, to treatment such as prescribed bed-rest or medical appliances, to attitudes such as expectations towards mobility or hospital stay, and institutional aspects such as nursing to patient ratio, or availability of equipment influence individuals' mobility behavior [13]. Many of these limitations also occur in nursing home settings [8]. The organizational structure and routines of these institutions have shown an overwhelming influence on LSM in nursing home residents [14].

Some of the factors that lead to institutionalization in hospitals or nursing homes [15,16] and negatively influence mobility behavior in older, institutionalized persons also affect or restrict the validity of self-report assessments. Accuracy of reports on health-related status in hospitalized or institutionalized persons can severely be limited by chronic conditions such as cognitive impairment (CI), which is highly prevalent in this population [17], or acute medical conditions related to critical illness such as delirium, catastrophic trauma, or exhaustion/fatigue [18–20]. To generate representative data, exclusion of patients with such problems in self-reporting health status may cause a systematic bias.

Currently, with the self-report Life-Space Assessment in Institutionalized Settings (LSA-IS) [21] and the Nursing Home Life-Space Diameter (NHLSD) [22], there are only two LSM surveys published and validated in institutionalized persons. The LSA-IS as an interview-based, self-report version was developed and comprehensively validated for use in hospitalized or institutionalized persons with and without CI [21]. Despite the excellent psychometric properties of the LSA-IS, the success of the assessment substantially depends on the ability of a person to be interviewed and the competence of the interviewer using the advanced interview support of the measure, which may not be provided in all settings. While collaborative, structured approaches allow assessment of the self-perspective of geriatric patients with cognitive impairment [23], such approaches have shown to be time-consuming, to require specific expertise of the assessor, and/or to have limits concerning severely cognitively impaired persons [23–25].

The NHLSD as an alternative and established LSM survey for institutionalized persons is based on a proxy report by the institution's staff [22]. However, some characteristics of the NHLSD limit its applicability and some validation issues have not been addressed. First, the long observation period of two weeks compromises its use, in the hospital settings due to the varying duration of hospitalization that often tends to be shorter than two weeks.

Second, the reliability of the NHLSD and its construct validity has been analyzed by a restricted number of construct variables (functional characteristics). However, testing of detailed feasibility aspects, construct validity based on a comprehensive framework of mobility, and sensitivity to change of the NHLSD has not yet been conducted [22]. In addition, although the NHLSD provides an option to include the level of personal support in the LSM assessment, this approach has not fully been integrated into the validation.

Proxy-based information has shown to be an adequate solution in case of the inability of a person to report their health status [26,27]. However, attempts to compare patients' and proxies' therapy preferences or ratings on health-related status have also shown limitations of proxy reports [28–30], indicating problems with the congruence of self- and proxy-report. The quality of proxy reports depend on the domain being tested and the objective of the documentation, with acceptable results for lower extremity/physical functioning [31], but also references to interpret results for physical functioning with caution [32]. Data on LSM provided by a proxy as a surrogate solution for self-report have shown loss of precision, and bias with over-or under-reporting [33]. However, this direct comparison between a proxy report and a self-report has only been conducted for the University of Alabama at Birmingham Life-Space Assessment (UAB-LSA) [34], which represents an assessment for rather higher functioning community-dwelling persons with an observation period of one month. It is, therefore, less suitable to assess trajectories of LSM in institutionalized/hospitalized, impaired persons.

Thus, the objective of the present study was to comprehensively validate a new, detailed, proxy-reported LSM assessment instrument with a short observation period (proxy-reported Life-Space Assessment in Institutionalized Settings, LSA-IS-proxy), specifically designed and adjusted for institutionalized older persons in hospitals, rehabilitation settings or nursing homes. Concurrent and construct validity, test-retest reliability, sensitivity to change, and feasibility were analyzed in hospitalized geriatric patients. Differentiated analyses were also performed for subgroups according to cognitive status.

2. Materials and Methods

This comprehensive validation study was performed within a prospective, longitudinal cohort study to document and analyze physical activity behavior and mobility during hospitalization in geriatric patients, with and without CI ("Physical Activity in Geriatric patients during Early Rehabilitation", PAGER; trial registration number: DRKS00016028). The study was conducted following the Declaration of Helsinki and was approved by the ethics committee of the Medical Department of the University of Heidelberg (S-709/2018).

Persons admitted to acute medical wards of a German geriatric hospital were included according to pre-defined inclusion criteria. Inclusion criteria were: receipt of complex early geriatric rehabilitation treatment according to the German hospital payment system (German Diagnosis-Related Groups), age $\geq$ 65 years, Mini-Mental State Examination (MMSE [35]) score $\geq$ 10, no delirium (Confusion Assessment Method [36]), ability to walk at least 4 m with or without walking equipment, no terminal illness, no very severe functional, sensorial or behavioral impairments that compromised study participation or assessment, no uncontrolled infection, basic communication in the German language possible, and written informed consent by the patient or the patients' legal representative within 72 h after admission.

2.1. Descriptive Measures

Sociodemographic and clinical characteristics were documented from patient charts or by standardized patient interviews at hospital admission to characterize the study sample and for analysis of construct validity. Age, gender, and multi-morbidity (number of medications) were retrieved from patient charts. Trained interviewers assessed frailty status (Clinical Frailty Scale, CFS [37]), falls in the previous year [38], pain (Present Pain Intensity scale, PPI [39,40]), cognitive status (MMSE [35]), health-related quality of life (EuroQol questionnaire, EQ-5D-3L [41]), apathetic symptoms (Apathy Evaluation Scale-Clinical version, AES-C [42,43]), and concerns about falling (Short Falls Efficacy Scale-International, 7-item version, Short-FES-I [44,45]). Motor–functional status was assessed by the Activities of Daily Living (ADL) (Barthel-Index [46]), and the Short Physical Performance Battery (SPPB [47]). Physical activity (duration of activity and gait, number of steps) over 48 h was measured with the uSense, a sensor that has been validated to assess physical activity sensor in multi-morbid, geriatric patients [48].

2.2. Life-Space Mobility Assessment

The LSA-IS-proxy is based on an external (proxy) report and represents a newly designed LSM assessment instrument adjusted for the institutionalized environment (hospital setting) and is consistent in content and documentation with the self-report, LSA-IS version [21]. The main difference is the type of assessment (self vs. proxy report). The LSA-IS documents mobility in the environment, divided into six concentric zones within and around an institutionalized setting (level 0: own bed, level 1: own room, level 2: within the ward, level 3: within the facility, level 4: immediate outdoor area of the facility, level 5: beyond the area of the facility). Additionally, the LSA-IS considers the frequency of activity in each zone (1: 1 × per day, 2: 2–3 × per day, 3: 4–5 × per day, 4: >5 × per day), and the level of assistance needed to be mobile in each respective zone (1: with personal support, 1.5: with equipment, 2: without any support). The observation period includes the previous day (24 h). Corresponding to the LSA-IS, different outcomes can be calculated. The total score is composed of the sum of the scores for all zones, while each zone score consists of the product of zone score, frequency score, and independence score. The LSA-IS-proxy total score has a range of 0–120. Zero indicates absolute immobility (confined to bed), and 120 points as the maximal score indicate independent mobility beyond the facility's outdoor area six or more times a day without assistance or equipment. Additionally, three sub-scores of the LSA-IS-proxy serve as detailing outcome parameters: The maximal life-space, achieved (1) with equipment or personal assistance if needed (range 0–5), (2) the life-space achieved with equipment, if needed, but without personal assistance (range 0–5), and (3) the independent life-space, achieved without any assistance (range 0–5) [34,49]. For details of the test proceeding, see the manual and assessment form attached in the Supplementary Materials (Supplementary Material File 1).

The assessment of the proxy-based version of the LSA-IS should be administered by a person involved in the organizational and treatment routines of the setting/institution, allowing comprehensive observation during the assessment period. The observation period may focus on weekdays to document LSM during routine hospital proceedings.

2.3. Assessment of Measurement Properties and Assessment Procedure

Concurrent validity was determined using the proxy-based and the self-report version of the LSA-IS [21], which was assessed simultaneously at hospital admission by different assessors.

For construct validity, correlational analyses were conducted between LSA-IS-proxy scores and descriptive variables that have shown moderate to high associations with LSM in previous comparable validation studies, such as studies for the UAB-LSA [34], the Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI) [49] and the NHLSD [22]. Analyses were based on data assessed at hospital admission. Selection and classification of variables were conducted following a comprehensive and well-established model for mobility by Webber [1], and included the demographic variables age and gender, as variables for health status number of medications, the PPI, and the CFS, for cognitive status the MMSE [35], for the psychosocial status the EQ-5D [41], the AES-C [42,43], and the FES-I [25], for motor-functional status the ADL Barthel Index [46] and the SPPB [47], and physical activity sensor-based measurements of activity and gait duration, and the number of steps [48].

To analyze the test-retest reliability, the LSA-IS-proxy was assessed on two consecutive days by the same trained assessor, if possible, immediately after hospital admission, in case the retest was not possible after admission (due to weekend or diagnostic procedure), test and retest were conducted before discharge.

Sensitivity to change was analyzed in all available participants that could be tested at admission and immediately before the discharge, under the assumption that the "complex early geriatric rehabilitation"—as an early, multidisciplinary, geriatric rehabilitation program established in German geriatric hospitals routines—would positively affect ward-based LSM.

The feasibility of the LSA-IS-proxy was checked for completion rate, as well as floor and ceiling effects, using the baseline LSA-IS-proxy scores. Floor and ceiling effects, defined as the proportion of respondents scoring the minimal or maximal possible score, were classified as significant if more than 15% of participants achieve the lowest or highest score [50].

Assessors were members of the study group, working in the hospital daily and were familiar with the hospital procedures/organization and study participants.

2.4. Subgroup Analyses

All analyses were conducted for the total group and differentiated for subgroups corresponding to their cognitive status regarding the high prevalence of CI in institutions such as hospitals or nursing homes and the potential influence of CI on self-report. Participants with MMSE scores < 24 (range: 10–23) were assigned to the group of persons with CI and participants with scores $\geq$ 24 (range: 24–30) were assigned to the group of persons with intact cognition [35].

2.5. Statistical Analysis

Descriptive measures are presented as frequencies and percentages for categorical variables and means and standard deviations (SD) or medians and ranges for continuous variables as appropriate. The concurrent validity of the LSA-IS-proxy against the self-reported version of the LSA-IS and the test-retest reliability of the LSA-IS-proxy were determined by calculating intra-class correlation coefficients ($ICC_{3,1}$) for absolute agreement with 95% confidence intervals for the total and sub-scores. ICCs below 0.4 were rated as poor, between 0.4 and 0.75 as fair to good, and above 0.75 as excellent [51]. Additionally, a Bland–Altman plot was constructed with the between-method differences (bias) and 95% limits of agreement (LOA = $mean_{bias} \pm 1.96 \times SD_{bias}$) to visualize the level of agreement between the total scores of the self-and proxy-reported LSA-IS. Correlation coefficients (Spearman's rank-order and point-biserial correlation as appropriate) between the LSA-IS-proxy scores and demographic, health, cognitive, psychological, and motor-functional status, and physical activity were calculated to assess construct validity. Correlation coefficients (*r*) of 0.1–0.3 were considered small, between 0.3–0.5 moderate, and above 0.5 high [52]. Based on previous findings [21,34,49], we expected lower correlation coefficients of the LSA-IS-proxy scores to demographic, health, cognitive, and psychological variables, representing different domains, and higher associations with motor-functional variables and physical activity, representing a common motor domain.

Sensitivity to change was examined with standardized response means (SRMs) and paired *t*-tests. Paired *t*-tests were computed to test for significant within-group differences between baseline and post-intervention assessment. To quantify the magnitude of change, SRMs were calculated as the difference in mean change scores divided by the *SD* of the change score [53]. To interpret the value of the SRMs in terms of Cohen's thresholds for effect sizes (trivial <0.2, small $\geq$0.2 <0.5, moderate $\geq$0.5 <0.8, and large $\geq$0.8) [52], SRMs were adjusted for the size of correlation coefficients between the baseline and post-intervention scores [54].

A two-sided *p*-value of <0.05 indicated statistical significance. All statistical analyses were performed using the Software IBM SPSS Statistics Version 25 for Windows (IBM Corp., Armonk, NY, USA).

3. Results

Out of 934 patients that were admitted to the hospital during the study period, 155 were included in the PAGER study according to the predefined inclusion criteria and 94 patients were rated with the LSA-IS-proxy assessment, as the assessment of LSM was only conducted on and for weekdays to document habitual mobility during routine hospital proceedings.

3.1. Sample Characteristics

The total sample included 94 multi-morbid (mean number of medications: 9.9 ± 4.0), frail (clinical frailty scale mean 5.5 ± 1.0, indicating a moderate frailty status), geriatric patients (mean age 83.3 ± 6.1 years) with mild to moderate CI (MMSE: 22.8 ± 4.8) and reduced motor status (SPPB: 4.2 ± 2.4), and with 61.6% female participants. Persons with CI were slightly older and had a lower functional and physical activity status compared to persons with intact cognition. Detailed participant characteristics are summarized in Table 1. Primary diagnoses of the participants included musculoskeletal disorders (19%), neurological disorders (15%), infections (13%), acute medical illness (11%), cardiovascular disorders (10%), gastrointestinal disorders (10%), and others (23%). The number of participants included in the different psychometric property analyses varied based on the study design (*n* = 69–94 for the total group analyses).

Table 1. Sample characteristics.

Variables	Total Sample (*n* = 94)	Persons without CI (*n* = 48)	Persons with CI (*n* = 46)
Gender (female)	58 (61.7)	31 (64.6)	27 (58.7)
Age (years)	83.3 (6.1)	82.3 (5.9)	84.4 (6.2)
Number of medications	9.9 (4.0)	9.5 (4.0)	10.2 (4.0)
CFS	5.5 (1.0)	5.2 (0.9)	5.8 (1.0)
PPI	1.4 (1.5)	1.2 (1.3)	1.6 (1.7)
MMSE	22.8 (4.8)	26.7 (1.7)	18.8 (3.4)
EQ-5D	0.65 (0.31)	0.69 (0.28)	0.58 (0.33)
AES-C	24.3 (8.6)	26.7 (7.9)	21.7 (8.7)
Short-FES-I	12 [7–28]	11 [7–25]	12 [7–28]
Falls in the previous year	1.2 (0.8)	1.1 (0.8)	1.2 (0.8)
ADL Barthel-Index	75 [5–100]	85 [25–100]	65 [5–100]
SPPB	4.2 (2.4)	4.6 (2.3)	3.8 (2.5)
Number of steps in 48 h (uSense)	2560 (3361)	3115 (3642)	1960 (2961)
LSA-IS-proxy scores			
Total score	12.7 (7.1)	14.4 (8.3)	11.0 (5.2)
Maximal life-space	2.2 (0.7)	2.3 (0.7)	2.1 (0.8)
Equipment-assisted life-space	1.7 (1.0)	2.0 (0.9)	1.4 (1.0)
Independent life-space	0.4 (0.8)	0.4 (0.8)	0.4 (0.7)

Notes: Data are presented as n (%), median [range], or mean (SD). For single variables, the size of subsamples deviates depending on feasibility. Abbreviations: ADL Barthel-Index = Activities of daily living (range 0–100, higher values indicating higher independence in activities of daily living); AES-C: Apathy Evaluation Scale-Clinical Version (range 0–40, higher values indicating lower apathy); CFS = Clinical Frailty Scale (range 1–9, higher values indicating higher frailty status); CI = cognitive impairment; EQ-5D = EuroQol questionnaire, health-related quality of life (range 0.00–1.00, higher values indicating higher quality of life status); Short-FES-I = Short Falls Efficacy Scale-International (range 7–28, higher values indicating lower falls efficacy); LSA-IS-proxy = Life-Space Assessment for Institutionalized Settings proxy report; MMSE = Mini-Mental State Examination (range 0–30, higher values indicating higher cognitive status); *n* = numbers; PPI = Present Pain Intensity Scale (range 0–5, higher values indicating higher pain); SPPB = Short Physical Performance Battery (range 0–12, higher values indicating higher physical performance).

3.2. Concurrent Validity

The LSA-IS-proxy showed a good to excellent level of agreement with the self-reported LSA-IS for the total score in the total group and both subgroups (see Table 2; $ICC_{3,1}$ = 0.69–0.79). The mean total score for the proxy-based version was 13.13 (SD 7.16), while the mean total score for the self-reported version was 12.78 (SD 5.57), with a mean difference of 0.34 (95% Confidence Interval −0.71–1.40 and LOA of −9.70 to 10.39 (Figure 1). ICCs for the sub-scores were only slightly lower, with still fair to good or excellent agreement in the total group ($ICC_{3,1}$ = 0.59–0.70) and the subgroups (without CI: $ICC_{3,1}$ = 0.56–0.79; with CI: $ICC_{3,1}$ = 0.55–0.71). A Bland Altman analysis (Figure 1) displays the high association between the LSA-IS total score of the self-report vs. the proxy-reported version (see Figure 1). Overall, the level of agreement did not differ substantially between subgroups of participants according to cognitive status.

Table 2. Concurrent validity of the LSA-IS-proxy with the self-reported LSA-IS.

Self-Reported LSA-IS Scores	LSA-IS-Proxy Scores			
	Total Score	Maximal Life-Space	Equipment-Assisted Life-Space	Independent Life-Space
Total score				
total group	0.77 (0.67–0.84)			
without CI	0.79 (0.66–0.88)			
with CI	0.69 (0.50–0.82)			
Maximal life-space				
total group		0.65 (0.51–0.57)		
without CI		0.56 (0.33–0.73)		
with CI		0.71 (0.52–0.83)		
Equipment-assisted life-space				
total group			0.59 (0.44–0.71)	
without CI			0.54 (0.31–0.72)	
with CI			0.55 (0.32–0.73)	
Independent life-space				
total group				0.70 (0.58–0.79)
without CI				0.79 (0.66–0.88)
with CI				0.61 (0.39–0.76)

Note: Presented are Intraclass Correlation Coefficients ($ICC_{3,1}$) for absolute agreement between the self-and proxy-reported LSA-IS for the total group (n = 93) and the subgroups with (n = 47) and without cognitive impairment (n = 46). Abbreviations: LSA-IS = Life-Space Mobility Assessment for Institutionalized Settings, CI = cognitive impairment.

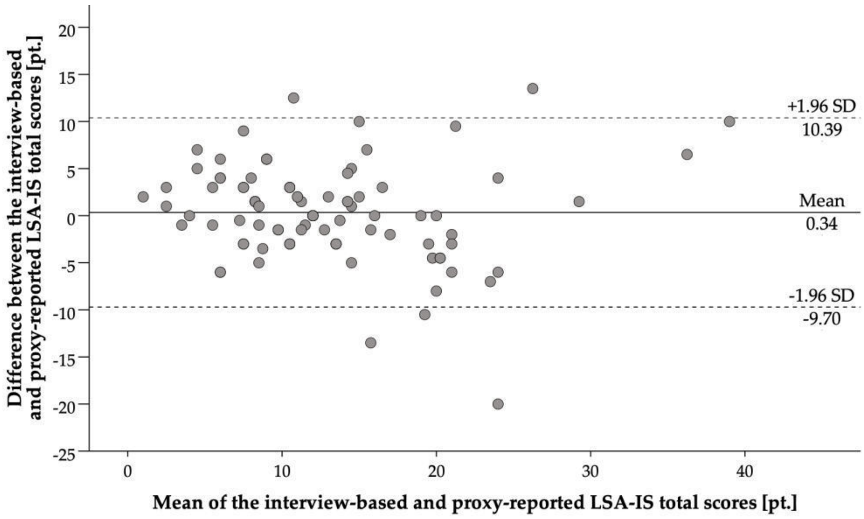

Figure 1. Bland-Altman plot for agreement between proxy-reported and self-report LSA-IS. Note: Presented is a Bland-Altman plot for agreement between proxy-reported and self-report LSA-IS. The solid line indicates the mean between-method difference (bias) and dashed lines the upper and lower 95% LOA (±1.96 SD of the bias).

3.3. Construct Validity

The LSA-IS-proxy total score (total sample) showed moderate to high correlations with motor-functional status and physical activity (r = |0.30|–|0.59|), and small to moderate associations with age, frailty, cognitive status, health-related quality of life, and apathy (r = |0.21|–|0.41|), while lower and also non-significant results were obtained for gender, pain, and fall-related self-efficacy (r = |0.05|–|0.18|) as hypothesized (Table 3).

Overall, results for the LSA-IS-proxy sub-scores confirmed the results documented for the total score. For the motor-functional status and physical activity, significant correlation coefficients for the equipment-assisted life-space sub-score (r = 0.47–0.66) and predominantly significant correlation coefficients for the independent sub-score (r = 0.32–0.57) were documented. Meanwhile, the results for the maximal sub-score were lower and partially non-significant (r = 0.13–0.25). The results for demographic, health status, cognitive, and psychosocial variables varied. Significant small to high correlation coefficients were documented for the equipment-assisted sub-score and age, frailty, pain, cognition, and psychosocial variables (r = 0.27–0.56), and for the independent score and frailty (r = 0.46). Other variables of these domains showed predominantly non-significant associations with the LSA-IS sub-scores. The sub-score for equipment-assisted life-space stood out among the sub-scores with superior associations to construct variables in general.

Results for the two subgroups according to cognitive status were lower as compared to the total score, but comparable for most variables and confirming results of the total sample, with no major differences between the two sub-groups.

Table 3. Construct validity of the LSA-IS-proxy.

		LSA-IS-Proxy Scores			
Variables	**Group**	**Total Score**	**Maximal Life-Space**	**Equipment-Assisted Life-Space**	**Independent Life-Space**
Demographic factors					
Age	total group	−0.31 *	−0.10	−0.37 *	−0.20
	without CI	−0.32 *	−0.06	−0.21	−0.24
	with CI	−0.26	−0.10	−0.43 **	−0.16
Gender [1]	total group	−0.05	0.02	0.05	−0.05
	without CI	−0.06	0.05	0.12	−0.20
	with CI	−0.01	0.01	−0.04	0.01
Health status					
No. of medication	total group	−0.13	−0.04	−0.02	−0.13
	without CI	−0.13	−0.04	0.08	0.08
	with CI	0.10	−0.01	−0.06	−0.15
CFS	total group	−0.41 **	−0.21	−0.56 **	−0.46 **
	without CI	−0.30 *	−0.22	−0.43 **	−0.32 *
	with CI	−0.44 **	−0.21	−0.60 **	−0.60 **
PPI	total group	−0.10	0.02	−0.27 *	0.12
	without CI	−0.04	−0.16	−0.21	0.21
	with CI	−0.12	0.11	−0.27	0.04
Cognitive Status					
MMSE	total group	0.21 *	0.13	0.30 **	−0.02
	without CI	0.22	0.13	0.13	−0.01
	with CI	−0.13	−0.14	0.09	−0.09
Psychosocial status					
EQ-5D	total group	0.30 **	0.22*	0.43 **	0.21
	without CI	0.16	0.30*	0.45 **	0.07
	with CI	0.34 *	0.10	0.39 **	0.29
AES-C	total group	0.23 *	0.14	0.36 **	0.13
	without CI	0.27	0.09	0.43 **	0.08
	with CI	0.07	0.13	0.14	0.21
Short-FES-I	total group	−0.18	−0.15	−0.37 **	−0.13
	without CI	−0.08	−0.21	−0.48 **	−0.03
	with CI	−0.25	−0.08	−0.31 *	−0.25
Motor-functional status					
ADL Barthel Index	total group	0.47 **	0.20	0.66 **	0.35 **
	without CI	0.40 **	0.25	0.61 **	0.26
	with CI	0.46 **	0.14	0.65 **	0.47 **
SPPB	total group	0.50 **	0.25 *	0.59 **	0.43 **
	without CI	0.39 **	0.21	0.51 **	0.32 *
	with CI	0.56 **	0.28	0.60 **	0.57 **

Table 3. *Cont.*

		LSA-IS-Proxy Scores			
Variables	**Group**	**Total Score**	**Maximal Life-Space**	**Equipment-Assisted Life-Space**	**Independent Life-Space**
Physical activity					
Duration of activity	total group	0.41 **	0.13	0.55 **	0.29 **
	without CI	0.34 *	0.16	0.47 **	0.24
	with CI	0.38 *	−0.01	0.53 **	0.36 *
Duration of gait	total group	0.53 *	0.19	0.56 **	0.43 **
	without CI	0.46 **	0.24	0.52 **	0.48 **
	with CI	0.58 **	0.10	0.60 **	0.40 **
No. of steps	total group	0.30 **	0.20	0.55 **	0.41 **
	without CI	0.45 **	0.26	0.53 **	0.44 **
	with CI	0.59 **	0.10	0.54 **	0.40 **

Note: Presented are Spearman's rank correlation coefficients, except for gender [1] point-biserial correlation coefficients, showing results for the total group (n = 93)/persons without CI (n = 47)/persons with CI (n = 46). For single variables, size of subsamples deviates depending on feasibility (n = 85–94 for the total group, n = 44–48 for the group without CI, n = 41–46 persons with CI). Abbreviations: AES-C = Apathy Evaluation Scale-Clinical version; CFS = Clinical Frailty Scale; EQ-5D score = EuroQol-questionnaire; LSA-IS = Life-Space Mobility Assessment for Institutionalized Settings; MMSE = Mini-Mental State Examination; PPI = Present Pain Intensity Scale; SPPB = Short Physical Performance Battery; Short-FES-I = Short Falls Efficacy Scale-International. Correlation coefficients (r): small (r = 0.1–0.3), moderate (r = 0.3–0.5), or high (r > 0.5). * $p < 0.05$. ** $p < 0.01$.

3.4. Test-Retest Reliability

Test-retest reliability was excellent to good for the total score and the equipment-assisted and independent life-space sub score, which indicates very stable results for the LSA-IS proxy in general, while the sub-score for maximal life-space showed lower reliability as compared to other scores. Subgroup analysis according to cognitive status confirmed the results for the total group and different LSA-IS scores. In trend, a slightly lower reliability occurred for the subgroup without CI (for detailed results see Table 4).

Table 4. Test–retest reliability of the LSA-IS-proxy.

LSA-IS-Proxy Scores	**Group**	**Mean (SD)**		**ICC (95% Confidence Interval)**
		Test	**Retest**	
Total score	total group	14.45 (8.58)	14.50 (8.74)	0.74 (0.63–0.82)
	without CI	16.32 (10.17)	15.53 (7.95)	0.68 (0.45–0.82)
	with CI	13.01 (6.90)	13.71 (9.31)	0.80 (0.67–0.88)
Maximal life-space	total group	2.31 (0.74)	2.34 (0.81)	0.44 (0.25–0.60)
	without CI	2.43 (0.73)	2.38 (0.64)	0.36 (0.04–0.61)
	with CI	2.21 (0.74)	2.31 (0.93)	0.48 (0.23–0.67)
Equipment-assisted life-space	total group	1.92 (1.04)	1.82 (1.16)	0.76 (0.65–0.83)
	without CI	2.24 (0.93)	2.03 (0.96)	0.52 (0.24–0.72)
	with CI	1.67 (1.06)	1.67 (1.28)	0.86 (0.77–0.92)
Independent life-space	total group	0.48 (0.95)	0.47 (0.91)	0.87 (0.81–0.91)
	without CI	0.57 (1.04)	0.51 (0.90)	0.83 (0.69–0.91)
	with CI	0.42 (0.87)	0.44 (0.92)	0.91 (0.84–0.95)

Note: Presented are Intraclass Correlation Coefficients for the total group (n = 85) and subgroups according to cognitive status (without cognitive impairment (CI) n = 37, with CI n = 48). LSA-IS = Life-Space Mobility Assessment for Institutionalized Settings. ICC = Intraclass Correlation Coefficient (<0.4 = poor, 0.4–0.74 = fair to good, >0.75 = excellent).

3.5. Sensitivity to Change

The mean duration between hospital admission and discharge and discharge was 18.5 (7.9) days (with CI: 20.1 (9.1) vs. without CI: 16.9 (6.1)). The total score and sub-scores for equipment-assisted and maximal life-space showed significant improvements over this treatment period for the total group and subgroups (single exception: maximal life-space, subgroup without CI), while for the sub-score for independent life-space no significant change could be documented. Overall, sensitivity to change was small to moderate for all LSA-IS-proxy scores (SRM = 0.32–0.58), except for the results for the independent life-space sub score (SRM = 0.07–0.13). Results for the subgroups differentiated with respect to cognitive status were comparable for all scores, with a trend for slightly higher values in the group of persons with CI (SRM = 0.17–0.58) compared to the group of persons without CI (SRM = 0.07–0.45). Results are shown in Table 5.

Table 5. Sensitivity to change of the LSA-IS-proxy.

LSA-IS-Proxy Scores	Group	Mean (SD)		*p*-Value	SRM
		Baseline	Post-Intervention		
Total score	total group	13.80 (7.87)	17.70 (9.40)	>0.001	0.44
	without CI	15.13 (8.90)	18.52 (8.34)	0.048	0.39
	with CI	12.78 (6.92)	17.08 (10.21)	>0.001	0.45
Maximal life-space	total group	2.17 (0.73)	2.54 (0.80)	0.001	0.47
	without CI	2.27 (0.74)	2.50 (0.73)	0.109	0.32
	with CI	2.10 (0.72)	2.56 (0.85)	0.006	0.58
Equipment-assisted life-space	total group	1.83 (0.94)	2.23 (1.09)	>0.001	0.40
	without CI	1.93 (0.98)	2.37 (0.96)	0.021	0.45
	with CI	1.74 (0.91)	2.13 (1.17)	0.002	0.35
Independent life-space	total group	0.46 (0.88)	0.59 (1.06)	0.151	0.13
	without CI	0.50 (0.97)	0.57 (0.97)	0.601	0.07
	with CI	0.44 (0.82)	0.62 (1.14)	0.164	0.17

Note: Presented are the results of effects of early ward-based complex geriatric rehabilitation on LSM for the total group (n = 69) and subgroups according to cognitive status (without cognitive impairment (CI) n = 30, with CI n = 39). Only participants that were tested at baseline and directly before discharge were included. Abbreviations: LSA-IS = Life-Space Mobility Assessment for Institutionalized Settings, SRM = standardized response mean.

3.6. Feasibility

No missing values were documented and 100% of assessments performed in both subgroups were successful. Results for the LSA-IS-proxy total score ranged from 2 to 44, out of a range from 0 to 120 score points, indicating no ceiling or floor effects. The distribution of the LSA-IS-proxy total score was skewed, with a median score of 12 points, suggesting a highly restricted LSM as expected in the multi-morbid, vulnerable sample in the hospital setting. The range of results differed between subgroups. In persons without CI a range of 3 to 44 scores, in persons with CI, a range of 2 to 26 was documented.

None of the participants reached the maximal life-space zone without equipment or personal assistance, and only 2.1% achieved life-space level 5 with assistance by other persons, indicating no ceiling effects for the sub-scores. The lowest possible score 0 was reached by 0% for the maximal sub-score, 20.2% for the equipment-assisted sub-score, and 77.7% for the independent sub-score, indicating floor effects for the equipment-assisted and independent LSA-IS-proxy sub-scores with more than 15% of participants achieving the lowest possible score.

Feasibility for subgroups according to cognitive status was similar for most variables except for floor effects in the equipment-assisted sub-score which were more apparent in persons with (30.4%) than without CI (10.4%). Floor effects for the independent sub-score were comparable in both subgroups (with CI: 77.1%, without CI: 78.3%). Overall, the results for the subgroups confirm the excellent feasibility results as achieved in the total group.

4. Discussion

Results of the present study documented an overall good concurrent and construct validity, test-retest-reliability, sensitivity to change, and feasibility of the newly developed proxy-based version of the LSA-IS. Results for LSA-IS-proxy sub-scores were in line with most results of the total score. Results for subsamples according to cognitive status were comparable for most included variables or different biometrical properties. The high completion rate confirms excellent feasibility for application in research or clinical routines.

4.1. Concurrent Validity

For this study, the analysis of concurrent validity was included, targeting a psychometric property not analyzed before for LSM assessments in institutionalized persons by comparing the proxy-based with the self-reported version for the same persons, period, and the setting within the same study. The only study analyzing concurrent validity of a proxy-based against a self-reported version of an LSM assessment also reported an excellent level of agreement for the UAB-LSA. However, study participants were healthy, ambulatory community-dwelling elderly without acute illness, and the analysis was only based on the UAB-LSA total score [33], limiting the comparability. Another study compared the NHLDS with a home-based Life-Space Assessment with good concurrent validity, with both tools using proxy reporting [55]. The on-average good absolute agreement for the total score, as well as the sub-scores in the present study, indicated a high assessment standard for both measures. Similar results could be achieved by two optimized assessment strategies specifically tailored for the target population represented by an interview-based self-report with supportive interview strategies [21], as compared to a proxy report by an assessor engaged in daily ward routines and organization with detailed information on patients' activities as in the present study. Overall, results did not differ substantially between subgroups of participants according to cognitive status indicating that the proxy-based and the self-report version of the LSA-IS have successfully been developed to accurately document LSM even in vulnerable persons with CI. Although a high concurrent validity could be documented, we do not suggest a mix of both assessment methods, representing a flawed methodological approach for data on physical ability [56]. As both versions did not differ substantially for results and both present with overall good validity in multi-morbid patients with and without CI, an assessment by independent methods is preferable.

4.2. Construct Validity

For construct validation of the LSA-IS-proxy, we used construct variables from different domains relevant for the hospital setting within a comprehensive framework of mobility [1]. Based on their relevant association to LSM as documented in previous comparable studies [21,34,48,49,57] and oriented on an established mobility framework [1], different levels of associations to included domains were hypothesized. Present results for construct validity were in line with these assumptions between construct variables and the LSA-IS-proxy, documenting good construct validity. As expected for demographic, cognitive, psychosocial, and health status, significant moderate associations could be identified. Frailty status and age stood out among these variables and are in line with previous results for associations of physical activity and aging [58–60]. The lower associations of non-motor domains were expected as these variables represent "distant" domains to spatial behavioral activity measures such as the LSA-IS-proxy. As hypothesized, motor-functional status and physical activity showed moderate to high associations that were significant for all construct variables out of the common motor domain. Results were in line with previous comparable validation studies of LSM assessments (UAB-LSA, LSA-CI, NHLSD) in community-dwelling [34,49,57] or institutionalized older persons [21,22]. Tinetti & Ginter showed high associations of the NHLSD with specific diseases, while the focus in the present study laid on the functional performance [22]. In another study with a new framework for LSM, aspects of psychosocial status such as aspirations and plans or the motivation to be mobile were shown to be important for LSM [61] and might also have relevance for LSM in institutions but have not been implemented in the present study. Established associations between selected construct variables might be harder to observe in an institutionalized setting as compared to the community-dwelling setting. In an institutionalized setting, the life-space and its use are much more restricted by organizational or medical/ therapeutic routines, which in general, address all persons in such a setting [13], thereby equalizing potential effects as represented by the construct variables. Documented significant associations can therefore be considered hard evidence for the construct validity of the LSA-IS-proxy.

The sub-scores on the equipment-assisted and independent life-space followed the results for the total score. In trend, lower associations were documented for the maximal life-space sub-score, especially for associations with variables from the common motor domain. The lower association may relate to the infrequency of maximal mobility in multi-morbid, high aged, geriatric patients during acute, ward-based medical care with highly standardized organizational and therapeutic routines with less individual freedom to roam the life-space available in a hospital setting.

Good results for construct validity did not differ substantially between subgroups with and without CI in most included variables, documenting good validity in persons with moderate to more advanced cognitive impairment, who represent a high percentage if not most patients in geriatric hospitals, as well as other institutionalized settings [17,62].

4.3. Test-Retest Reliability

We found a good to excellent test-retest reliability for the total score, as well as the equipment-assisted and independent life-space sub-score, indicating high reliability for the LSA-IS-proxy in general. Only the sub-score on the maximal life-space showed lower reliability. Results are comparable to those reported in previous studies on LSM assessments (UAB-LSA, LSA-CI) in community-dwelling older persons [34,49] and the previously published study on the self-reported versions of the LSA-IS in a geriatric hospital setting [21]. The maximal life-space sub-score was implemented in the LSA-IS for good reasons to cover activities in the patients with above-average mobility and to prevent potential ceiling effects from a methodological perspective. The lower reliability may relate to the above-discussed range of maximal life-space in in-hospital settings, which also included distant areas of hospital-based mobility, such as walks to the cafeteria or the hospital vicinity. Such events are not part of hospital routines and depend on external support by proxies. By their infrequent and random nature, they reduce test-retest reliability especially so when tested in a short period but may not document a methodological limitation of the assessment [63,64].

Results of subgroups by cognitive status were comparable in general with a trend for lower reliability in persons without CI. The marginal differences might be based on the slightly superior functional status of the cognitively intact subgroup (see Table 1), allowing a wider range of mobility with the potential of an increased day-to-day variability with a potentially detrimental effect on test-retest reliability.

4.4. Sensitivity to Change

Most LSA-IS proxy scores significantly increased over the relatively short treatment period, indicating a global sensitivity to change of the assessment method with an unspecific intervention for life-space changes and a well-documented risk for hospital-associated functional decline during acute medical geriatric care [56]. Most other validation studies of LSM assessment instruments did not analyze this psychometric property which is mandatory to document the effects of interventions in research or clinical practice.

The comparison to the few previously published studies is partly limited using different statistical strategies, study design, and settings. In community-dwelling persons, Baker et al. demonstrated sensitivity to change of the UAB-LSA over time within a longitudinal, observational study design using only descriptive statistics [34]. Ullrich et al. reported comparable sensitivity to change for the LSA-CI to detect intervention-induced effects of an activity promotion program by established statistical methods as used in the present study [49]. The directly comparable study by Hauer et al. documented similar sensitivity to change for the self-report version of the LSA-IS-proxy [21]. In the present study, sensitivity to change was small to moderate for the main total score and the maximal and the equipment-assisted life-space sub-scores.

The LSA-IS-proxy documented effects of a ward-based geriatric rehabilitation, which was not primarily targeted to increase in-hospital life-space but led to significant improvements to the extent of LSM based on effects of the functional training and use of technical or personal support as part of the early, multidisciplinary geriatric rehabilitation treatment.

The lowest sensitivity to change was observed for the sub-score on the independent life-space. Only a minority of higher functioning patients not dependent on external support qualified for this sub-score, contrasting on average the low health status of geriatric patients and the mandatory ambulation support of multi-morbid persons within hospitals [65], often requested by insurance regulations even in higher functioning persons. The somewhat lower sensitivity of the independent sub-score may therefore be an indicator of a small subgroup of patients with higher functional status, resulting in a smaller intervention effect and also statistical effect of the basic early rehab training, which focuses on very basic functional limitations.

In line with other psychometric properties evaluated in this study, we found no relevant differences between subgroups with and without cognitive impairment, indicating good sensitivity to change irrespective of the cognitive status. The slightly higher sensitivity to change observed for the subgroup with CI may be based on the often-documented dose-response effect of training resulting in higher training gains for persons with initially lower motor status [66,67], as present in the subgroup with CI, than for persons with higher motor status when a standardized training is applied [68,69].

4.5. Feasibility

Excellent feasibility of the LSA-IS-proxy was documented based on the 100% completion rate and the complete lack of missing values in a very frail, multi-morbid population during acute medical, ward-based treatment with high failure risk for assessments. The external proxy-based approach by a trained assessor involved in daily routines of the patients guaranteed the completeness and the accuracy of reporting even when including persons with mild to more advanced stages of CI and other potential limitations with respect to self-reporting (e.g., fatigue, pain, delirium, etc.). Based on the chosen strategy by proxy reporting, no relevant differences for feasibility were documented between subgroups with and without CI. The highly organized setting with restricted degrees of freedom for mobility following standardized in-hospital routines, which are easy to document, may also have further supported proxy-based documentation to achieve this extraordinary result.

The LSA-IS-proxy was tailored to the target group, resulting in no ceiling or floor effects for the main total score, which has also been documented for the NHLSD [22], indicating excellent applicability of LSM measures to document mobility status. To prevent potential ceiling effects in persons with higher functional status, the LSA-IS includes extramural life-space areas that extend beyond the institution to document the crucial clinical transition from supervised indoor to demanding outdoor activity. These marginal areas for an institutional setting have also been included by comparable questionnaires (e.g., NHLSD) [22] or sensor-based life-space assessment [14] for the same reasons. In the present study, no relevant ceiling effects occurred in all scores/sub-scores confirming results of previous validation studies of LSM assessments with similar hierarchically structured categories of life-space zones [34,49].

We found relevant floor effects in the equipment-assisted or independent life-space sub scores. Results mirror the low health status of the multi-morbid, acutely affected study population partly not being able to be active without (independent sub-score) or even with support (equipment-assisted sub-score), leading to the documented floor effects comparable to the self-reported version of the LSA-IS or the LSA-CI [21,49]. We interpret the low LSM as a highly relevant, but so far neglected marker for health status rather than a methodological shortcoming of the assessment. The trend for low LSM was more prevalent for the equipment-assisted life-space in the subgroup with CI, confirming the ability to detect parameters highly associated with low physical and cognitive function, levels of support, and quality of life, such as life-space in more affected populations as persons with CI [21,49].

4.6. Limitations

The present study analyzed the LSA-IS-proxy's psychometric properties in a geriatric hospital setting. Although the LSA-IS-proxy has been developed for generic use, formally, the generalizability of study results may have to be confirmed for other settings such as ward-based rehabilitation, nursing homes, or other comparable environments. Although the LSA-IS documents LSM of a multi-morbid, sedentary population with multiple restrictions of life-space leading to floor effects in related assessments, floor effects as documented for single sub-scores may formally represent a limitation of the assessment method.

5. Conclusions

The LSA-IS-proxy showed on average good feasibility, validity, reliability, and sensitivity to change in a most vulnerable population of multi-morbid, hospitalized geriatric patients irrespective of their cognitive status. Although not analyzed in the present study, the overlap of a hospital, rehabilitation, and nursing home settings with respect to organizational structures and the frail, multi-morbid populations may allow the use of the assessment in these institutionalized environments. However, a future formal repetition of the validation process may further document and analyze the biometrical quality of the LSA-IS-proxy in these different settings.

The proxy-based version ideally amends the self-reported version of the LSA-IS [21] in handicapped populations with various restrictions for accuracy and feasibility of reporting. Along with the self-report version, the LSA-IS proxy assessment allows for the first time, comprehensive and detailed documentation of life-space in a hospital setting with methodological specifications based on its organizational structure and the vulnerable health status of multi-morbid patients, including persons with cognitive impairment.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph18083872/s1, Life-Space Assessment in Institutionalized Settings (proxy LSA-IS) questionnaire form, and Life-Space Assessment for Persons in institutionalized settings reported by a Proxy (LSA-IS proxy)-User Manual/instructions.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the University of Heidelberg (S-709/2018) on 7 November 2018.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets generated and/or analyzed during the current study are not publicly available as the ethical vote did not include open data access but are available from the corresponding author on reasonable request.

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Life-space mobility in older persons with cognitive impairment after discharge from geriatric rehabilitation

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A R T I C L E I N F O

Keywords:
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A B S T R A C T

Objectives: To describe life-space mobility and identify its determinants in older persons with cognitive impairment after discharge from geriatric rehabilitation.

Methods: A cross-sectional study in older community-dwelling persons with mild to moderate cognitive impairment (Mini-Mental State Examination, MMSE: 17–26) following geriatric rehabilitation was conducted. Life-space mobility (LSM) was evaluated by the Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI). Bivariate analyses and multivariate regression analyses were used to investigate associations between LSM and physical, cognitive, psychosocial, environmental, financial and demographic characteristics, and physical activity behavior.

Results: LSM in 118 older, multimorbid participants (age: 82.3 ± 6.0 years) with cognitive impairment (MMSE score: 23.3 ± 2.4 points) was substantially limited, depending on availability of personal support and equipment. More than 30% of participants were confined to the neighborhood and half of all patients could not leave the bedroom without equipment or assistance. Motor performance, social activities, physical activity, and gender were identified as independent determinants of LSM and explained 42.4% (adjusted R^2) of the LSA-CI variance in the regression model.

Conclusion: The study documents the highly restricted LSM in older persons with CI following geriatric rehabilitation. The identified modifiable determinants of LSM show potential for future interventions to increase LSM in such a vulnerable population at high risk for restrictions in LSM by targeting motor performance, social activities, and physical activity. A gender-specific approach may help to address more advanced restrictions in women.

1. Introduction

The ability to move independently where and when a person wants to move is relevant for challenges in everyday life (Satariano et al., 2012), quality of life (Metz, 2000), and participation in society and natural environment (Barnes et al., 2007; Rosso, Taylor, Tabb, & Michael, 2013). In the course of progressive cognitive decline complex activities, such as outdoor activities, are the first to be lost (Njegovan, Hing, Mitchell, & Molnar, 2001). Especially older persons are, as a consequence of physical and cognitive decline, at high risk for reduced community mobility (Gill, Gahbauer, Murphy, Han, & Allore, 2012), being homebound (A. R. Smith, Chen, Clarke, & Gallagher, 2016), or institutionalized (Luppa et al., 2010; Sheppard, Sawyer, Ritchie, Allman, & Brown, 2013). To sustain social networks and familiar environment, most of older persons prefer to "age in place" (Gitlin, 2003). Thus maintaining or improving mobility in and out of home is particularly important as a prerequisite for independence.

Webber, Porter, & Menec (2010) developed a theoretical framework, which depicts mobility – broadly defined as life-space mobility (LSM) – to be influenced by physical, cognitive, psychosocial, financial and environmental factors embedded by influences of gender, cultural and biographical aspects (Webber et al., 2010). The framework has been successfully tested in older persons (Umstattd Meyer, Janke, & Beaujean, 2014) and has been supported by empirical research that provide evidence for relationships between the individual factors and LSM in older community-dwelling persons: Associations with LSM have

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been found for relative stable or immutable factors including sociodemographic variables such as age (Al Snih et al., 2012; Suzuki, Kitaike, & Ikezaki, 2014), gender (Peel et al., 2005; Phillips, Dal Grande, Ritchie, Abernethy, & Currow, 2015), marital status (Phillips et al., 2015), educational level (Eronen et al., 2016; Phillips et al., 2015), or financial situation (Peel et al., 2005; Phillips et al., 2015), as well as environmental conditions such as housing standard, living environment (Rantakokko, Iwarsson, Portegijs, Viljanen, & Rantanen, 2015), or weather conditions (Portegijs, Iwarsson, Rantakokko, Viljanen, & Rantanen, 2014). Associations were also found for variable or modifiable factors including health-related factors such as physical performance or medical diagnoses (Al Snih et al., 2012; Peel et al., 2005; Phillips et al., 2015), hospitalization (Brown et al., 2009), which constitutes also a risk factor for institutionalization (Goodwin, Howrey, Zhang, & Kuo, 2011), psychosocial status documented as fear of falling (FOF), depression, apathy, or social involvement (Al Snih et al., 2012; Auais et al., 2017; Peel et al., 2005; Uemura et al., 2013), global cognitive status (Peel et al., 2005), and domain-specific cognitive functions (processing speed) (Uemura et al., 2013). Physical activity (PA), itself influenced by physical, cognitive and psychosocial factors and environmental conditions (Franco et al., 2015; Stubbs et al., 2014), has also been closely linked to LSM (Portegijs, Tsai, Rantanen, & Rantakokko, 2015; Sawyer & Allman, 2010; Tsai et al., 2015), representing - as well as LSM - an aspect of movement behavior. Among the factors that have been related to LSM, motor and functional performance stand out as major determinant for LSM in older adults (Al Snih et al., 2012; Peel et al., 2005). Overall, accumulation of deficits, such as motor and cognitive impairments, might be associated with an accumulation of restrictions in LSM and an extraordinary risk of losing independence and autonomy. Studies in populations associated with multiple risk factors for LSM restrictions are, however, lacking. Previous studies most frequently focused on healthy older individuals (Al Snih et al., 2012; Peel et al., 2005), and only few studies addressed subgroups with single risk factors, such as orthopedic disorders (Suzuki et al., 2014), hospitalization (Brown et al., 2009), or persons with amnestic mild cognitive impairment (Uemura et al., 2013). Some studies assessed life-space (LS) in persons with CI using a questionnaire (Stalvey, Owsley, Sloane, & Ball, 1999) or GPS-based tracking devices (Tung et al., 2014), though these measures do not include frequency, the use of equipment or assistance, or indoor activity and are therefore not comparable. LSM was usually assessed via self-administered questionnaires with rather long retrospective assessment periods (Brown et al., 2009; Peel et al., 2005). However, the use of such questionnaires in cognitively impaired persons may hamper the accuracy of LSM documentation, as declining cognitive abilities (e.g., memory impairment, loss of orientation in time and locus) are associated with relevant recall bias (Bhandari & Wagner, 2006), which may have resulted in the exclusion of older people with cognitive impairment (CI) from most previous studies. To cope with such limitations and to document LSM in persons with CI, an interview-based assessment tool adjusted to their specific requirements has recently been developed and successfully validated for use in this population group closing this methodological gap (Ullrich et al., 2018).

In summary, the objectives of the study were to describe the LSM in older patients with mild to moderate CI after geriatric rehabilitation, representing a highly vulnerable population with multiple risk factors, and to investigate potential determinants of LSM in this population.

2. Methods

2.1. Study design

The present study is based on cross-sectional baseline data from a double-blinded, randomized, placebo-controlled trial (RCT) to improve motor performance and PA in older patients with mild to moderate CI discharged from geriatric rehabilitation (ISRCTN82378327; (Bongartz et al., 2017). The RCT was approved by the ethics committee of the Medical Department of the Heidelberg University (S-252/2015) in accordance with the Declaration of Helsinki and was registered at www.isrctn.com (ISRCTN82378327).

2.2. Recruitment and participants

Participants were recruited consecutively from rehabilitation wards of a German geriatric hospital between September 2015 and April 2017. Eligible participants were assessed for CI using the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). Only individuals with MMSE scores of 17 to 26, indicating mild to moderate CI, were included in the study (Monsch et al., 1995). Further inclusion criteria to participate in the RCT were: age ≥ 65 years; ability to walk at least 4 m without a walking aid; residence within 30 km of the study center; discharge to the patients' home (i.e., no nursing home residents); no terminal disease; no delirium; German-speaking, and written informed consent.

2.3. Measurements

The measurements were conducted right before randomization and start of the intervention. Only tests established in geriatric assessment and validated in older persons and if available in cognitively impaired individuals were used.

2.3.1. Life-space assessment

LSM was assessed using the Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI), a modified version of the University of Alabama at Birmingham Study of Aging Life-Space Assessment (UAB-LSA) (Baker, Bodner, & Allman, 2003) specifically developed and validated for use in persons with CI (Ullrich et al., 2018). The assessment captures the life-space (LS) zones (from bedroom = 0, home = 1, immediate surroundings of one`s home = 2, neighborhood = 3, home town = 4 to unlimited area = 5) within the previous week, the frequency of mobility for each zone (1 = "1–3 times per week", 2 = "4-6 times per week", 3 = "daily"), and the assistance needed to travel within a zone (1 = "help of another person", 1.5 = "use of assistive device only", 2 = "no assistance"), while using an interview technique specifically developed for older people with CI (Ullrich et al., 2018). A composite score can be calculated by multiplying the zone score with scores for frequency and assistance, and then adding the scores for each zone. The lowest LSA-CI score of 0 indicates total immobility and the maximum LSA-CI score of 90 indicates daily independent out-of-town mobility. The LSA-CI covered also subscores (range 0–5) for (1) the maximum LS zone achieved without any assistance, or with equipment or personal assistance (LSA-CI-M); (2) the maximum LS zone achieved with equipment (e.g. walking sticks, rollator), if needed, but without personal assistance (LSA-CI-E), and (3) the maximum LS zone achieved independently without equipment and without personal assistance (LSA-CI-I). To extract the role of the specific assistance (i.e., equipment, personal assistance) in individual's LS, we developed two new subscores in addition to the established subscores based on the available LSA-CI data. The subscore (a) for the LS increased due to the assistance by another person (LSA-CI-AP) was calculated by subtracting the equipment-assisted from the maximal LS score (i.e. LSA-CI-M – LSA-CI-E) and subscore (b) for the LS increased due to the assistance by equipment (LSA-CI-AE) was calculated by subtracting the independent from the equipment-assisted LS score (i.e. LSA-CI-E – LSA-CI-I). By this approach, we were able to document the specific effect of personal assistance and equipment, respectively, which represents a novel perspective for LSA assessment.

2.3.2. Potential determinants of life-space mobility

Based on the mobility framework by Webber et al. (2010), physical, cognitive, psychosocial, environmental, and financial status and gender, cultural and biographical variables were assessed to examine their associations with LSM. Physical variables included the Short Physical Performance Battery (SPPB) for the assessment of motor performance (Guralnik et al., 1994), the number of diagnoses as documented in patient charts indicating multimorbidity, and the Body Mass Index (BMI) documenting relative weight. Cognitive status was assessed using the Mini-Mental State Examination (MMSE) (Folstein et al., 1975). To assess different domains of psychosocial status we used the Falls Efficacy Scale – International (FES-I) (Hauer et al., 2011), the Fear of Falling Avoidance-Behavior Questionnaire (FFABQ) (Landers, Durand, Powell, Dibble, & Young, 2011; translated according to Beaton, Bombardier, Guillemin, & Ferraz (2000), stage 1–4), the 15-item version of the Geriatric Depression Scale (GDS) (Allgaier, Kramer, Mergl, Fejtkova, & Hegerl, 2011; Greenberg, 2007), the Apathy Clinical Evaluation Scale – Clinical Version (AES-C) (Lueken et al., 2006; Marin, Biedrzycki, & Firinciogullari, 1991), and the total duration of private, unpaid care by family members or friends within the previous three months (one item of a questionnaire for health-related resource use (Seidl et al., 2015)). A questionnaire for the assessment of the social situation (Erhebungsbogen SOziale Situation - SOS) (Nikolaus, Specht-Leible, Bach, Oster, & Schlierf, 1994) with four components was used to measure social contacts (including frequency, quantity and quality of relationships to other persons), social activities (existence and development of hobbies/interests), living situation (including indoor and outdoor aspect of the living situation such as comfort, barriers, infrastructure, duration of residence), and financial status (addressing the self-related sufficiency of actual income and the existence of savings). To complement environmental status in addition to living situation, weather data comprising mean temperature, precipitation height and snow depth for each of the subject`s assessment period were recorded at the weather station closest to the study center. Sociodemographic characteristics including age and gender were documented from patient charts, educational and marital status were assessed by standardized interviews. PA was assessed by the number of steps within 48 h measured with a body-fixed accelerometer (PAMSys™, BioSensics, Cambridge, MA, USA), using a validated algorithm for older persons (Najafi et al., 2003). For sample description, also falls in the previous year were documented by standardized interview (Zieschang, Schwenk, Becker, Oster, & Hauer, 2012).

2.4. Statistical analysis

Descriptive data are presented as frequencies and percentages for categorical variables, and means and standard deviations or median and range for continuous variables as appropriate. Differences in descriptive variables and LSA-CI scores between participants who received and those who did not receive personal assistance or equipment were analyzed by unpaired t-tests for continuous variables and chi-square tests for categorical variables. To identify potential determinants of LSM, we calculated bivariate correlation coefficients (Spearman (r_s) and point-biserial (r_{pb}) correlation coefficients) between LSA-CI composite score and variables for physical (SPPB, number of diagnoses, BMI), cognitive (MMSE), psychosocial (FES-I, FFABQ, GDS, AES-C, social contacts and social activities – SOS, duration of private unpaid care), environmental (living situation - SOS), financial (financial situation - SOS), sociodemographic status (age, gender, marital status, educational level), and total amount of PA (number of steps). Correlation coefficients (r) were interpreted as low ($r < 0.2$), moderate ($r = 0.2–0.5$), or high ($r > 0.5$) (Cohen, 1988). Variables that showed significant correlations ($p < 0.05$) were entered in a standard multiple linear regression analysis to examine independent determinants of LSM. Potential multicollinearity of independent variables was taken into account defined as correlation coefficients among independent variables $r > 0.7$ (Kleinbaum & Kupper, 1978) and a variance inflation factor (VIF) < 10 (Chatterjee & Hadi, 2013). Appropriateness of further assumptions of linear regression models of homoscedasticity and normality of the residuals (Ernst & Albers, 2017) and autocorrelation was considered. Two regression models were constructed: Model 1: a basic model including significant correlated variables for physical, cognitive, psychosocial, environmental, financial status, and sociodemographic influences oriented at the model by Weber et al (Webber et al., 2010); Model 2: all status-based variables from model 1 amended by a quantitative parameter for movement behavior (number of steps). Beta weights for all independent variables included in the regression equations (range of values: −1 to 1) and adjusted R^2 (including p-values for significance) for the total model were analyzed. A p-value < 0.05 was considered statistically significant. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 23 for Windows (IBM Corp., NY, USA).

3. Results

3.1. Participant characteristics

Out of 1981 patients screened for eligibility, 118 community-dwelling individuals were enrolled according to predefined inclusion criteria. The study sample comprised multimorbid (number of diagnoses = 11.4 ± 4.4), older patients (82.3 ± 6.0 years) with motor (SPPB = 5.2 ± 2.3) and cognitive impairment (MMSE = 23.3 ± 2.4), and mild depressive (GDS = 5.3 ± 3.0) and apathetic (AES-C = 40.2 ± 9.1) symptoms approximately 7.5 weeks (45.7 ± 47.1 days) after discharge from geriatric rehabilitation. Further sample characteristics are detailed in Table 1.

3.2. Description of life-space mobility

Based on 117 participants (one participant was excluded due to unrealistic statements, advanced disorientation, and confabulation), the mean LSA-CI composite score was 23.9 ± 13.2 within a range of 4.5 to 70 out of a maximum score of 90 (Table 2) with mainly highly restricted and dependent persons as well as a few relatively unrestricted and independent persons (Fig. 1). Results for LSA-CI subscores differed substantially (Table 2), depending on the degree of assistance with the highest scores when support by equipment or another person was included (LSA-CI-M), substantially lower scores for the LS achieved with equipment but without personal assistance (LSA-CI-E), and very low scores for the LS achieved independently without any assistance by equipment or another person (LSA-CI-I). The maximum LS achieved (LSA-CI-M), independent of the degree of assistance, indicated an activity area between the neighborhood (= LS zone 3) and the hometown (= LS zone 4) (LSA-CI-M = 3.7 ± 1.2). Despite support from another person or equipment, seven participants (6.0%) were completely homebound (LSA-CI-M ≤ 1) and 38 participants (32.5%) were restricted to their neighborhood (LSA-CI-M ≤ 3; Table 3). The equipment-assisted LS score (LSA-CI-E) showed that without personal assistance LS decreased substantially by more than one LS zone (-1.1 ± 1.3) and covered an area between the immediate surroundings of the home (= LS zone 2) and the neighborhood (= LS zone 3) (LSA-CI-E = 2.5 ± 1.2; Table 2). Further analysis of the LS achieved with equipment showed that more than half of the participants (n = 70, 59.8%) were bound to the immediate surroundings of the home (≤ LS zone 2), and more than three fourths (n = 90, 76.9%) were restricted to the neighborhood (≤ LS zone 3; Table 3). The LS achieved independently without any assistance (LSA-CI-I) was on average restricted to the home (= LS zone 1) (LSA-CI-I = 1.1 ± 1.4; Table 2). A closer look at the independent LS revealed that - without equipment or personal assistance - half of all participants (n = 58, 49.6%) were not able to leave their bedroom, overall 84.7% (n = 99) were restricted to the immediate surroundings of the home (LSA-CI-I ≤ 2), and 92.4% (n = 108) were restricted to their neighborhood (LSA-CI-I ≤ 3; Table 3). The analysis of the specific benefit from personal assistance (LSA-CI-AP) revealed that more than half of all participants (n = 63,

Table 1
Sample characteristics.

Characteristics	Variables	n = 118
Physical status	SPPB Score (0–12), mean (SD)	5.2 (2.3)
	Number of diagnoses, mean (SD)	11.4 (4.4)
	Body Mass Index, mean (SD)	27.3 (5.3)
	At least one fall in the previous year, n (%)	79 (67)
Cognitive status	MMSE Score (0–30), mean (SD)	23.3 (2.4)
Psychosocial status	Social Contacts Score (0–6; SOS), mean (SD)	5.4 (0.7)
	Social Activities Score (0–5; SOS), mean (SD)	2.5 (1.1)
	FES-I Score (7–28), median (range)	11 (7-25)
	FFABQ Score (0–56), mean (SD)	18.5 (12.6)
	GDS Score (0–15), mean (SD)	5.3 (3.0)
	AES-C Score (18–72), mean (SD)	40.2 (9.1)
Environmental status	Living situation (0–11), mean (SD)	8.7 (1.4)
Sociodemographic status	Age (years), mean (SD)	82.3 (6.0)
	Gender (female/male), n (%)	90(76.3) / 28(23.7)
	Marital status (married/not married), %	30.5/69.5
	Educational level (only school/vocational education/ university or comparable), %	31.4/50.0/18.6
Physical activity	Number of steps per day, mean (SD)	2843 (2264)

Presented are the characteristics of the study sample. *Abbreviations:* AES-C: Apathy Evaluation Scale – Clinical Version; FES-I: Falls Efficacy Scale – International; FFABQ: Fear of falling Avoidance Behavior Questionnaire; GDS: Geriatric Depression Scale; MMSE: Mini Mental State Examination; SOS: Questionnaire on social status; SPPB: Short Physical Performance Battery.

Table 2
Results of life-space assessment in persons with cognitive impairment.

LSA-CI score	Mean	(SD)	Median	Range
LSA-CI composite score (-C)	23.9	(13.2)	20.5	4.5–70
LSA-CI maximal score (-M)	3.7	(1.2)	4.0	1–5
LSA-CI equipment assisted score (-E)	2.5	(1.2)	2.0	1–5
LSA-CI independent score (-I)	1.1	(1.4)	1.0	0–5

Presented are results of the LSA-CI composite score and subscores; n = 117, one measurement had to be excluded due to unrealistic statements by the patient. *Abbreviations:* LSA-CI = Life-Space Assessment for Persons with Cognitive Impairment.

Table 3
Subscore analysis - Life-space zones and part of persons that reached maximal the respective zone.

Life-space zone	LSA-CI-M	LSA-CI-E	LSA-CI-I
0 (bedroom)	0 (0.0)	1 (0.9)	58 (49.6)
1 (home)	7 (6.0)	19 (16.2)	20 (17.2)
2 (immediate surroundings of the home)	20 (17.1)	50 (42.7)	21 (17.9)
3 (neighborhood)	11 (9.4)	20 (17.1)	9 (7.7)
4 (home town)	45 (38.5)	17 (14.5)	5 (4.3)
5 (unlimited area)	34 (29.1)	10 (8.5)	4 (3.4)

Presented are subscore analyses and the number of persons (percentage of persons) that reached maximal the respective zone; Abbreviations: LSA-CI-M = maximum life-space with equipment or personal assistance if needed; LSA-CI-E = maximum life-space with equipment if needed; LSA-CI-I = maximum independent life-space without equipment or personal assistance.

53.8%) increased their maximal LS through personal assistance, with more than two thirds of them (n = 45) showing an increase of at least two LS zones (Table 4). Participants who benefitted from personal assistance showed a significantly higher maximal LS (LSA-CI-M, $p < 0.001$), but a lower equipment-assisted (LSA-CI-E, $p < 0.001$) and independent LS (LSA-CI-I, $p = 0.004$), a lower motor performance (SPPB) ($p = 0.038$), and were mostly female ($p = 0.015$) compared to those who did not receive personal assistance (n = 54, 46.2%), indicating that personal assistance may be related to decreased functional status. No significant differences between these two groups were found

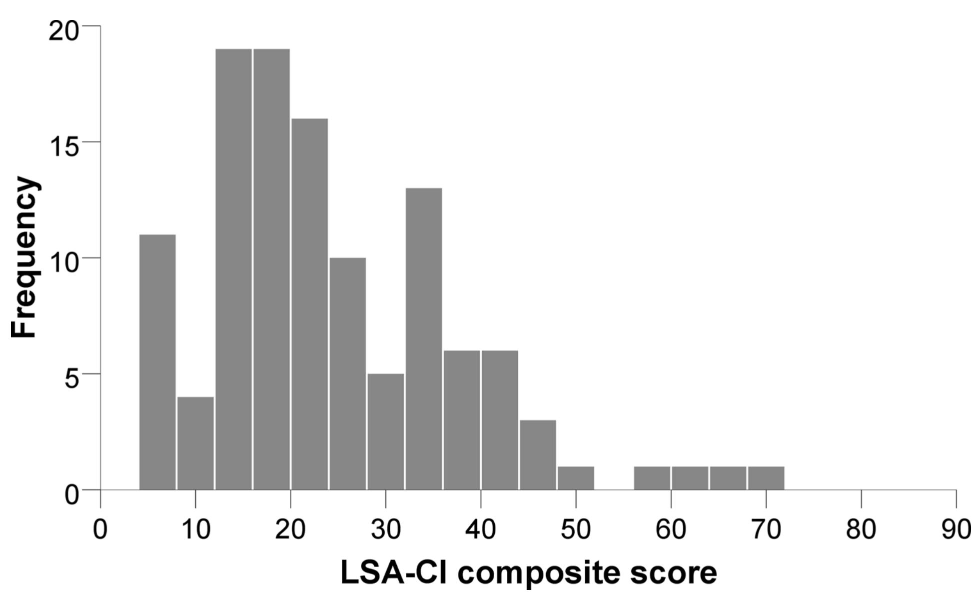

Fig. 1. Histogram of the LSA-CI composite score for the sample of 117 multimorbid, older people with cognitive impairment.

Table 4
Use of and benefit from personal assistance and equipment.

Increase of life-space zone by…	LSA-CI-AP, n (%)	LSA-CI-AE, n (%)
+ 0	54 (46.2)	38 (32.5)
+ 1	18 (15.4)	20 (17.1)
+ 2	24 (20.5)	41 (35.0)
+ 3	18 (15.4)	8 (6.8)
+ 4	2 (1.7)	8 (6.8)
+ 5	1 (0.9)	2 (1.7)

Presented are increases in life-space zones due assistance by a person or equipment. Abbreviations: LSA-CI-AP = life-space increased in persons with cognitive impairment due to assistance by a person; LSA-CI-AE = life-space increased in persons with cognitive impairment due to assistance by equipment.

Table 5
Differences between persons using and benefitting from personal assistance (LSA-CI-AP) and persons using and benefitting from equipment (LSA-CI-AE).

	LSA-CI-AP		LSA-CI-AE	
Group difference with respect to:	LSA-CI-AP ≥ 1 vs. LSA-CI-AP = 0	p	LSA-CI-AE ≥ 1 vs. LSA-CI-AE = 0	p
LSA-CI-C	23.0 vs. 25.0	.409	26.9 vs. 22.5	.113
LSA-CI-M	4.2 vs. 3.0	**< .001**	3.6 vs. 3.7	.794
LSA-CI-E	2.1 vs. 3.0	**< .001**	2.5 vs. 2.6	.820
LSA-CI-I	0.8 vs. 1.5	**.004**	2.5 vs. 0.4	**< .001**
age	83.0 vs. 81.5	.192	81.0 vs. 82.9	.125
gender (female)	85.7% vs. 66.7%	**.015**	85.5% vs. 63.2%	**.014**
diagnoses	11.8 vs. 10.8	.247	11.0 vs. 11.6	.464
MMSE	23.1 vs. 23.5	.347	22.9 vs. 23.5	.189
SPPB	4.8 vs. 5.7	**.038**	6.4 vs. 4.6	**< .001**
social activities	2.5 vs. 2.5	.951	2.5 vs. 2.5	.837
falls	1.1 vs. 1.0	.715	0.9 vs. 1.2	.141
FES-I	12.4 vs. 12.1	.749	11.1 vs. 12.8	**.035**
FFABQ	20.4 vs. 16.7	.118	13.1 vs. 21.3	**.001**
GDS	5.3 vs. 5.3	.966	5.0 vs. 5.4	.417
AES-C	22.2 vs. 21.9	.868	23.2 vs. 21.5	.375
PA (steps)	2538 vs. 3191	.127	3363 vs. 2591	.074

Presented are differences between groups according to use and benefit with respect to life-space zones due assistance by a person or equipment. Abbreviations: LSA-CI-AP = life-space increased in persons with cognitive impairment due to assistance by a person; LSA-CI-AE = life-space increased in persons with cognitive impairment due to assistance by equipment.

for the LSA-CI composite score and other descriptive variables (Table 5). Over two thirds of all participants (n = 79, 67.5%) specifically benefited from the use of equipment (LSA-CI-AE), with 59 (74.7%) of them showing an increase of at least two LS zones (Table 4). These participants showed significantly lower independent LS (LSA-CI-I, $p < 0.001$) and motor performance ($p < 0.001$) compared to those who did not use equipment (n = 38, 32.5%), but showed higher levels of FOF ($p = 0.035$) and avoidance behavior due to FOF ($p < 0.001$) and were mostly female ($p = 0.014$). No significant group differences were found in other LSA-CI scores or in other descriptive variables (Table 5).

3.3. Determinants of life-space mobility

As basis of the regression models, bivariate correlational analyses revealed that physical activity (PA) showed the highest correlations with LSA-CI score (PA/number of steps: $r_s = 0.590$; $p < 0.001$), followed by moderate correlations with social activities (social activities – SOS), motor performance (SPPB), FOF (FES-I), FOF-related avoidance behavior (FFABQ), age, gender, and living situation (living situation – SOS) ($r = |0.233\text{-}0.435|$; $p = < 0.001\text{–}0.012$). Correlations with duration of private unpaid care and cognition (MMSE) were low although reaching significance($r = |0.186\text{-}0.199|$; $p = 0.031\text{-}0.045$). Significant variables were included in the subsequent regression

Table 6
Correlation between life-space mobility and related factors.

Factors	Variable	r_s or r_{pb}	p
Physical status	SPPB Score	**.387**[**]	< .001
	Number of diagnoses	.015	.875
	Body Mass Index (BMI)	−.028	.766
Cognitive status	MMSE Score	**.186**[*]	.045
Psychosocial status	Social Contacts Score (SOS)	−.028	.762
	Social Activities Score (SOS)	**.435**[**]	< .001
	FES-I Score	**−.238**[**]	.010
	FFABQ Score	**−.380**[**]	< .001
	GDS Score	−.108	.246
	AES-C Score	−.141	.129
	Private unpaid care	**−.199**[*]	.031
Environmental status	Living Situation Score (SOS)	**.233**[*]	.012
	Weather: Average temperature	−.005	.961
	Weather: Precipitation height	.007	.940
	Weather: Average snow depth	−.080	.392
Financial status	Financial Status (SOS)	−.021	.825
Sociodemographic factors	Age	**−.321**[**]	< .001
	Gender[a]	**.282**[**]	.002
	Marital Status[a]	−.074	.431
	Educational Level	.072	.442
Physical activity	Number of steps[b]	**.590**[**]	< .001

Presented are Spearman coefficients rho between LSA-CI composite score and associated factors; n = 117; except for [a]point biserial correlation (dichotomous measures); [b]n = 114; [c]n = 112; [d]n = 108. Correlations coefficients (r): < 0.20 = low, .20–.50 = moderate, > 0.50 = high. Bolding indicates significant correlations; [*]$p < .05$; [**]$p < .01$. *Abbreviations:* AES-C: Apathy Evaluation Scale – Clinical Version; FES-I: Falls Efficacy Scale – International; FFABQ: Fear of falling Avoidance Behavior Questionnaire; GDS: Geriatric Depression Scale; LSA-CI: Life-Space Assessment for Persons with Cognitive Impairment; MMSE: Mini Mental State Examination; SOS: Questionnaire for social status; SPPB: Short Physical Performance Battery.

models. No significant correlations ($r = |0.005\text{–}0.141|$; $p = 0.129\text{–}0.961$) were found for number of diagnoses, BMI, measures of social contacts (social contacts - SOS), depressive and apathetic symptoms (GDS, AES-C), weather, financial status, marital status and educational level (Table 6). Regression model 1 (without PA) revealed that higher motor performance (SPPB), more social activities and being male were independently associated with higher LSA-CI-C scores, with the highest β-weight for motor performance, while cognition, FOF-related factors (FFABQ, FES-I), duration of private unpaid care, living situation and age were not independently associated with the LSA-CI-C score (Table 7). No multicollinearity between included variables or

Table 7
Regression model for determinants of life-space mobility.

	Model 1 (n = 117)	Model 2 (n = 114)
adjusted R^2	.363	.424
Variable	ß	ß
MMSE	.076	.064
SPPB	**.341****	**.243****
Social activities (SOS)	**.296****	**.257****
FES-I	.083	.025
FFABQ	−.076	−.064
Living situation	.058	.033
Gender	**.218****	**.182***
Age	−.109	−.102
Private unpaid care	.007	.027
No. of steps	–	**.265****

Bolding indicates significant correlations; *$p < 0.05$; **$p < 0.01$.
Presented are linear regression analyses for LSA-CI composite score and potential determinants. Bolding indicates significant factors. Abbreviations: FES-I: Falls Efficacy Scale – International; FFABQ: Fear of falling Avoidance Behavior Questionnaire; LSA-CI = Life-Space Assessment for Persons with Cognitive Impairment; MMSE: Mini Mental State Examination; SOS: Questionnaire for social status; SPPB: Short Physical Performance Battery.

autocorrelation was found (highest r = 0.642 for FES-I and FFABQ; max VIF = 2.045; Durbin-Watson 1.920). Model 1 explained a variance of 36.3% in the LSA-CI-C score (adjusted $R^2 = 0.363$). When the activity behavior-related variable for PA was additionally included in the regression model 2, higher motor performance (SPPB), more social activities, being male and higher amount of PA were independently associated with higher LSA-CI-C scores, with the highest β-weight for PA. No multicollinearity between included variables was found also for this model (max VIF = 2.019; Durbin-Watson 2.096). By adding PA into model 2, the total amount of explained variance increased from 36.3% to 42.4% (adjusted $R^2 = 0.424$, Table 7).

4. Discussion

To the best of our knowledge, this is the first study to investigate LSM and its determinants in multimorbid, older patients with CI after discharge from geriatric rehabilitation, a highly vulnerable population with multiple risk factors for LSM restrictions. Study results show that: 1) LSM is highly restricted in such a population, which becomes particularly apparent when analyzing the LS achieved independently without assistance of another person or equipment. 2) Higher motor performance, increased PA, more social activities, and male gender were identified as important determinants for increased LSM, explaining a considerable part of the LSA-CI´s variance.

4.1. Description of life-space mobility

The mean LSA-CI-C of 23.9 out of maximal 90 scores demonstrated that LSM was substantially limited among the study population. The majority of the participants were highly restricted and dependent on personal assistance as well as equipment. Previous studies in cognitively intact community-dwelling older adults have shown that average maximal LS covered an activity area between the hometown (= LS zone 4) and areas beyond (= LS zone 5) (maximal LS: 4.2–5.0) (Baker et al., 2003; Curcio et al., 2013; Fristedt, Kammerlind, Bravell, & Fransson, 2016). As expected, due to the impaired physical, cognitive and psychological status and the preceding hospitalization of the vulnerable study population, average maximal LS only ranged between neighborhood (= LS zone 3) and hometown (= LS zone 4) (LSA-CI-M: 3.7) in this study. The restricted mobility status in our population became particularly obvious when support mechanisms (personal assistance and use of equipment) were excluded, indicating a higher dependence on transportation support and a higher number of unfulfilled transportation needs (Cvitkovich & Wister, 2001). Without any assistance, the vast majority of persons were restricted to the home area, which is associated with decreased opportunities for participation in social and community activities (Szanton et al., 2016).

The use of equipment and personal assistance seem to play a key role in the LSM of multimorbid, older persons with motor and cognitive impairment as demonstrated by the newly introduced subscores LSA-CI-AP and LSA-CI-AE that enabled us to document separately the effect of personal assistance or equipment. The majority of participants used equipment and received help of another person, thus increasing their LSM to a level comparable to that of persons without the need for personal assistance or equipment. Interestingly, the participants receiving assistance and/or using equipment were those with a lower independent LS, lower motor performance, higher FOF, and higher avoidance behavior due to FOF, indicating that such limitations can successfully be compensated by personal assistance and equipment. Both, personal assistance and equipment, have been crucial to broaden the LSM in the multimorbid sample and therefore represent potential targets for increasing the mobility in vulnerable populations with multiple risk factors for LSM restrictions (Bertrand, Raymond, Miller, Martin Ginis, & Demers, 2017; Latham, Clarke, & Pavela, 2015), for example promoting the use and acceptance of existing equipment, examining the need of specific additional equipment, or encouraging relatives or caregivers to support outdoor mobility.

4.2. Determinants of life-space mobility

Based on the theoretical mobility framework by Webber et al. (2010), we considered a high number of potentially relevant factors to provide a comprehensive analysis of LSM in our sample. To our best knowledge, only one study in a large sample of older community-dwelling persons examined a comparable range of potentially relevant factors to analyze community mobility, identifying physical, cognitive, environmental and sociodemographic variables, but not psychosocial and financial factors, as independent determinants of mobility with physical health as strongest predictor (Umstattd Meyer et al., 2014). The current study conducted in multimorbid, older persons with motor and cognitive impairment focused, for the first time, on a specific population at high risk for restricted LSM, dependency, and institutionalization. Study results revealed that only variables addressing the participants' physical and (psycho-) social status, gender, and PA were independent determinants of LSM, accounting for a considerable part of the LSA-CI´s variance, while cognitive, financial, environmental, cultural and biographical factors as assessed in this population were negligible.

Among the physical variables, a comprehensive assessment for key motor functions (SPPB) was identified as an independent determinant of LSM, representing also the strongest factor in the first regression model. The result is in accordance with previous studies investigating multiple, potential factors of LSM in mixed populations of older adults with and without CI, that also identified functional and motor performance as the most powerful determinants of LSM (Al Snih et al., 2012; Peel et al., 2005). LSM was not significantly associated with number of medical diagnoses as a surrogate marker for multimorbidity, nor with the moderate BMI in our sample, thus supporting previous results observed in older adults with and without CI (Al Snih et al., 2012; Sawyer & Allman, 2010). In contrast to functional status as indicated by the SPPB, diseases or body characteristics seem to play rather a minor role for LSM. This is consistent with the World Health Organization's International Classification of Functioning, Disability and Health and its basic idea that a disease itself provides an incomplete perspective on health status and disability. Instead, the impact of diseases on an individual's functional status and impairment level as shown by the motor performance status is important for engagement in everyday life (Escorpizo et al., 2013).

Global cognitive status was not independently associated with LSM in our study population which was homogenous in this respect with a small-ranging mild to moderate CI level (MMSE range 17–26). Previous studies investigating associations between cognitive status and LSM showed conflicting results (Beland et al., 2018). Cross-sectional studies that showed associations between cognitive status and LSM included samples that covered the full range of cognitive performance including cognitively intact and severely impaired persons (MMSE range 0–30) (Al Snih et al., 2012; Peel et al., 2005), which might explain the different study results. Differences in outdoor activity might be more obvious in cognitive demanding outdoor activities (Wettstein et al., 2015), however, these differences with respect to the cognitive demand of an activity cannot be assessed using the LSA-CI. Our study design did not allow analysis of the risk of developing cognitive impairment as investigated in previous studies (Beland et al., 2018; James, Boyle, Buchman, Barnes, & Bennett, 2011).

Among the variables for psychosocial factors, we identified social activities as a significant and independent determinant of LSM, corresponding to results reported for cognitively healthy adults using a questionnaire assessing only LS, more specifically spatial distances (Barnes et al., 2007). Given that social activities are based on the volition of an individual to get around outside the own home and participate in the community or society (Levasseur, Richard, Gauvin, & Raymond, 2010) and that social activities had been identified to account for a substantial proportion (about 20%) of trips outside the home among older adults (Mollenkopf et al., 1997), this finding is reasonable. Thus, our results support the idea of the LSM concept depicting not only spatial-temporal movement patterns, but also reflecting participation in the society (Parker, Baker, & Allman, 2002). Social contacts as documented by the SOS questionnaire and private unpaid care were not identified as independent determinants of LSM, even though the initial descriptive analysis of LSM showed that the assistance provided of another person increased LS substantially in our sample (LSA-CI-E = 2.5 ± 1.2 vs. LSA-CI-M = 3.7 ± 1.2). This might be explained by the assessment of social contacts and private unpaid care that was more likely to cover passive forms of social interaction that were mainly located in the home as suggested by Dale et al. (Dale, Saevareid, Kirkevold, & Soderhamn, 2008), while assessment of social activities included questions on active engagement (existence and development of hobbies/interests), thus better reflecting outdoor activity. FOF-related factors (FES-I and FFABQ) were bivariately associated with LSM, but these associations were not statistically independent of other determinants as shown by the regression analysis. These findings contrasted with previous studies demonstrating independent associations of LSM and FOF in older adults with (Uemura et al., 2013) and without CI (Auais et al., 2017). The effects may be mediated by motor performance and PA, as these variables were moderately correlated with FOF (Denkinger, Lukas, Nikolaus, & Hauer, 2015), or compensated by the use of equipment as suggested by the descriptive analysis with higher benefit by equipment in persons with higher levels of FOF. No associations between LSM and depressive or apathetic symptoms were found in our study sample, in contrast to previous studies in older mixed populations with and without CI (Al Snih et al., 2012; Peel et al., 2005). Apathy and depression may especially affect higher-level daily activities (e.g., shopping, public transportation) (Fitz & Teri, 1994; Kazama et al., 2011; Yeager & Hyer, 2008), and to a less extent lower-level activities of daily living (e.g. food preparation, doing the laundry), which might be the focus in everyday life in our vulnerable study population.

Environmental factors did not significantly influence the LSM of our sample. The living situation and weather conditions may have an influence on higher outdoor LSM, however, due to the low outdoor activity observed in our sample, the potential impact of such factors may have been reduced in our study.

Out of the sociodemographic factors (financial, cultural, biographical factors) only gender was identified as an independent determinant of LSM in our study population, with females showing lower LSM than males. The influence of gender on LSM was previously also reported for persons with orthopedic diseases (Suzuki et al., 2014), or unspecific populations (Peel et al., 2005; Phillips et al., 2015) and might be related to the generally higher disability level (Gill, Gahbauer, Lin, Han, & Allore, 2013), lower physical activity level (L. Smith, Gardner, Fisher, & Hamer, 2015) or to a preference for home leisure activities in older women (Gagliardi et al., 2007). Age was not independently associated with LS, which may be due to mediation effects of motor performance and PA that are in turn predicted by age (Browning, Sims, Kendig, & Teshuva, 2009; Guralnik et al., 1993).

PA behavior was identified as the strongest independent determinant of LSM in our second regression model. High associations of PA with LSM have also been previously reported by studies in older persons without CI, showing that a higher amount of PA is accompanied by greater spatial extension of mobility (Portegijs et al., 2015; Sawyer & Allman, 2010; Tsai et al., 2015). PA and LSM both represent aspects of movement behavior, with PA focusing on activity regardless of location and target and LSM focusing on the location and spatial extent of activity regardless of physically active or passive locomotion. Thus, the results were in line with our expectations of PA to explain a large amount of the LSA-CI´s total variance, which was the reason for calculating a second regression model with PA in addition to the first model, including only status-based variables. Furthermore, it might be also argued that the number of steps (i.e., walking), by which we quantified PA in our study, is a prerequisite to moving through LS zones independently (Collia, Sharp, & Giesbrecht, 2003; Satariano et al., 2012).

In summary, the theoretical mobility framework by Webber et al. (Webber et al., 2010), successfully tested in older persons (Umstattd Meyer et al., 2014), may only have a relevance for specific variables in multimorbid, older people with motor and cognitive impairment, as not all model assumptions were met in our study sample. However, our comprehensive analysis of LSM revealed independent determinants that were modifiable, except for gender. Previous studies have already demonstrated that physical training is feasible and effective to improve motor performance in older people with and without CI (for review, see (Heyn, Johnson, & Kramer, 2008), that social interventions (e.g., support interventions, home visiting, service provision) can promote social activities in older people (for review, see (Dickens, Richards, Greaves, & Campbell, 2011), and that physical home training (Hauer et al., 2017) or specific behavior change intervention techniques (goal setting, social support, using a credible source) (Nyman, Adamczewska, & Howlett, 2018) can increase PA. Thus, interventions that address motor performance, social activities, and PA may also have a high potential to increase LSM in a vulnerable population of multimorbid older adults with motor and cognitive impairment. Women were identified as a high risk subgroup for LSM restriction with a potential accumulation of converging negative factors, indicating a special need for interventions with focus on women.

Future studies could include differentiated analyses of social contacts, activities and support, specific diseases and cognitive subdomains or behavioral factors (activities of daily living). As a limitation of the study, we have to mention that the SOS was not validated in persons with cognitive impairment. However, as the documentation of the SOS was interview-based and performed by trained assessor, representing an established procedure to compensate potential record bias in persons with cognitive impairment, we assume that the documentation meets established documentation standards.

5. Conclusions

LSM was substantially restricted in a multimorbid, vulnerable population of older persons with CI following geriatric rehabilitation. Equipment and personal assistance played a key role for LSM in this population, as dependency on both is highly prevalent, providing opportunities for increasing LSM by improving the availability and use of equipment or by providing personal assistance. The identified determinants of LSM show potential for future interventions to increase LSM in such vulnerable persons at high risk for LS restrictions by targeting motor performance, social activities, and PA.

Conflict of interest

The authors declare that there is no conflict of interest.

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- Manuskript X: Werner C, **Ullrich P**, Abel B, Bauer JM, Hauer K. Comment on: "Mobility of Older Adults: Gait Quality Measures Are Associated With Life-Space Assessment Scores" by Suri et al. J Gerontol A Biol Sci Med Sci. 2021 Aug 13:glab237. doi: 10.1093/gerona/glab237. Online ahead of print.

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Letter to the Editor

Comment on: "Mobility of Older Adults: Gait Quality Measures Are Associated With Life-Space Assessment Scores" by Suri et al.

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Dear Editor,

We have read with great interest the article by Suri et al. (1) who reported an association between gait quality measures recorded in the laboratory and life-space mobility (LSM) in community-dwelling older adults. Given the negative consequences of limited mobility for daily functioning, social participation, and quality of life, it is mandatory to identify relevant determinants of LSM that can be targeted by specific interventions. The findings of Suri et al. are an important contribution in this regard.

Intrigued by their work, we intended to expand their findings by analyzing associations between gait quality measures collected in an individual's real environment during daily life and LSM in community-dwelling older adults (aged ≥65 years) with cognitive impairment (CI; Mini-Mental State Examination [MMSE] = 17–26 points), and the relevance of these gait measures for LSM in combination with other explanatory factors in this population (2).

We assessed LSM by the Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI) (3) and daily-life gait quality by an activity monitor (uSense), consisting of a 3-axial accelerometer, gyroscope, and magnetometer, attached to the participants' lower back over 48 hours (4,5), in 92 community-dwelling older adults (age = 82.4 ± 3.1 years) with mild-to-moderate CI (MMSE = 23.2 ± 2.4 points) and mobility limitations (Short Physical Performance Battery [SPPB] = 5.2 ± 2.3 points; 4-m walk test [4MWT] = 0.50 ± 0.20 m/s) recently discharged home from geriatric rehabilitation. Other participant characteristics collected as potential explanatory factors for LSM included sociodemographic factors (age, gender, marital status, education, economic conditions), cognitive status, psychological factors (depressive symptoms, fear of falling [FoF] avoidance behavior), social activities, living situation, physical capacity (SPPB, 4MWT), and physical activity (mean steps per day over 48 hours; PAMSys 3-axial accelerometer) (6). Similar to Suri et al.'s hypothesis, we expected greater LSM to be associated with better daily-life gait quality in terms of less variability, more regularity, higher intensity and turning quality, and greater smoothness. We also hypothesized that daily-life gait quality would be an independent determinant of LSM, when controlled for other explanatory factors.

Univariate analyses showed significant correlations of the LSA-CI with cadence, harmonic ratio in all anterior–posterior, medial–lateral, and vertical directions, anterior–posterior step regularity, turning duration and angle, mean and peak turning velocity (ρ = |0.216–0.448|, $p \leq .001$–.038). Daily-life gait quality measures and other participant characteristics that correlated with the LSA-CI at a significance level of $p < .10$ were entered into a multivariate stepwise linear regression model to identify independent determinants of LSM. This model revealed that, among other significant factors (steps per day, FoF avoidance behavior, social activities, and gender), the daily-life gait quality measures of vertical harmonic ratio and mean turning velocity were independently associated with LSM (Table 1). No significant independent associations were found for age, marital status, economic conditions, living situation, cognitive status, depressive symptoms, and physical capacity (p = .494–.906).

We can confirm the findings of Suri et al. that gait quality is also a relevant determinant of LSM in community-dwelling older adults with CI and mobility limitations. However, in contrast to Suri et al.'s study, we measured gait quality in the real world rather than in the laboratory, used an activity monitor allowing for angular velocity measurements to assess daily-life turning quality, and considered a wide range of other potential explanatory factors. We expand their findings by having shown independent associations of LSM with daily-life gait smoothness and turning

Table 1. Univariate and Multivariate Associations Between Participant Characteristics and the Life-Space Assessment in Persons With Cognitive Impairment ($n = 92$)

		Univariate Analysis		Multivariate Analysis‡		
Characteristics	Descriptive Statistics*	ρ†	*p*	β	*p*	R^{2}§
						0.538
Age (years)	82.4 ± 3.1 [78.0–87.0]	−0.331	.001			
Gender (female)	69 (75)	0.389	<.001	−0.281	.001	
Marital status (married)	29 (31.5)	−0.187	.073			
Educational level		0.111	.294			
School only	27 (29.3)					
Vocational education	46 (50.0)					
University or comparable	19 (20.7)					
SoS—Economic conditions (0–3 points)	2.0 ± 0.8 [1.0–3.0]	0.192	.066			
SoS—Social activities (0–5 points)	2.5 ± 1.1 [2.0–3.0]	0.411	<.001	0.195	.011	
SoS—Living situation (0–11 points)	8.7 ± 1.4 [8.0–10.0]	0.339	.001			
MMSE	23.2 ± 2.4 [22.0–25.0]	0.258	.013			
GDS	5.3 ± 3.1 [3.0–7.8]	−0.166	.270			
FFABQ	18.0 ± 12.8 [5.3–29.8]	−0.486	<.001	−0.167	.046	
SPPB	5.2 ± 2.3 [4.0–6.0]	0.354	.001			
4MWT (m/s)	0.50 ± 0.20 [0.36–0.63]	0.454	<.001			
Step count per day	2 975 ± 2 374 [1 209–4 070]	0.622	<.001	0.260	.003	
Daily-life gait quality measures						
Gait variability						
CV of step duration (%)	29.55 ± 3.40 [26.68–32.29]	−0.359	<.001			
Gait regularity						
Step regularity AP (–)	0.37 ± 0.06 [0.33–0.39]	−0.033	.755			
Step regularity ML (–)	0.44 ± 0.10 [0.38–0.51]	0.166	.111			
Step regularity V (–)	0.32 ± 0.07 [0.27–0.36]	0.240	.020			
Gait smoothness						
Harmonic ratio AP (–)	1.06 ± 0.09 [0.99–1.12]	0.386	<.001			
Harmonic ratio ML (–)	1.42 ± 0.17 [1.31–1.55]	0.279	.007			
Harmonic ratio V (–)	1.15 ± 0.09 [1.09–1.20]	0.379	<.001	0.172	.030	
Gait intensity						
Cadence (steps/min)	73.77 ± 7.18 [70.14–78.19]	0.241	.020			
Turning quality						
Turning angle (°)	62.87 ± 9.93 [55.93–69.33]	0.344	.001			
Turning duration (s)	2.14 ± 0.50 [1.86–2.35]	−0.342	.001			
Mean turning velocity (°/s)	32.84 ± 7.22 [28.07–36.96]	0.458	<.001	0.206	.013	
Peak turning velocity (°/s)	79.46 ± 17.54 [67.82–86.49]	0.351	.001			

Note: SoS = Nikolaus Social Situation questionnaire; MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale (15-item); FFABQ = Fear of Falling Avoidance Behavior Questionnaire; SPPB = Short Physical Performance Battery; 4MWT = 4-m walk test; CV = coefficient of variance; AP = anterior–posterior; ML = medial–lateral; V = vertical.

*Data given as mean ± standard deviation [interquartile range] or *n* (%).

†Spearman correlation coefficients (ρ), except for gender and marital status (point-biserial correlation coefficient).

‡Multivariate stepwise linear regression model (entry criterion: $p < .05$, removal criterion: $p > .10$).

§Adjusted R^2.

quality, even after accounting for other factors such as physical capacity and activity, social activities, environment, cognitive and psychological status, education, and economic conditions, which were not accounted for in the analyses by Suri et al. Physical capacity measures (SPPB, 4MWT) were not identified as independent determinants of LSM, suggesting that these measures collected under standardized conditions are inferior in determining LSM compared to gait quality measures collected in free-living conditions. This might be explained by the fact that LSM and daily-life gait quality relate to what an individual actually does in his or her usual environment ("performance"), while the SPPB and 4MWT relate to what an individual can optimally do in a standardized environment ("capacity"). These 2 constructs have often been shown to be only weakly related to each other in older adults (7–9).

In conclusion, we identified gait smoothness and turning quality measured in daily life to be independently associated with LSM in community-dwelling older adults with CI and mobility limitations. These daily-life gait measures have a closer relationship to LSM than standardized physical capacity measures. Future studies should include both daily-life and laboratory gait quality measures as well as this combination will provide more detailed information on their differential contribution to LSM in old age.

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Effects of a home-based physical training and activity promotion program in community-dwelling older persons with cognitive impairment after discharge from rehabilitation: A randomized controlled trial

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Title page

Effects of a home-based physical training and activity promotion program in community-dwelling older persons with cognitive impairment after discharge from rehabilitation: A randomized controlled trial

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Abstract

Background: Older people with cognitive impairment (CI) are at high risk for mobility limitations and adverse outcomes after discharge from geriatric rehabilitation settings. Study aim was to estimate the effects of a specifically designed home-based physical training and activity promotion program on physical capacity, different aspects of physical activity (PA), and psychosocial status.

Methods: Patients with mild-to-moderate CI (Mini-Mental State Examination [MMSE]: 17-26 points) discharged home after rehabilitation were included in this randomized, double-blind, placebo-controlled trial with a 12-week intervention and 12-week follow-up period. The intervention group performed a CI-specific, autonomous, home-based strength, balance and walking training supported by tailored motivational strategies to foster training adherence and promote PA. The control group participated in an unspecific motor placebo activity. Primary outcomes were physical capacity (Short Physical Performance Battery [SPPB]) and PA (sensor-based activity time).

Results: Among 118 randomized participants (82.3±6.0 years) with CI (MMSE: 23.3±2.4) and high levels of multi-morbidity, those participants undergoing home-based training demonstrated superior outcomes to the control group in SPPB (mean difference between groups 1.9 points; *95%-CI:* 1.0-2.8; $p<.001$), with persistent benefits over the follow-up (1.3 points; *95%-CI*: 0.4-2.2; $p<.001$). There were no differences in PA across any time points. Among secondary outcomes, fear of falling and activity avoidance behavior were reduced in the intervention group at all time points, life-space mobility improved short-term.

Conclusions: Study results demonstrate clinically important benefits of an individually tailored autonomous physical training and activity promotion program on physical capacity and secondary outcomes in different domains in a vulnerable, multi-morbid population.

Keywords: Exercise, Physical activity, Home Care, Post-ward Rehabilitation, Clinical trials

INTRODUCTION

The post-discharge phase after geriatric rehabilitation is associated with high risk of adverse events in geriatric patients (1), with mobility-, functional- and cognitive impairments, and fear of falling being among the most persistent syndromes (2). Since physical capacity as well as physical activity (PA) levels in the transition period following discharge have been identified as markers of readmission risk and overall health (3), there is a need for interventions to prevent readmission and loss of mobility and autonomy. To support the transition between intensive medical treatment and autonomous living in the community, transitional care interventions have been implemented, with prevention of physical decline as a relevant but underrepresented element (4). Additionally, such interventions rarely include older people with CI (4), despite the high prevalence of cognitive impairment (CI) in rehabilitation settings (5), and the trend for worse healthcare outcomes such as higher risk for hospital readmission and mortality in persons with CI compared to peers without CI (6).

Considering the overall limited health care resources, low-budget, autonomous, home-based training programs with low entry barriers (e.g. no transport and predetermined schedule), that have already been proven to be feasible, safe and effective in community-dwelling older adults with CI (7), may also be feasible in the post-discharge phase to close this crucial gap in healthcare provision.

To our knowledge, no randomized controlled trials (RCTs) evaluating such home-based training programs after discharge from geriatric rehabilitation in older persons with CI have been published, except for the pilot study of the present trial (8). Some RCTs were conducted in mixed samples that included people with and without CI, but their intervention approach was not specifically tailored to support people with CI (9-14). Motivational strategies have been used in only a few studies (9, 11-13), but with no consistent approach to the type of the strategies used. No strategy specifically targeted older people with CI. Overall, home-based training programs showed good feasibility, but heterogeneous intervention effects on physical capacity, with some studies reporting positive effects (8-11), while others could not show such effects (12-14). Effects on objectively assessed PA (12) or self-reported activity parameters (8, 10) were also inconsistent, while effects on psychosocial outcomes such as fear of falling (10, 11), quality of life (14), or life-space mobility (9, 15) were rarely reported.

Thus, the primary objective of this study was to determine whether an easy-access, low-cost, autonomous, home-based physical training and activity promotion program, specifically developed for older persons with CI after discharge from geriatric rehabilitation, can improve the physical capacity, PA, and psychosocial status in this target group, and whether intervention effects have a sustainable impact after the end of the training period.

METHODS

This is the primary trial report of a single-center, double-blinded, randomized, placebo-controlled trial (RCT) with a 12-week intervention and 12-week follow-up. Study objectives were to improve physical capacity, PA, and psychosocial status in older persons with mild to moderate CI after discharge from geriatric rehabilitation (trial registration: http://www.isrctn.com/ISRCTN82378327). Study details have been described in the study protocol (16). The study was approved by the Ethics Committee of the Medical Faculty of Heidelberg University, Germany (reference number: S-252/2015) and conducted in accordance with the Helsinki Declaration.

Participants

Participants were screened and recruited during geriatric rehabilitation, consisting of a 3-week multidisciplinary, daily treatment program with physiotherapy, occupational therapy, language and speech therapy, psychological and social support according to the individual patient needs. Inclusion criteria were age ≥65 years, mild to moderate CI (Mini-Mental-State-Examination [MMSE] score of 17 to 26) (17), no delirium (according to the Confusion Assessment Method [CAM]) (18), ability to walk at least 4 meters without walking equipment, discharge home, residence within 30 kilometers of the study center, no terminal or severe disease hampering study participation, no language restrictions, and written informed consent or consent by a legal representative. Based on German guidelines for CI classification (20) and the limitation of the MMSE cutoff of 24 in detecting mild cognitive impairment (19, 21), we used the MMSE cutoff of 26. Participants were equally allocated to the intervention group (IG) and control group (CG) using an urn design for clinical trials (22) stratified by gender, with the procedure conducted after baseline assessment by a person not involved in the study.

Interventions

Participants in the IG performed a home-based training program specifically developed for home-dwelling older persons with CI, which has been proven to be feasible and effective in this patient group after geriatric rehabilitation in a pilot study (8). In addition, a motivational program for activity promotion was included (16, 23). The physical training was easy to apply and feasible in a home environment and was based on basic exercises to improve key motor performances relevant for mobility autonomy such as postural control (side by side, semi-tandem and tandem stance) and strength (tiptoe stance, sit-to-stand transfers/chair-rise, stair rise), and an individualized walking course to improve overall physical activity (16). During a first home visit, exercises and walking course were explained to the participant and practiced under the supervision of a trained study instructor (academic sports scientists experienced in geriatric rehabilitation). A large poster with a graphical description of the exercises and a comprehensive training manual was provided to support the autonomous training (independent continuation). Difficulty levels of the indoor exercises and of the outdoor walking course were individually tailored to the functional status and the environmental setting, thereby also considering safety aspects, and were progressively adapted during the course of the program via four more home visits and weekly phone calls by the training instructors. Participants were instructed to perform the training on a daily basis. The training was designed to be conducted autonomously by the participants, proxies were free to support, motivate or accompany during the training or walk (see also Suppl. Table 1).

Participants in the CG received a training manual focusing on seated exercise including unspecific flexibility and strength exercises, and generic information on nutrition and relaxation.

All participants in the IG and CG were supported by an identical organizational structure including a total of five home visits with decreasing frequency and weekly phone calls to control for potential psychosocial effects by the immanent social support. During the follow-up period, both groups did not receive any further support or contact (Suppl. Table 1). Participants were not aware of their own group allocation

Motivational strategies

The intervention was complemented by a motivational approach, specifically developed to support training adherence and long-term behavioral changes in persons with CI. The motivational approach was based on theory-based behavioral change techniques and included validation, social support (using five home visits and weekly phone calls by the trainer), improving knowledge on the benefits of regular exercise and PA, individual goal-setting (identification of personally relevant activity goals from a selection of potentially relevant indoor and outdoor activities; rating of importance, self-perceived competence, and chance of success in improvement of standing, walking, sit-to-stand transfer/chair-rise, and stair climbing), identification and removal of barriers to exercise and walking, and self-monitoring strategies (training logs including frequency of exercising, adverse events, steps taken with a pedometer; YAMAX Digiwalker CW 700) to promote adherence and PA (16, 23). Communication was based on empathy, respect, and reassurance oriented on validation strategies (16), and specifically adapted to the needs of persons with CI by simple and repetitively used instructions, haptic support, picturesque language, and positive feedback (on training success or number of steps taken). A special focus was given to improved self-efficacy related to progress of functional training and perceived training gains in this vulnerable sample of older persons with multi-morbidity and CI often deprived of positive experience and feedback.

Measurements

All other assessments were performed after discharge from rehabilitation in the participant´s home prior to randomization (T1), at the end of the 12-week training period (T2), and after the 12-week follow-up period (T3) by assessors blinded to group allocation. Age, gender, primary admission diagnoses, number of diagnoses and medications were documented from patient charts at discharge from rehabilitation. During standardized interviews, assessors documented the educational status hierarchically classified as low (≤8 years education); intermediate (9-12 years education); or high (≥13 years education), marital status, and history of falls in the previous year.

The primary study outcomes were physical capacity, assessed by the total score of the Short Physical Performance Battery (SPPB) (24), and PA, assessed as the "active time" (duration of standing and walking) using a validated activity monitor (PAMSys, BioSensics, Cambridge, MA, USA) (25) attached on the participants' chest for a 48-hour measurement period, which has been shown to be sufficient to assess PA in older persons (26). The activity monitoring was based on registration of accelerations in frontal, vertical, and lateral directions of a tri-axial accelerometer at a sampling frequency of 40 Hz.

Secondary study outcomes were included to allow a detailed analysis and to cover a wider range of intervention-induced effects. To complement the assessment of physical capacity, the sub-scores of the SPPB were analyzed, habitual and maximal gait speed, and the Timed-up-and-go (TUG) was measured (27). Life-Space Mobility, describing spatial habitual activity, was measured using the modified Life-Space Assessment for Persons with CI (28).

Psychosocial status was assessed using the EuroQol 5-Dimensions questionnaire (EQ-5D-3L) (29), the Geriatric Depression Scale – Short Form (GDS-SF) (30), the Apathy Evaluation Scale-Clinical version (AES-C) (31), and for fear/concerns of falling and related activity avoidance the Short Falls Efficacy Scale International (Short FES-I) (32), and the Fear of Falling Avoidance Behavior Questionnaire (FFABQ) (33).

Exercise logs were used to document daily training adherence in the IG, and falls in both groups. All participants also received weekly phone calls by trainers to ascertain falls (34).

Statistical analysis

Sample size calculation was determined for the primary outcome PA based on results of a previous study (35) using GPower 3.1 software, and yielded a total sample size of *n*=101. With an estimated drop-out of 15%, a sample size of 116 participants in total was targeted (16). We assumed equal allocation, alpha 0.05, and power 80%.

Descriptive data were presented as absolute and relative frequencies, mean and standard deviation or median and range as appropriate. Unpaired t-tests and Mann–Whitney U-tests were used to test for differences between study completers and drop-outs.

For primary and secondary outcomes linear mixed models for repeated measures (MMRM) with treatment contrasts (36, 37) were used to compare the differences between groups (IG vs. CG) and changes over time (T1, T2 and T3). The model included the baseline value of the outcome variable and gender (as part of the randomization mechanism) as fixed effects (36, 37), and participants as a random effect. The within-group correlation of participants across different time points was estimated from the data using a "general" structure. The model was estimated using restricted maximum likelihood. Therefore, and in line with the ITT principle, missing data was handled by maximum likelihood (38). The model-based between group effects were presented as mean change with 95%-confidence intervals and associated *p*-values. Group-trajectories were also graphically displayed in an interaction plot, using the model-based means. A *p*-value below α=0.05 (two-sided) was considered statistically significant. Within the efficacy analyses of the primary outcomes (SPPB, PA), multiplicity was controlled for using the Bonferroni method. Reported *p*-values referring to analyses of secondary outcomes were not controlled for multiplicity and are therefore to be interpreted as descriptive.

We further examined whether across all observed time points and within the individual participants an increase / decrease in major study variables was associated with an increase / decrease in other major variables, by calculating repeated measures correlations (39, 40).

Statistical analyses were performed using R version 3.6.1 and IBM SPSS Statistics Version 27 for Windows (IBM Corp., NY, USA).

RESULTS

Study participants

Among 1981 patients admitted to geriatric rehabilitation and screened for inclusion (Figure 1), 118 participants were enrolled between August 2015 and April 2017. Main exclusion criteria were inappropriate cognitive status (*n*=553), residence more than 30 kilometers away from study center (*n*=241), and medical contraindications (*n*=217) (Figure 1).

Among patients included in the study, n=63 were randomly assigned to the IG, and n=55 to the CG, with balanced baseline characteristics between groups (see Table 1). Study participants were multi-morbid (number of medical diagnoses: 11.4±4.4), high-aged (82.3±6.0 years), had moderate cognitive (MMSE: 23.3±2.4 scores) and advanced physical impairment (SPPB: 5.2±2.3 scores). Primary admission diagnoses for geriatric rehabilitation (mean treatment duration: 19.4±4.4 days) were predominantly related to cardiovascular diseases (20%), degenerative joint diseases (18%), neurological diseases (16%), and consequences of falls (14%). Participants were at high risk of falling (67% reported a fall in the previous year), and had moderate to high level of concerns about falling (Short FES-I: 11 [7-25] scores) (Table 1).

After 12 weeks (T2), 13 individuals (11.0%) dropped out (IG: *n*=9 / 14.3%; CG: *n*=4 / 7.3%) due to serious medical events (*n*=8), death (*n*=4), and unwillingness to continue participation (motivation) (*n*=1). After 24 weeks (T3), another 13 (11.0%) participants dropped out (IG: *n*=4 / 6.3%; CG: *n*=9 / 16.4%) due to serious medical events (*n*=3), death (*n*=1), unwillingness to continue participation (motivation) (*n*=7), and loss of contact (*n*=1). The total attrition rate was 22.0% with 13 drop-outs in each group. Adverse events (deaths, serious medical events, see Figure 1) were associated with preexisting conditions and not directly or indirectly related to the intervention. Study completers (*n*=93) and drop-outs (*n*=25) were comparable for most descriptive variables, except for lower physical capacity status (SPPB total score completers: 5.5±2.4; dropouts: 4.5±1.7), and more apathetic symptoms (AES-C score completers: 38.9±8.7; dropouts: 44.6 ± 9.5) of the drop-outs at baseline. IG and CG dropouts were comparable for all descriptive variables at baseline. Invalid sensor-based PA data was received for *n*=3 at T1, *n*=6 at T2 and *n*=6 at T3. Mean training adherence over the 12-week intervention period was relatively high, with daily training and walking conducted on approximately 60% of all days. More detailed results on adherence rates have been previously reported (21).

Effects of the intervention: Primary outcomes

The IG participants improved in their SPPB total score from 5.3 to 7.2 (T2) and 6.6 (T3), while CG participants decreased from 5.3 to 5.2 (T2) and stabilized at 5.2 (T3). The exercise intervention resulted in a statistically significant and clinically relevant benefit of 1.9 score points in the SPPB for the IG compared to the CG (*95%-CI:* 1.0-2.8; $p<0.001$; Table 2 and Figure 2). The benefit in favor of the IG was sustainable and persisted, although in attenuated form, at T3 (benefit of 1.3 SPPB score points; *95%-CI:* 0.4-2.2; $p=0.001$; Table 2, Figure 2, Suppl. Table 2).

The IG was not significantly different from the CG with regard to the effects on PA as measured by sensor-based monitoring at T2 nor at T3 (Table 2, Suppl. Table 2, Suppl. Figure 1).

Effects of the intervention: Secondary outcomes

Among secondary study outcomes, significant benefits of the intervention on physical capacity were documented supporting the results for the primary outcome, the SPPB total score: The TUG significantly improved in the IG compared to the CG at post-intervention (-5.73 seconds; *95%-CI:* -10.90--0.66; $p=0.027$), as well as all sub-scores of the SPPB (Table 2). Participants in the IG improved their habitual gait speed from 0.47 to 0.62 m/s, resulting in a significant benefit of 0.11 m/s (*95%-CI*: 0.05-0.17; $p<0.001$) compared to the CG with improvements of 0.47 m/s to 0.51 m/s. The improvement of maximal gait speed was also significantly higher for the intervention, with an increase from 0.72 to 0.84 m/s in the IG and 0.71 to 0.74 in the CG, yielding a benefit of 0.09 m/s (*95%-CI*: 0.01-0.18; *p*=0.029). Significant effects were sustainable for the improvements of habitual and maximal gait speed, and for two out of three SPPB sub-scores (chair-rise, gait) (Table 2).

The results for the behavioral effects on life-space mobility were a benefit of 8.15 (*95%-CI*: 2.89-13.41; *p*=0.003; Table 2). In comparison to the CG, the IG improved falls efficacy (*b*: -2.00; *95%-CI*: -3.48--0.53; *p*=0.008; Table 2; Suppl. Table 2, Suppl. Figure 2) and reduced fear of falling-related activity avoidance behavior (*b*: -8.62; *95%-CI*: -13.02--4.21; *p*=0.001; Table 2) documenting a comprehensive positive impact of the intervention beyond physical capacity. While the effects on concerns about falling and activity avoidance related to fear of falling remained significant, effect on life-space mobility waned during the follow-up. No significant effects on depression, apathy, health-related quality of life, and self-rated health status were detected for the intervention and follow-up period (Table 2, Suppl. Table 2).

Number of falls during the intervention period were equally distributed between groups (16 falls (IG, n=54) vs.13 falls (CG, n=51)), with 80% of the participants in the IG and 82% in the CG reporting no fall.

Additional analysis of associations between included variables

In individual patients, increases in physical capacity variables targeted by the intervention strategy were associated with an increase in activity parameters associated with life-space mobility, fear of falling related activity avoidance, and concerns about falling. Additionally, health-related quality of life measures, and partially depressive and apathetic symptoms showed associations with physical capacity. In contrast, also at the individual level, no association of PA with other variables except for life-space mobility could be shown (Table 3).

DISCUSSION

The present RCT demonstrates a clinically relevant and statistically significant benefit of home-based, physical training and activity promotion program on physical capacity in vulnerable, older persons with CI in the immediate phase after discharge from geriatric rehabilitation. Habitual PA remained unchanged. The program also showed comprehensive positive effects on interrelated secondary outcomes such as life-space mobility as previously reported (15), psychosocial status related to fear of falling, and associated activity avoidance.

Except for the pilot study of this trial (8), to our knowledge, this RCT is the first study to document the effectiveness of an easy-access, low-cost, home-based intervention approach with limited external supervision specifically designed for post-ward rehabilitation in older persons with CI.

Effects on physical capacity

The training program was effective. It improved physical capacity by 1.9 points in the SPPB, which is more than a one third increase of the participants' SPPB baseline score. An increase by 1.0 point is classified as substantial and meaningful in a younger, higher functioning study sample with baseline SPPB values of more than 8.0 points (41). The difference of almost two points was achieved in a particularly vulnerable population with physical capacity levels substantially lower than the levels of participants in the study that provided the classification of a meaningful effect. Therefore, our results indicate a large training-induced gain of physical capacity. For persons with advanced physical impairment as in the present study even "a small improvement in a performance test may translate into a large benefit in daily life and perceived by the participant" (42). From a clinical perspective, physical improvements as achieved in the present study may have a high relevance for vulnerable persons with CI and low physical capacity as the latter may be regarded as a main potential mechanism and a precursor of catastrophic disability (43). The significant improvements in different domains of physical capacity as documented by the secondary study outcomes such as the TUG, walking speed and functional strength with the SPPB sub-score chair-rise measure indicate an overall and comprehensive effect of the exercise intervention on motor-functional status. Training-induced improvements are also relevant reaching beyond substantial, clinically meaningful changes provided for gait speed (41), also exceeding a cut-off value recently developed to distinguish persons with mobility complaints (44). Results for the TUG as well as the SPPB sub-score chair-rise also clearly exceeded the thresholds indicative of a real change (45, 46). Training-induced physical improvements reversed the expected negative natural course of physical capacity in advanced age as shown in the CG of our study. Most of the improvements in capacity measures, including the primary outcome SPPB total score, were persistent during the follow-up period, indicating sustainability of effects after training cessation. The results of the present study confirm the results of the pilot study with regard to a significantly improved physical capacity (8) and document the high effectiveness of a program tailored to the needs and remaining resources of patients with CI. The comparability to other studies conducted in the post-discharge setting is limited, which is mainly due to the missing focus on persons with CI, but it is also a consequence of differing study objectives, interventions, and target samples. When compared to studies including mixed populations with participants with and without CI, the results of the present study demonstrate stronger effects on the SPPB total score that those achieved in hip fracture patients (11), and greater improvements of gait speed than in frail participants after a long-term intervention (9), and when compared to other studies that showed no improvements of physical capacity (mainly assessed by SPPB) (10, 12-14).

Effects on physical activity

Despite implementing a multitude of motivational strategies in the IG (e.g., goal setting, self-monitoring, social support, feedback) that have shown promise for promoting PA in older adults (47-49), and that were feasible and well-accepted by the participants of this study (23), no increase in objectively measured PA was observed after the intervention period compared to the control. Although the overall adherence to the implemented motivational strategies was high, the initially very high adherence decreased over time along with the decreasing frequency of home visits as previously reported (23). We assume that the PA may have increased during the 12-week intervention period, especially in the initial phase, due to the high adherence to the home-based training and motivational strategies for promoting PA. However, as PA changes were measured after training cessation, direct intervention-induced effects on the PA could not be documented for this period. We suggest that for sustainably improving PA in older persons with CI, more continuous and prolonged implementation of motivational strategies may be needed as indicated during another long-term PA intervention (50).

The few previous RCTs reporting benefits of home-based interventions on PA in older persons with CI were conducted in younger, more active and less comorbid persons and not in the transition phase from inpatient rehabilitation to the home setting (50, 51), were pilot studies with methodological limitations (e.g., small sample sizes, no analysis of between-group changes over time, and/or no objective PA measurement) (8, 51), or had CGs that did not receive a placebo intervention (e.g., usual care) (8, 50), limiting thereby the comparability of results.

In contrast, the present full-scale RCT included a sample of vulnerable, older persons with multi-morbidity, CI and low physical capacity, recently discharged home from geriatric rehabilitation, for whom PA promotion may be more challenging to achieve, as coping with everyday life may already be (too) exhaustive for allowing an increase in PA. Additionally, the CG in the present study received information on unspecific home exercises, nutrition and relaxation, as well as the same number of home visits and phone calls to facilitate recruitment, to allow the blinding of participants and to control for psychosocial effects due to social contacts. Between-group changes over time may thus have been more difficult to achieve than in usual care CGs.

Other RCTs also conducted in the transition phase from rehabilitation to home in older persons with mixed cognitive status yielded similar results with respect to PA, with no positive effects of home-based training programs on self-reported (10) or objectively measured PA (12). A potential reason for the failure to promote PA by such programs might be their strong focus on training adherence as well as on associated health benefits of regular exercise and PA (e.g. by provision of related information, definition of training goals, barrier identification and removal to the exercise) rather than the implementation of a wider set of goals that are not primarily related to activity, but that have a greater personal importance for the participants (52). Despite our attempts to link activity-related goals to personal relevance by giving participants the opportunity to identify goals they personally felt to be most important, they might have been too focused on improving physical capacity and on promoting PA. Future interventions and motivational strategies may therefore need to focus more on how PA can contribute to life satisfaction, meaningfulness, role fulfillment and social connections of older persons (52).

Effects on secondary outcomes of life-space mobility and psychosocial status

The present study showed also effects on secondary outcomes with clinical and personal relevance for mobility behavior and autonomy. Effects on life-space mobility have already been presented and discussed in detail in another publication (15), and they underline the positive short-term impact of the intervention on overall health status also including habitual spatial activity behavior. In contrast to general PA, life-space mobility documents spatial activity and the amount of different support levels including social support and therefore represents a more sensitive marker of mobility as compared to activity duration in minutes in a population still handicapped by limited physical capacity. As life-space mobility documents the area in which the activity takes place (15, 28), the increase of this variable may hold options for -and may represent a marker of- substantially increased autonomy, self-efficacy, and social participation with high relevance for the study population.

As documented by repeated measure correlations, the high association throughout the whole observation period between physical capacity, life-space mobility, fear of falling, and associated activity avoidance indicates a complex, significant interaction of different domains, which are in line with a previous study (28). Especially the effects of improved physical capacity on fear of falling in older populations with advanced motor impairment have been the focus of previous research (53). A potential link for this association may constitute the vicious circle of physical impairment, fear of falling, related activity avoidance, reduction of mobility, resulting in motor detraining and loss of capacity. In the present study this negative down-spiraling might have been interrupted by increasing physical capacity by the training program, thus increasing fall-related self-efficacy, lowering associated activity avoidance, and finally improving life-space mobility. Reducing negative consequences in any of the components of the aforementioned vicious circle, as documented in this study may have positive effects on other variables indicating an interwoven and interactive association between motor, social and psychological domains. As we developed a tailored approach for the training of this population with CI, we used positive exercise feedback during the program to motivate participants by targeting their self-efficacy, thus successfully improving motor capacity and adherence but also the individual self-validation of achievements, which may represent a basic mechanism of the effects of exercise training on fear of falling and associated symptoms (53). Comparable studies failed to show effects on fear of falling assessed via self-rated fall risk (10) and falls self-efficacy (10, 11), without analyzing related activity avoidance, while the present study results documented a theoretically well founded pathway of interacting motor and psychosocial domains which offers different but potentially interdependent opportunities for successful interventions.

As documented by non-significant associations of other psychosocial variables including depression and quality of life in the present study, the effects achieved in the present study may be specific for the fear of falling syndrome.

Repeated measures correlations document that a significant association of physical capacity, psychosocial and habitual activity related variables can be shown across the individual level during the whole observation period (Suppl. Figure 3). These correlations support the interrelation of function and mobility on overall health and psychosocial status.

No serious adverse events that were related to the intervention occurred, indicating the safety of the specifically adjusted training program in this vulnerable group of former geriatric rehabilitation patients with CI.

Future implementation

An important question for the implementation of such programs into health care systems as a routine care path is whether the observed improvements were associated with increased health care costs and whether such programs will have an impact on resource use. The results of the economic evaluation of this intervention have been reported in an associated article (54), with mean costs to implement the home-based physical training and activity promotion program of EUR 284 per patient, indicating a high cost-effectiveness with respect to improved physical capacity in older adults with CI after discharge from rehabilitation. The established ward based rehabilitation approach without bridging trans-sectoral rehabilitation efforts at peoples' home should be regarded as insufficient for many patients with mobility limitations (1, 2). Thus, transitional care interventions such as presented in this article that effectively reduce impairments, ameliorate a crucial life situation for these patient group (and potentially also for their caregivers), and reduce health care costs seem mandatory to be included in rehabilitation pathways.

Strength and Limitations

The strengths of the study include the successful implementation of the intervention in a high-risk population that tends to have high complication rates, and that is threatened by mobility and autonomy loss, while being often excluded from studies. Strengths include also the use of a manualized, highly effective physical training program with minimal resource consumption, an assessment strategy via established and validated tests as well as the objective measurement of PA level, and the positive intervention results with a number of benefits with high clinical and personal relevance for the participants.

A limitation is the assessment of PA levels immediately after the intervention, thus potential effects during the active phase of the intervention with social support by the trainer could not be documented.

CONCLUSIONS

The present study provides evidence for the effectiveness of an intervention program in older persons with CI after discharge from rehabilitation with regard to improvements of physical capacity, but it also provides evidence for benefits in life-space mobility and fear of falling related factors. The intervention program may help to fill an important gap in the health care continuum in geriatric rehabilitation by supporting these persons to continue ward base rehab at home, thereby creating the necessary conditions for an autonomous living in the community and participation in society. The present intervention program could easily be incorporated into the public health system with the intention to improve the continuum of care by offering therapy and secondary prevention in vulnerable older people with CI after discharge from rehabilitation, representing a very vulnerable population with currently insufficient therapy provision.

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AUTHOR`S CONTRIBUTIONS

PU, CW and KH drafted the manuscript. KH is responsible for the conception of the study and study design. PU, MB, TE and RB participated in data collection. The data analysis was carried out by AS and PU. BA, AS, JMB, and SL critically revised the article. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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DATA ELEMENTS

Table 1: Baseline sample characteristics for study groups

Characteristics	Total group (n=118)	IG (n=63)	CG (n=55)
Age (years), mean (SD)	82.3 (6.0	82.2 (5.8)	82.4 (6.2)
Gender (female/male), %	76.3/23.7	76.2/23.8	76.4/23.6
Marital status (married), %	30.5	27.0	34.5
Education (low/intermediate/high)[a], %	31/50/19	33/48/19	29/53/18
Number of diagnoses [n], mean (SD)	11.4 (4.4)	11.3 (3.6)	11.4 (5.3)
Number of medications [n], mean (SD)	9.5 (3.5)	9.4 (3.3)	9.6 (3.7)
MMSE score (0-30), mean (SD)	23.3 (2.4)	23.3 (2.7)	23.3 (2.1)
SPPB score (0-12), mean (SD)	5.2 (2.3)	5.4 (2.1)	5.0 (2.4)
≤1 fall in the previous year, %	67	76	56
Short FES-I score (7-28), median (range)	11 (7-25)	11 (7-25)	11 (7-25)
GDS score (0-15), mean (SD)	5.3 (3.0)	5.2 (3.0)	5.4 (3.1)
AES-C score (18-72), mean (SD)	40.2 (9.1)	39.9 (8.9)	40.5 (9.5)

Note: Presented are baseline comparisons between study groups as randomized. Scoring range is given in bracket. [a] low (≤8 years education); intermediate (9-12 years education); high (≥13 years education)

AES-C: Apathy Evaluation Scale – Clinical Version; CG: control group; Short FES-I: Falls Efficacy Scale – International short version; GDS: Geriatric Depression Scale; IG: Intervention group; MMSE: Mini Mental State Examination; n: number; SD: standard Deviation; SPPB: Short Physical Performance Battery. Higher values in scores indicate better cognitive (MMSE) and functional status (SPPB), higher level of concerns about falling (Short FES-I), depressive symptoms (GDS), and apathy (AES-C).

Table 2: Estimates of the difference between groups (mean and 95% confidence intervals) adjusted for baseline value and gender for outcome variables collected at T2 and T3 after the intervention

Outcome	T2		T3	
	b **[95% CI]**	***P*-value**	***b*** **[95% CI]**	***P*-value**
(Primary outcomes)				
SPPB total score	1.90 [1.00; 2.80][a]	<.001[a]	1.30 [0.42; 2.18][a]	.001[a]
Physical Activity – sensor-based active time	-14.68 [-81.27; 51.92] [a]	>.999[a]	-24.17 [-91.92; 43.57][a]	>.999[a]
(Secondary outcomes)				
SPPB chair-rise sub-score	0.65 [0.23; 1.06]	.002	0.46 [0.05; 0.87]	.027
Chair-rise duration	-5.75 [-.10.03; -1.47]	.010	-.611 [10.57; -1.65]	.008
SPPB balance sub-score	0.72 [0.28; 1.16]	.001	0.21 [-0.21; 0.65]	.324
SPPB gait sub-score	0.54 [0.23; 0.86]	.001	0.67 [0.34; 0.99]	<.001
Habitual gait speed	0.11 [0.05; 0.17]	<.001	0.10 [0.04; 0.16]	.001
Maximal gait speed	0.09 [0.01; 0.18]	.029	0.12 [0.04; .20]	.005

TUG	-5.73 [-10.90; -0.66]	.027	-3.64 [-8.48; 1.21]	.140
LSA-CI	8.15 [2.89; 13.41]	.003	3.03 [−2.39; 8.46]	.274
Short FES-I	-2.00 [-3.48; -0.53]	.008	-2.00 [-3.55; -0.44]	.012
FFABQ	-8.62 [-13.02; -4.21]	<.001	-8.03 [-12.30; -3.76]	<.001
EQ-5D-3L index score	0.05 [-0.12; 0.15]	.415	0.02 [-0.12; 0.15]	.797
EQ-5D VAS	1.45 [-6.49; 9.39]	.720	2.68 [-5.27; 10.64]	.507
AES-C	-4.04 [-8.19; 0.11]	.056	-1.01 [-4.84; 2.82]	.604
GDS-SF	0.10 [-1.04; 1.24]	.865	-0. 07 [-1.18; 1.04]	.902

Note: Results of linear mixed-model repeated-measures (MMRM) analysis for differences between study groups for the intervention period (T2) and follow up (T3).

[a] *p*-values and *CI*s for primary outcomes are Bonferroni controlled.

Abbreviations: *AES-C: Apathy Evaluation Scale – Clinical Version; CG: control group; CI= confidence interval; EQ-5D-3L: Euroqol 5 dimensional health-related quality of life questionnaire; EQ-5D VAS: health-related quality of life visual analogue scale (perceived health status); Short FES-I: Falls Efficacy Scale – International short version; FFABQ: Fear of falling avoidance behavior questionnaire; GDS: Geriatric Depression Scale; IG: Intervention group; LSA-CI: Life-Space Assessment for persons with cognitive impairment; SPPB: Short Physical Performance Battery; TUG: Timed-up-and-go.*

Table 3: Repeated Measures Correlations (with 95% CIs) of Major Study Variables

Variables	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. SPPB	1								
2. Short FESI	-.19** [-.33; -.06]	1							
3. FFABQ	-.26*** [-.38; -.12]	.43*** [.31; .54]	1						
4. Pamsys active. (min)	.07 [-.07; 22]	.06 [-.08; .20]	-.07 [-.21; .08]	1					
5. LSA-CI total	.39*** [.26; .50]	-.20** [-.33; -.06]	-.26*** [-.38; -.12]	.15* [.01; .29]	1				
6. TUG	-.47*** [-.58; -.35]	.31*** [.18; .44]	.30*** [.16; .42]	-.08 [-.22; .07]	-.24*** [-.37; -.10]	1			
7. GDS	.01 [-.13;	.12 [-.02;	.30*** [.16;	-.02 [-.16;	-.09 [-.23;	.04 [-.10;	1		

	.14]	.26]	.42]	.13]	.05]	.18]			
8. EQ-5D-3L	-.19** [-.32; -.05]	.35*** [.22; .47]	.28*** [.15; .41]	-.06 [-.21; .08]	-.24*** [-.37; -.11]	.21** [.06; .34]	.17* [.03; 30]	1	
9. AES-C	-.16* [-.29; -.02]	.07 [-.07; .21]	.17* [.03; .30]	-.10 [-.24; .04]	-.16* [-.29; -.01]	.14* [.00; .28]	.34*** [.21; .46]	.06 [-.08; .19]	1

Note: Presented are Repeated Measures Correlations (with 95% CIs) of Major Study Variables for the complete observation period (T1-T3). Available cases set.

*p < .05. **p < .01. ***p < .001.

Abbreviations: AES-C: Apathy Evaluation Scale – Clinical Version; CG: control group; CI= confidence interval; EQ-5D-3L: Euroqol 5 dimensional health-related quality of life questionnaire; Short FES-I: Falls Efficacy Scale – International short version; FFABQ: Fear of falling avoidance behavior questionnaire; GDS: Geriatric Depression Scale; IG: Intervention group; LSA-CI: Life-Space Assessment for persons with cognitive impairment; SPPB: Short Physical Performance Battery; TUG: Timed-up-and-go.

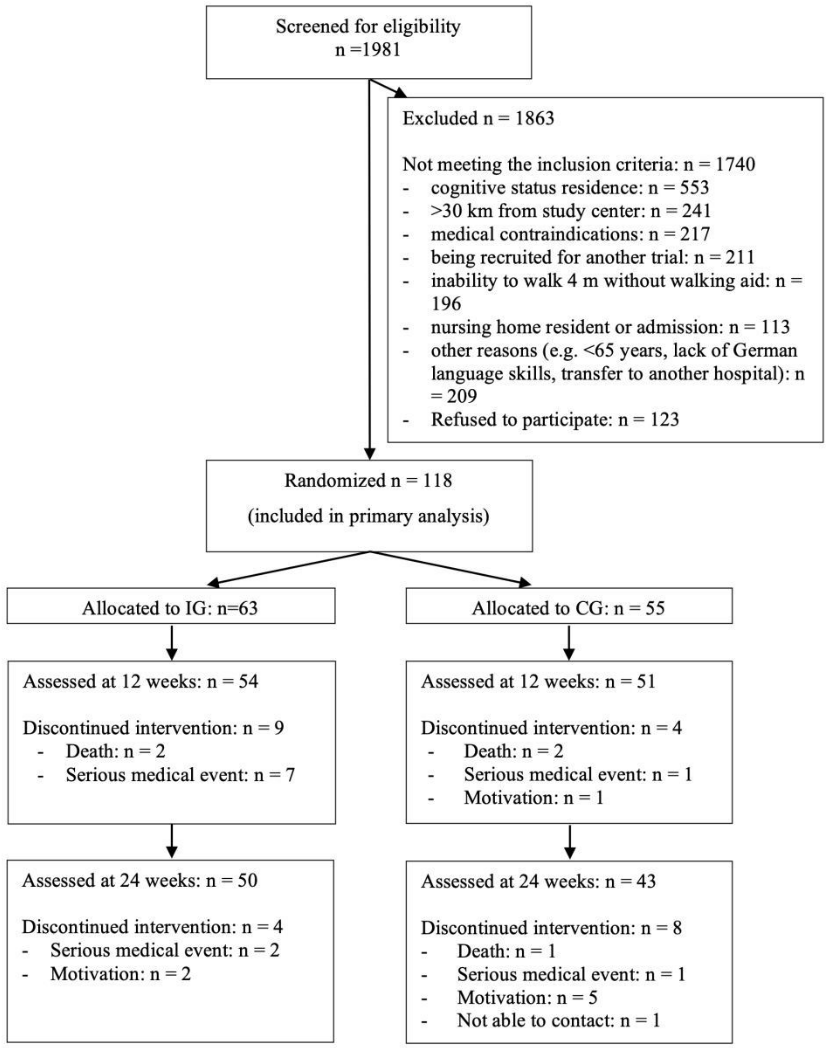

Figure 1: Flowchart of the screening and inclusion of study participants
Note: Presented is the flowchart of the screening process, enrollment, allocation, and follow-up of the study

175x200mm (300 x 300 DPI)

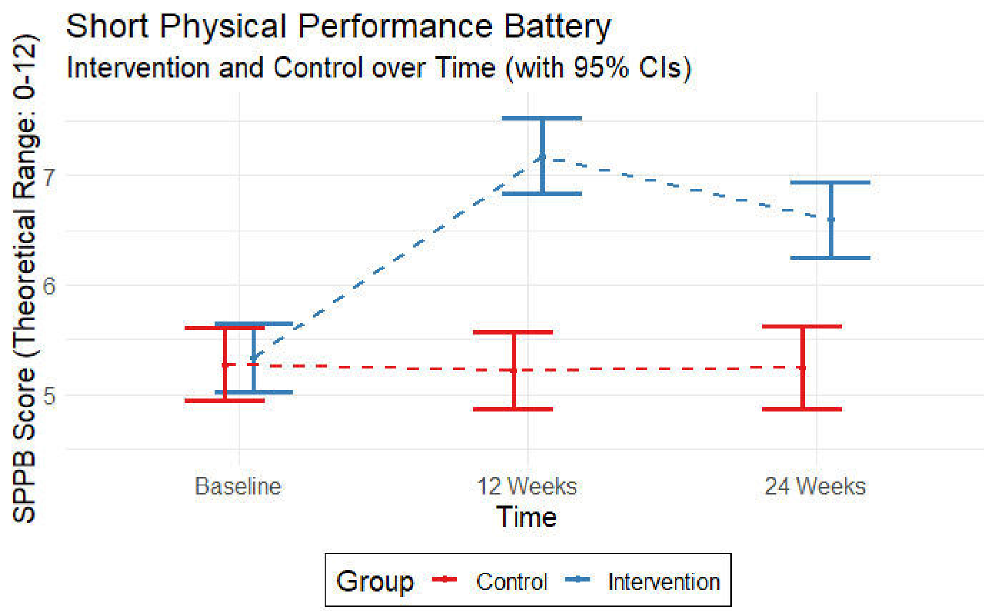

Figure 2

Figure 2: Presented are the model based means for the SPPB total score with 95% confidence intervals (CI) in the IG compared to the CG over the measurements (baseline, post intervention and after follow-up period).

378x233mm (47 x 47 DPI)

Supplemental Material

Supplemental Table 1: Description of the HeikE and control intervention using the Template for Intervention Description and Replication (TIDieR) checklist (Hoffmann et al., 2014)

Item	Description
1. Brief name	Intervention group: Heimtraining bei Kognitiver Einschränkung (HeiKE) – Home training in persons with cognitive impairment Control group: N/A
2. Why	Older people with cognitive impairment in the post-discharge phase after geriatric rehabilitation are at high risk for mobility limitations and adverse outcomes. There is a need for interventions to prevent readmission and loss of mobility and autonomy. The HeikE intervention has been tested in a pilot study and was enhanced by a motivational concept.
3. What: Materials	Intervention group: - A large poster (84.1 × 59.4 cm (Bongartz et al., 2017)) showing the six basic exercises to improve postural control (side by side, semi-tandem and tandem stance) and strength (tiptoe stance, sit-to-stand transfers/chair-rise, stair rise) was placed in the participants' home. - A printed HeiKE manual describing the rationale for the study, the relevance of physical training and physical activity, training principles, precautions and safety instructions, training instructions on the key elements for each exercise and possibilities to increase or reduce training load was provided to support the autonomous training. - Training logs (one for each week with boxes for every day) in which participants documented exercise frequency, adverse events (falls), steps taken with a pedometer, and achieved goals (referring to the daily walking course). - Information sheet containing (contact) information and a picture of the study personnel. - Pedometer (YAMAX Digiwalker CW 700) for self-monitoring of physical activity (number of daily steps). - Written document on the walking course defined jointly by the trainer and the participant. - Trainer's manual with all information on the content of each of the five home visits and the weekly phone calls, including text templates, materials needed (for the home visits), advice on necessary preparations, documentation forms and precautions. Control group: - Three exercise sheets describing unspecific flexibility and strength exercises in a sitting position for foot and leg muscles (8 exercises), arm and hand muscles (9 exercises), and abdomen and back muscles (9 exercises). - Two newsletters on nutrition, focusing on healthy eating and drinking behavior - Falls log (one for each week with one box for each day) All materials are written in German language and are available on request

	from the corresponding author (KH).
4. What: Procedures	Intervention group: Home visit 1: The HeikE intervention was introduced, all documents and training materials for the participants (poster, manual, training logs, walking course documentation, pedometer) were handed over, presented by the trainer and reviewed with the participants. Information about the benefits of regular exercise was given. An adequate training location in the home was identified. The exercises were explained to the participants, adapted to their individual abilities and practiced under the supervision of the trainer with a focus on safety. References were included to the participants' own training and activity goals as determined at the baseline assessment. If possible, the walking course was defined and also walked together with the trainer. Barriers to exercise and walking were identified and solutions discussed, and equipment needed for the walking course were determined. Optional free participation in weekly training sessions in a hospital-associated sports club specifically for older persons was offered. Relatives who wanted to support the training procedure were instructed in safety aspects and correct execution of exercises. Home visit 2 (within 2 to 3 days): The exercises were conducted together with the trainer, focusing on correct execution; if possible and required, opportunities to increase training load were discussed. If not yet introduced in home visit 1, the walking course was added to the training plan. Encouragement to engage in daily activity was given. The training logs were discussed. Home visit 3 (week 4) and 4 (week 8): Exercises and walking course were evaluated. Difficulty levels of the indoor exercises and the outdoor walking course were individually tailored to the physical capacities and training progress. The results as documented by the participant in the training logs were used to identify barriers, give feedback, or for motivation/positive reinforcement. Home visit 5 (week 10): Exercises and walking course were evaluated and adapted again to the participants' training progress, with a focus on autonomous training in the future after the study. The option of training in the hospital-associated sports club was mentioned. Relatives who wanted to support the training procedure were instructed in safety aspects and correct execution of exercises. Motivation of the participant to continue exercising after the end of the study. Weekly phone calls were used to ask for overall health status, encourage to exercise daily, to identify barriers, to increase motivation, to support self-monitoring, and to ascertain falls. Control group: Home visit 1: The control intervention was introduced. The exercises on foot and leg muscles were explained to the participant and practiced under the supervision of the trainer. Home visit 2 (within 2 to 3 days): The newsletter on nutrition (healthy eating) was handed out and discussed. If the participant was willing, the foot and leg exercises were performed together. Home visit 3 (week 4): The arm and hand exercises were explained to the participant and practiced under the supervision of the trainer.

	Home visit 4 (week 8): Another newsletter on nutrition (healthy drinking) was handed out and discussed. If the participant was willing, the foot, leg, arm and hand exercises were performed together. Home visit 5 (week 10): The exercises on abdomen and back muscles were explained to the participant and practiced under the supervision of the trainer. Weekly phone calls are used to ask for overall health status and to ascertain falls.
5. Who provided	Academic sports scientists experienced in geriatric rehabilitation provided the HeiKE intervention and the control intervention.
6. How	The HeiKE intervention and the control intervention were provided in one-on-one situations in participants' homes and via phone.
7. Where	Study center was in Heidelberg (Baden-Wuerttemberg, Germany), intervention was delivered in participants' homes (30 km around Heidelberg)
8. When and how much	5 home visits (2 in week 1, week 4, 8 and 10) à 40-90 min, weekly phone calls à 2-15 min Intervention group: Training prescription for the HeiKE intervention (exercises and walking course) included daily practice of the exercises and the walking course. Control group: Training prescription for the control intervention included unspecific instructions for regular exercise.
9. Tailoring	Intervention group: Individual tailoring of the exercises (intensity, volume), walking course (distance), and activity goals (number of steps) to the participants´ individual abilities and training progress was constantly given at each home visit. Phone calls by the trainer were used to support training progress and motivation. Control group: N/A
10. Modifications	N/A
11. How well: Planned	Intervention group: Training adherence was assessed using self-reported training logs. Training logs contained sheets with check boxes for each day that participants documented for number of exercise sessions completed, number of steps taken, outdoor activity, goal (referring to walking course) achieved, and falls. Motivational techniques of behavior change are used to increase training adherence: provision of knowledge on benefits of regular exercising and physical activity (HeiKE manual, trainer information); regular home visits/phone calls for social support and setting, reviewing and adapting individual training goals, barrier identification and problem-solving; self-monitoring by training logs and pedometer; motivational interviewing, and provision of feedback on training progress. Control group: N/A
12. How well: Actual	Intervention group: Mean training adherence over the 12-week intervention period was relatively high, with daily training and walking course conducted on approximately 60% of all possible training days. More detailed information on adherence rates can be found elsewhere (Eckert et al., 2020). Control group: N/A

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Supplemental Table 2: Model-based values for study outcomes at each time point over the entire study for the intervention and the control group

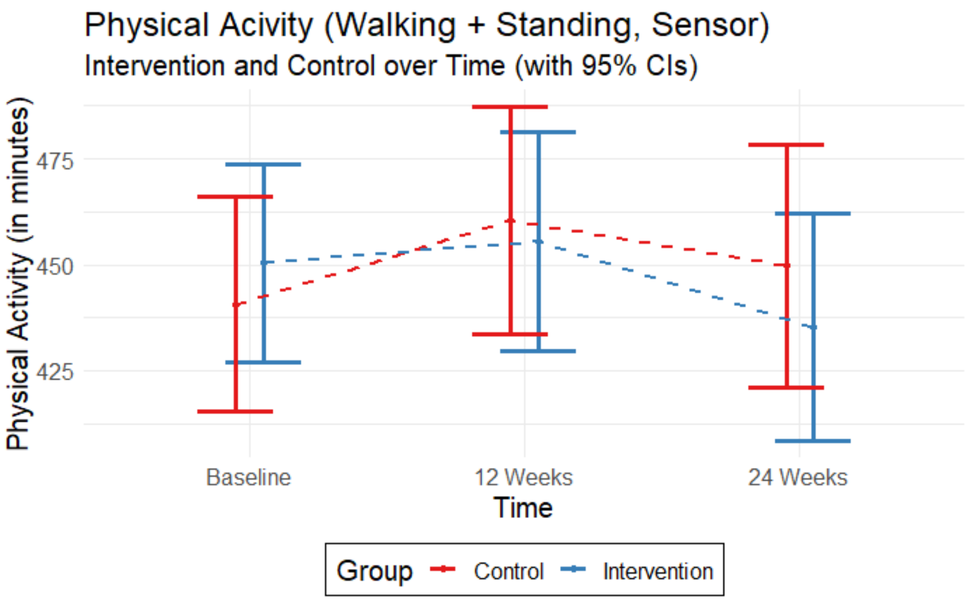
Outcome	Absolute values (mean (SD)) for T1, T2 and T3	
	IG	**CG**
(Primary outcomes)		
SPPB total score [scores]	T1: 5.33 (0.16) T2: 7.18 (0.17) T3: 6.59 (0.18)	T1: 5.27 (0.17) T2: 5.22 (0.18) T3: 5.24 (0.19)
PamSys Physical Activity (time in minutes)	T1: 450 (12) T2: 455 (13) T3: 435 (14)	T1: 441 (13) T2:460 (14) T3: 450 (15)
(Secondary outcomes)		
SPPB sub-score chair rise [scores]	T1 1.05 (0.87) T2: 1.94 (1.24) T3: 1.78 (1.23)	T1: 0.85 (1.01) T2: 1.00 (1.02) T3: 0.98 (1.00)
Chair rise duration sec	T1: 22.4 (0.8)	T1:20.9 (1.0)

	T2: 15.1 (0.8) T3: 15.2 (0.8)	T2: 19.4 (1.0) T3: 19.9 (1.1)
SPPB sub-score balance [scores]	T1: 2.65 (1.11) T2: 3.28 (0.79) T3: 2.92 (0.92)	T1: 2.36 (1.14) T2: 2.22 (1.14) T3: 2.43 (1.19)
SPPB subscore gait [scores]	T1: 1.73 (0.94) T2: 2.26(1.03) T3: 2.37 (0.97)	T1: 1.78 (0.94) T2: 1.67 (1.03) T3: 1.64 (1.10)
Habitual Gait speed m/s	T1: 0.47 (0.01) T2: 0.62 (0.01) T3: 0.57 (0.02)	T1: 0.47 (0.01) T2: 0.51 (0.02) T3: 0.47 (0.02)
Maximal gait speed m/s	T1: 0.72 (0.02) T2: 0.84 (0.02) T3: 0.83 (0.02)	T1: 0.71 (0.02) T2: 0.74 (0.02) T3: 0.70 (0.02)
TUG [seconds]	T1: 23.05 (12.35) T2: 17.40 (6.80) T3: 19.30 (11.67)	T1: 25.92(15.64) T2: 26.95 (17.07) T3: 24.46 (13.75)
LSA-CI	T1: 27.08 (13.60) T2: 38.37 (15.50) T3: 36.65 (17.37)	T1: 20.34 (11.79) T2: 21.97 (11.75) T3: 24.91 (12.61)
FES-I (total)	T1: 12.24 (4.25) T2: 10.48(3.82) T3: 10.38 (3.65)	T1: 12.18 (4.41) T2: 12.67 (4.86) T3: 12.67 (4.54)
FFABQ	T1: 19.54(12.86) T2: 13.07 (10.99)	T1: 17.33(12.37) T2: 19.96 (14.83)

	T3: 13.46 (12.40)	T3: 19.90(14.20)
EQ-5D index value (TTO)	T1: 0.64 (0.30) T2: 0.71 (0.31) T3:0.74 (0.27)	T1: 0.64 (0.30) T2: 0.63 (0.29) T3: 0.70 (0.26)
EQ-5D VAS score (perceived health status)	T1: 56.90 (17.17) T2: 63.84 (19.54) T3: 67.5 (17.36)	T1: 53.45 (13.97) T2: 58.82 (15.74) T3: 58.93 (17.45)
AES-C score	T1: 21.86(8.89) T2: 19.50 (9.74) T3: 21.82 (11.76)	T1: 22.51(9.51) T2: 24.16 (8.64) T3: 23.00 (9.75)
GDS-SF (total)	T1: 5.16(2.96) T2: 5.15 (3.44) T3: 5.30 (3.60)	T1: 5.38(3.08) T2: 5.41 (3.21) T3: 5.81 (3.77)

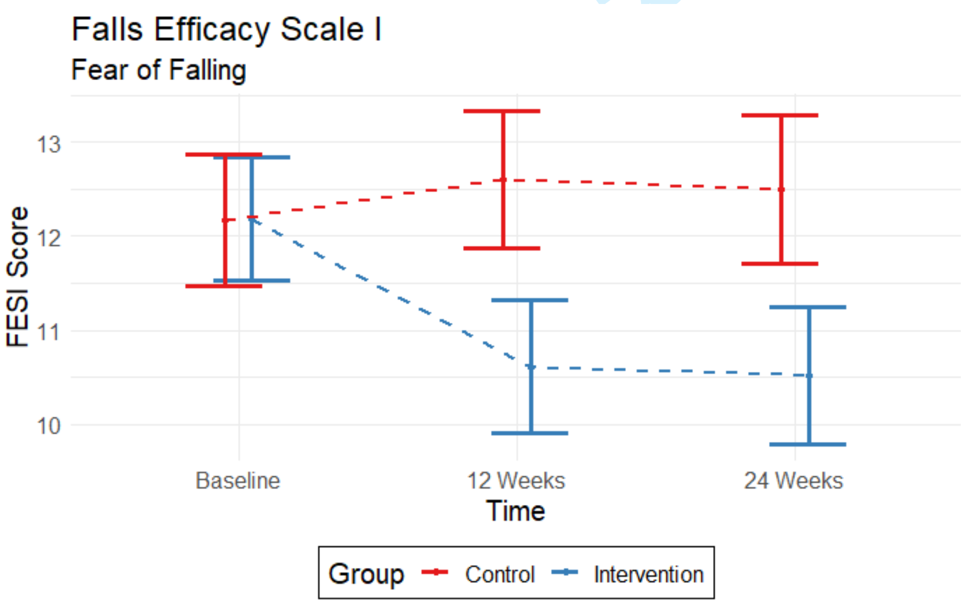
Abbreviations: *AES-C: Apathy Evaluation Scale – Clinical Version; CG: control group; CI= confidence interval; EQ-5D-3L: Euroqol 5 dimensional health-related quality of life questionnaire; EQ-5D VAS: health-related quality of life visual analogue scale (perceived health status); Short FES-I: Falls Efficacy Scale – International short version; FFABQ: Fear of falling avoidance behavior questionnaire; GDS: Geriatric Depression Scale; IG: Intervention group; LSA-CI: Life-Space Assessment for persons with cognitive impairment; SPPB: Short Physical Performance Battery; TUG: Timed-up-and-go.*

Supplemental Figure 1: Effects on physical activity



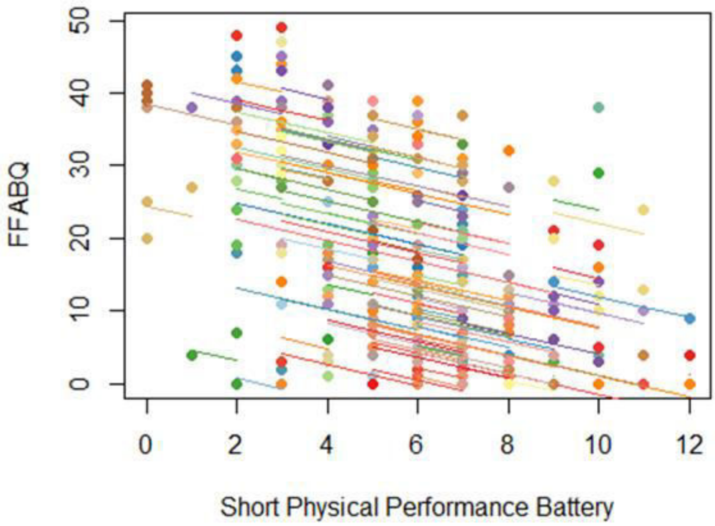
Presented are the model based means for the physical activity - active time with 95% confidence intervals (CI) in the IG compared to the CG over the measurements (baseline, post intervention and after follow-up period).

Supplemental Figure 2: Effects on falls efficacy



Presented are the model based means for the Short Falls Efficacy Score-International score with 95% confidence intervals (CI) in the IG compared to the CG over the measurements (baseline, post intervention and after follow-up period).

Supplemental Figure 3: Repeated measures correlation for Fear of Falling Avoidance Behavior Questionnaire and Short Physical Performance Battery



Repeated measures correlation to show within-individual associations between the two outcomes FFABQ (Fear of Falling Avoidance Behavior Questionnaire) and SPPB (Short Physical Performance Battery) assessed on all three time points for all participants.

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Research Article

Increasing Life-Space Mobility in Community-Dwelling Older Persons With Cognitive Impairment Following Rehabilitation: A Randomized Controlled Trial

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Abstract

Background: Community-dwelling older persons with cognitive impairment (CI) following discharge from geriatric rehabilitation are at high risk of losing life-space mobility (LSM). Interventions to improve their LSM are, however, still lacking. The aim of this study was to evaluate the effects of a CI-specific, home-based physical training and activity promotion program on LSM.

Methods: Older persons with mild-to-moderate CI (Mini-Mental State Examination: 17–26 points) discharged home from rehabilitation were included in this double-blinded, randomized, placebo-controlled trial with a 12-week intervention period and 12-week follow-up period. The intervention group received a CI-specific, home-based strength, balance, and walking training supported by tailored motivational strategies. The control group received a placebo activity. LSM was evaluated by the Life-Space Assessment in Persons with Cognitive Impairment, including a composite score for LSM and 3 subscores for maximal, equipment-assisted, and independent life space. Mixed-model repeated-measures analyses were used.

Results: One hundred eighteen participants (82.3 ± 6.0 years) with CI (Mini-Mental State Examination: 23.3 ± 2.4) were randomized. After the intervention, the home-based training program resulted in a significant benefit in the Life-Space Assessment in Persons with Cognitive Impairment composite scores (b = 8.15; 95% confidence interval: 2.89–13.41; p = .003) and independent life-space subscores (b = 0.39; 95% confidence interval: 0.00–0.78; p = .048) in the intervention group (n = 63) compared to control group (n = 55). Other subscores and follow-up results were not significantly different.

Conclusions: The home-based training program improved LSM and independent life space significantly in this vulnerable population. Effects were not sustained over the follow-up. The program may represent a model for improved transition from rehabilitation to the community to prevent high risk of LSM restriction.

Keywords: Clinical trials, Exercise, Home care, Physical activity, Post-ward rehabilitation

Life-space mobility (LSM) refers to the ability to move within one's environment, such as one's home, neighborhood, town or areas beyond, and considers the extent and frequency of moving, and the need for assistance in order to be mobile (1,2). The ability of moving, whenever and wherever a person wants to move, is relevant for activities of everyday life (3), social participation (4), quality of life (5), and is of high personal relevance for frail older persons (6,7). A reduced LSM can have severe consequences for older persons' lives, as it is associated with adverse health outcomes such as functional impairment (8), falls and fractures (9), institutionalization (10), and increased mortality (11). Mobility also contributes to healthy aging (12). Outdoor mobility is mandatory for maintaining physical function in frail older persons (8,13,14).

Multimorbid older persons with cognitive impairment (CI) recently discharged home from inpatient rehabilitation settings are associated with numerous factors that negatively affect LSM, such as advanced age, physical impairment (15), CI (15,16), and recent hospitalization (17), resulting frequently in severely restricted LSM (18,19). Despite the feasibility of interventions to improve physical function after hospitalization (20), interventions to support transition from hospital to home settings often excluded persons with CI (21,22). In particular, mobility in and around the home as well as social participation, aspects that are all covered by LSM, represent important care gaps in the postdischarge phase for vulnerable older persons (23).

Previous randomized controlled trials (RCTs) with LSM as a study outcome did not focus on the transition phase after hospitalization (24–32) and/or excluded or did not focus on persons with CI (24–27,33). In those RCTs that did include cognitively impaired persons, CI and its sequelae were not specifically addressed, although the presence of CI is associated with relevant behavioral and cognitive changes. These changes require adaptations of intervention programs (34), such as the implementation of adequate motivational strategies, including CI-specific communication, goal setting, barrier management, and self-monitoring strategies to foster a change of activity-related behavioral patterns with a focus on sustainability (35). This is of particular relevance if individuals live independently in the community with limited social support. Hence, it is not surprising that we identified only one RCT that included persons with CI and evaluated a home-based training approach in a community setting (30).

Beyond the lack of comparable RCTs with respect to population, setting, and timing of the interventions, there is limited evidence of the effectiveness of existing interventions on LSM. Study results were heterogeneous, with only a few studies documenting improvements on LSM (29,30,33), while most studies reported no significant effects on LSM (24–28,31,32). Effects on life space, focusing solely on the spatial distance from home and allowing a detailed insight on the area achieved with and without support, are not reported. Follow-up studies are scarce, and sustainable effects on LSM following the end of training have not been shown (25,26,28,29). None of these studies included interventional strategies to promote habitual, autonomous physical activity with a clear focus on the sustainability of intervention effects on LSM after cessation of active programs.

Within the context of heterogeneous results on the effect of interventions on LSM, as reported in previous RCTs, the analyses of factors that may influence training response are of high clinical relevance. The outcome is a better understanding of the training impacts, contributing to the development of future studies to improve LSM, which in turn can enhance treatment effectiveness, or improve the selection of persons with a larger likelihood of response to an LSM-enhancing program. Analyses in previous studies included adherence as a measure of training response (30,32) and additionally cognition and frailty (30). An evidence-based, comprehensive analysis including a wide range of potentially relevant predictors of training response, such as cognitive, psychosocial, physical, and sociodemographic factors, all of which have been identified to influence LSM in a comprehensive theoretical mobility model (2) and through an epidemiological study (18), has been lacking.

The aim of this study was to determine whether a standardized, home-based training and activity promotion program, specifically developed for persons with CI after discharge from rehabilitation, can improve LSM and whether intervention effects can be sustained during follow-up in this vulnerable population. Additionally, feasibility aspects of the intervention and predictors of training response for LSM were investigated.

Method

The present study analyzed secondary outcomes of a single-center double-blinded, randomized, placebo-controlled 12-week intervention trial with a 12-week follow-up period to improve physical function and physical activity in older persons with mild-to-moderate CI, recently discharged home from geriatric rehabilitation in Heidelberg, Germany (http://www.isrctn.com/ISRCTN82378327). Neither the assessors nor the participants were aware of group identity. The RCT was performed according to the Helsinki declaration and was approved by the ethics committee of the Medical Department of the Heidelberg University (S-252/2015). The study design and methods were previously described in detail (36).

Participants

Older people (aged ≥65 years) with mild-to-moderate CI as indicated by a Mini-Mental State Examination (MMSE) score of 17–26 (37,38) were consecutively recruited from rehabilitation wards of a geriatric hospital during an individualized multidisciplinary, geriatric rehabilitation program consisting of physiotherapy, occupational therapy, language and speech therapy, psychological and social support and counseling according to the individual patient needs. Further inclusion criteria were the ability to walk at least 4 m without walking equipment as a safety criterion for independent, unsupervised training at home; residence within 30 km of the study center; discharge to community settings; no terminal disease or severe medical conditions; no delirium; adequate language level; written informed consent. Individuals meeting these inclusion criteria were allocated using urn randomization (39) stratified by gender to either a home-based intervention group (IG) or a home-based control activity group (CG) after baseline assessment with a 1:1 allocation rate.

Intervention

The home-based training program of the IG was specifically tailored for geriatric patients with CI after geriatric rehabilitation and has been shown to be feasible and effective to improve physical function and physical activity in older adults with CI in a pilot study (40). As the intervention program included a multimodal activity promotion program, we hypothesized an intervention-based positive effect on LSM.

The training included 3 balance and 3 strength exercises, allowing the proper progression of intensity, and an individualized walking course in the participants' immediate home environment to enhance physical activity (36). Individual walking courses, as part of the activity promotion program, were tested together with trainers to ensure training stimulus, to prevent exhaustion, and to familiarize the participants with walking equipment as well as characteristics and safety aspects. Participants were instructed to independently perform the training and walking course as a daily routine depending on the participants' functional status and motivation. A large poster with the exercises and a printed manual, which were deliberately designed to be simple and easy to follow, were issued to each participant. The training was amended by a

CI-specific motivational approach developed to support training adherence and behavioral changes, including validation, social support, goal setting, identification and removal of barriers to exercise and walking, and self-monitoring via a training diary and pedometer (35). The intervention was implemented and the training progress was supported by trained sports scientists experienced in geriatric rehabilitation.

Participants in the CG received a training manual including unspecific flexibility and strength exercises in a sitting position at home and newsletter-based information on nutrition and relaxation.

All participants, including those of the CG, were supported by 5 home visits with decreasing frequency and weekly phone calls. The CG received the same amount of support to control for psychosocial effects induced by the visits of the trainers or regular phone calls. During the follow-up period, both groups did not receive any support or contact.

Measurements

The assessments were performed after discharge from rehabilitation in the participants` home before randomization (T1), at the end of the 12-week training period (T2), and after the 12-week follow-up period (T3). Sociodemographic characteristics including age, gender, and number of diagnoses and medications were documented from patient charts at discharge. Educational status, marital status, and history of falls in the previous year were assessed by standardized interviews. Physical function was assessed with the Short Physical Performance Battery (SPPB) (41). To assess psychosocial status, the Geriatric Depression Scale Short Form (GDS-SF) (42), the Apathy Clinical Evaluation Scale—Clinical Version (AES-C) (43), and Short Falls Efficacy Scale—International (Short-FES-I) (44) were used. Physical activity (documented by the number of steps) was determined using a validated activity monitor attached to the participants' chest for a 48-hour assessment period (PAMSys; BioSensics, Cambridge, MA) (45). Adherence was assessed in the IG as part of the motivational strategy using training diaries filled by the participants, considering the number of days with training, outdoor walking, achieved walking goals, and self-monitoring by pedometer (35).

LSM was assessed by the Life-Space Assessment in Persons with Cognitive Impairment (LSA-CI) representing an interview-based, self-report measure that has been specifically developed and successfully validated for use in older persons with CI (46). The LSA-CI extends the original University of Alabama at Birmingham Life-Space Assessment (UAB-LSA) (1) by an adjusted interview strategy, taking into account the resources and limitations of older persons with CI (ie, informal conversation, precise questions, and response options, structuring the observation period, highlighting landmark events). The assessment period is also condensed from 4 weeks to 1 week to reduce recall bias. The LSA-CI assesses LSM in 6 life-space zones (from bedroom = 0, home = 1, immediate surroundings of one's home = 2, neighborhood = 3, home town = 4 to unlimited area = 5) within the previous week, the frequency of mobility for each zone (1 point: 1–3 times per week, 2 points: 4–6 times per week, and 3 points: daily), and the assistance needed to travel within a zone (1 = "help of another person," 1.5 = "use of equipment only," and 2 = "no assistance"). A composite score, representing total LSM, is calculated by multiplying the zone score with scores for frequency and assistance and adding the scores for each zone. Zero indicates total immobility and 90 indicates daily independent out-of-town mobility. Three additional subscores document the spatial reach, including maximal life space (LSA-CI-M; independent, with equipment or personal support), equipment-assisted life space (LSA-CI-E; independent or with equipment), and independent life space (LSA-CI-I; without equipment or personal support) achieved within the previous week (each range 0–5).

Statistical Analysis

This study presents a secondary analysis of existing data and therefore the calculation of the required sample size is based on a different outcome. The details of the sample size calculation were reported in the work of Bongartz et al. (36). Taking into account an expected drop-out rate of 15%, a total of $n = 116$ participants with equal allocation was targeted. This study focused primarily on the intervention's effect on the LSA-CI composite score. The associated subscores were also examined.

Descriptive data were presented as absolute and relative frequencies for categorical variables and mean and standard deviation or median and range for continuous variables as appropriate. Unpaired *t* tests and Mann–Whitney *U* tests were applied to determine differences between participants who did not complete the intervention or the follow-up period.

To address the main research question, a linear mixed-model repeated-measures analysis was used to model the LSA-CI measures and compare the differences across groups and changes over time (47–49). The mixed-effects model therefore included group (IG vs CG) and time (T1, T2, and T3), as well as its interaction, and the covariates gender and baseline LSA-CI scores as fixed effects. Gender was included as a covariate because it was part of the randomization mechanism. Participants were treated as a random effect. The within-group correlation of participants across different time points was estimated from the data using a general structure. The model was estimated using restricted maximum likelihood which, following the intention-to-treat (ITT) principle, handles missing data and includes all randomized participants (50). We provided the model-based group effects in mean change with 95% confidence intervals and associated *p* values. Using the model-based means, group trajectories were also graphically displayed in an interaction plot. While the focus was on the LSA-CI composite score, the same modeling strategy was also applied to its subscores.

Analyses with respect to clinically relevant categories (increased, decreased, or stable LSM or life space) and thresholds (the ability to move outside the neighborhood using equipment if needed (1) and the ability to move outside the own bed independently (8,13)) were presented descriptively, including only available cases.

To determine predictors of training response, bivariate correlational analyses (Spearman [r_s] and point-biserial [r_{pb}] correlation coefficients) were performed between LSM changes (LSA-CI composite score between T1 and T2) of the IG and potentially associated variables. Variables that have been shown to determine LSM in a comprehensive model for mobility (2) and a cross-sectional study in the target group (18) included sociodemographic factors (age, gender, marital status, educational level, number of diagnoses, and medications), cognitive status (MMSE), physical function (SPPB, falls in the previous year), psychosocial status (Short FES-I, GDS, AES-C), physical activity (number of steps), baseline LSM, and variables for adherence to the training (number of days with training, outdoor walking, achieved walking goals, and pedometer use) (35). The variables with significant correlations of $p < .01$ were considered for the standard linear regression analysis to examine independent determinants of LSM. In this analysis, missing data were handled by pairwise deletion.

Except for the aforementioned variable selection process in the sensitivity analyses, $p < .05$ (two-sided) was considered statistically significant. Reported p values are to be interpreted as descriptive. Statistical analyses were performed using R version 3.6.1 (51) and IBM SPSS Statistics version 23 for Windows (IBM Corp., Armonk, NY).

Results

Recruitment

Out of 1981 persons screened for eligibility, n = 118 participants were enrolled according to the predefined inclusion criteria between August 2015 and April 2017. Primary causes for exclusion were inappropriate cognitive status (n = 553), residence more than 30 km from study center (n = 241), and medical contraindications (n = 217; Figure 1).

Study Sample

The study sample included multimorbid (medical diagnoses: n = 11.4 ± 4.4) older persons (82.3 ± 6.0 years) with cognitive (MMSE score: 23.3 ± 2.4 points) and physical impairment (SPPB score: 5.2 ± 2.3 points). Sixty-three participants were randomized to the IG and 55 to the CG. Baseline characteristics were balanced between the groups (Table 1). The main reasons for hospital admission were predominantly related to cardiovascular diseases (20%), degenerative joint diseases (18%), neurological diseases (16%), and consequences of falls (14%). Dropouts (attrition rate: 11% at T2 and 22% at T3) were related to serious medical events (n = 12), death (n = 4), lack of motivation (n = 8), loss of contact (n = 1), or refusal of relatives (n = 1; Figure 1) and were evenly distributed between the study groups (dropouts from each group n = 13). Adverse events were related to preexisting comorbidities and not directly or indirectly attributable to the training program. When participants who stayed in the study until the end of follow-up (n = 92) were compared with those who dropped out (n = 26), no significant differences for any baseline variables were found except for physical function and apathetic symptoms (Supplementary Table S1). Absolute results for the measurements are given in Supplementary Table S2.

Effects of the Intervention

At the post-intervention measurement, the mean treatment effect for the LSA-CI composite score resulted in a significant benefit of 8.15 score points for the IG compared to the CG (95% confidence interval [CI] 2.89–13.41, p = .003; Table 2). A significant improvement in the IG compared to the CG by 0.39 score points could also be documented for 1 of 3 subscores of the LSA-CI, the independent life space (95% CI 0.00–0.78, p = .048). Benefits for the other subscores were not significantly different between the IG and CG (LSA-CI-M: Difference 0.33 score points, 95% CI −0.18–0.84, p = .208; LSA-CI-E: Difference 0.43 score points, 95% CI −0.11–0.98, p = .122). Training gains decreased after the intervention, with no significant differences between the groups during the follow-up period. The benefit observed in the LSA-CI composite score was 3.03 (95% CI −2.39–8.46, p = .274), with a range between −0.02 and 0.35 for the subscores (Table 2). The model-based trajectories of LSA-CI scores for the groups across the different time points are also graphically displayed in Figure 2 and Supplementary Figures S1–S3.

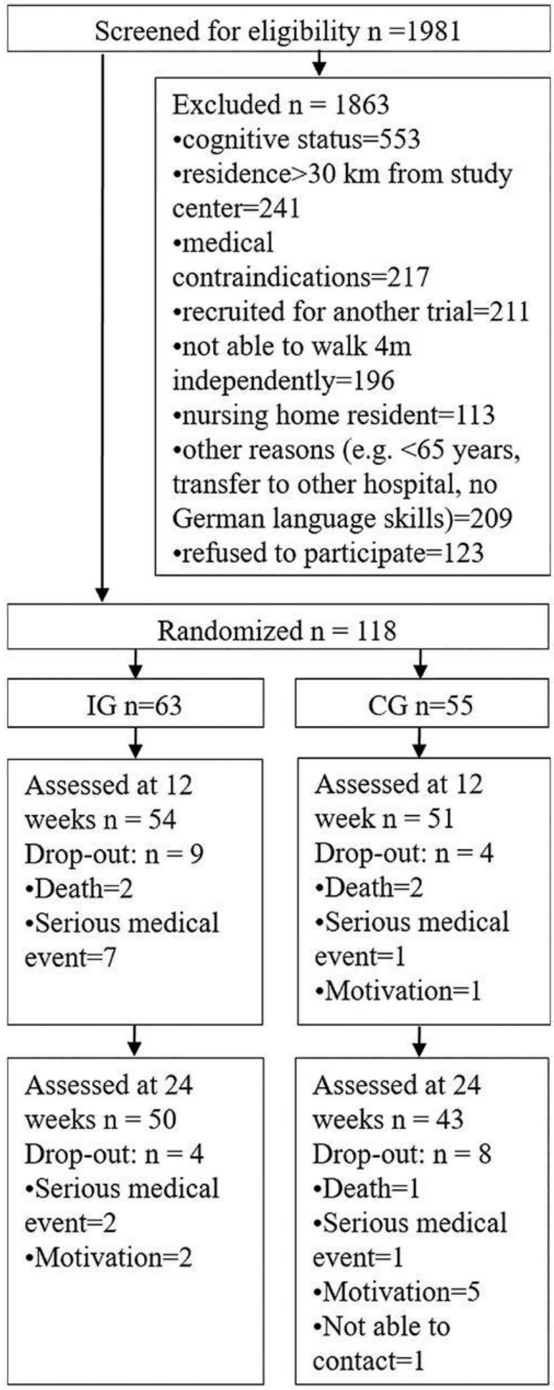

Figure 1. Flowchart of the screening process, enrollment, allocation, and follow-up of the study. CG = control group; IG = intervention group.

Additional Analyses

Results for changes in clinically relevant categories were also analyzed, to further describe the effects of the intervention. After the intervention, a considerably larger proportion of participants increased their LSA-CI composite score in the IG (75%) compared to the CG (40%), while decreases of the LSA-CI composite score were lower in the IG (19%) compared to the CG (44%). Similar results were achieved for the LSA-CI subscores: 36%–43% of participants of the IG in contrast to 16%–30% of the CG were able to improve their life space, and decrease of life space was shown for only 11%–17% participants of the IG versus 14%–22% of the CG (Supplementary Table S3). The number of individuals able to move beyond the immediate neighborhood (>life-space level 3) without personal assistance but with equipment, as well as the ability to get out of bed independently (≥ life-space level 1), increased in the IG (from 34% to 45% and from 58% to 72%), while the number of participants in the CG stagnated (from 18% to 20% and from 42% to 42%; Supplementary Table S4). The highest possible maximal life-space level 5 was achieved at baseline by 28% in the IG and 16% in the CG, indicating a potential ceiling effect for the subscore LSA-CI-M.

Predictors of Training Effects

Bivariate correlation analyses revealed baseline LSA-CI composite score ($r_s = -0.433$, $p = .001$), and adherence with respect to days with pedometer monitoring ($r_s = 0.471$, $p = .001$) to be significantly associated ($p \leq .01$) with a change in LSM during the intervention period (T1–T2; Supplementary Table S5).

In the regression model, baseline LSA-CI composite and adherence were identified as predictors of change in LSM for the intervention period and accounted for 21.8% of the variance (Table 3). Exclusion of subgroups according to baseline status did not alter our main findings. Results suggest a lower baseline LSM and higher self-monitoring by pedometer to be associated with higher training response for LSM.

Table 1. Baseline Sample Characteristics for Study Groups

Characteristics	IG (*n* = 63)	CG (*n* = 55)
Age (years), mean (*SD*)	82.2 (5.8)	82.4 (6.2)
Gender (female/male), %	76.2/23.8	76.4/23.6
Marital status (yes/no), %	27.0/73.0	34.5/65.5
Educational level*, %	33/48/19	29/53/18
Number of diagnoses (*n*), mean (*SD*)	11.3 (3.6)	11.4 (5.3)
Number of medications (*n*), mean (*SD*)	9.4 (3.3)	9.6 (3.7)
MMSE score (0–30), mean (*SD*)	23.3 (2.7)	23.3 (2.1)
SPPB score (0–12), mean (*SD*)	5.4 (2.1)	5.0 (2.4)
≤1 fall in the previous year, %	76	56
Short FES-I score (7–28), median (range)	11 (7–25)	11 (7–25)
GDS score (0–15), mean (*SD*)	5.2 (3.0)	5.4 (3.1)
AES-C score (0–54), mean (*SD*)	21.9 (8.9)	22.5 (9.5)

Notes: AES-C = Apathy Evaluation Scale—Clinical Version; CG = control group; FES-I = Falls Efficacy Scale—International; GDS = Geriatric Depression Scale; IG = intervention group; MMSE = Mini-Mental State Examination; *n* = number; SD = standard deviation; SPPB = Short Physical Performance Battery. Presented are baseline comparisons between study groups as randomized. Scoring range is given in bracket.

*Only school/vocational education/university or comparable.

Discussion

The present RCT demonstrates that the home-based physical training and activity promotion program were effective and improved LSM as well as independent life space in older multimorbid persons with CI in the phase after discharge from geriatric rehabilitation. However, effects decreased and were not significantly different after the follow-up period.

Effects of the Intervention

Participants in the IG improved the LSA-CI composite and independent scores, demonstrating the effectiveness of the trialed home-based training and activity promotion program, reflecting an increased spatial range of mobility, increased frequency of actual mobility behavior, and/or decreased use of assistance after the intervention period. An improvement of 8 score points for the composite LSM score corresponds, for example, with the ability to reach zone 3 (neighborhood) on 1–3 days a week with only equipment instead of being only mobile in zone 1 (own home); or with the ability to reach life space zone 4 (out of the neighborhood) instead of zone 3 (within the neighborhood) on most days of the week with personal assistance. From a clinical point of view, the surpassing of a previous life-space zone can be regarded as a notable and practically relevant improvement. These achievements suggest that the home-based training program might be effective to support autonomous living at home and to increase participation in the community in older adults with CI following discharge from rehabilitation, thus contributing to improvements in emotional well-being and overall quality of life (3–5). The success of the intervention might be due to its multimodal focus, targeting motivation, improvements of physical function, and physical activity promotion, with attention paid specifically to factors that have been shown to determine LSM in older adults with

Table 2. Model-Based Effects of the Intervention on Life-Space Mobility for the Postintervention (12 weeks) and Follow-up Period (24 weeks) in the IG (*n* = 63) Compared to the CG (*n* = 55)

	Model-Based Difference Between Groups Controlled for LSA-CI Baseline Score and Gender			
	Postintervention (12 weeks)		**After Follow-up (24 weeks)**	
	Mean difference (95% CI)	*p* Value†	Mean difference (95% CI)	*p* Value†
LSA-CI-C	8.15 (2.89 to 13.41)	**.003****	3.03 (−2.39 to 8.46)	.274
LSA-CI-M	0.33 (−0.18 to 0.84)	.208	−0.16 (−0.69 to 0.37)	.553
LSA-CI-E	0.43 (−0.11 to 0.98)	.122	0.35 (−0.21 to 0.90)	.220
LSA-CI-I	0.39 (0.00 to 0.78)	**.048***	0.29 (−0.15 to −0.72)	.195

Notes: CG = control group; CI = confidence interval; IG = intervention group; LSA-CI = Life Space Assessment in Persons with Cognitive Impairment, M = maximal life space (achieved independently, with equipment or another person), E = equipment-assisted life space (achieved independently or with equipment), and I = independent life space (achieved independently); *n* = number. Presented are data for the effects of the intervention for the measurement times post-intervention (12 weeks after baseline) and for follow-up (24 weeks after baseline).

†*p* Values are based on the mixed-model estimates and therefore controlled for gender and baseline LSA-CI.

Bold indicates statistically significant with *$p < .05$, **$p < .01$.

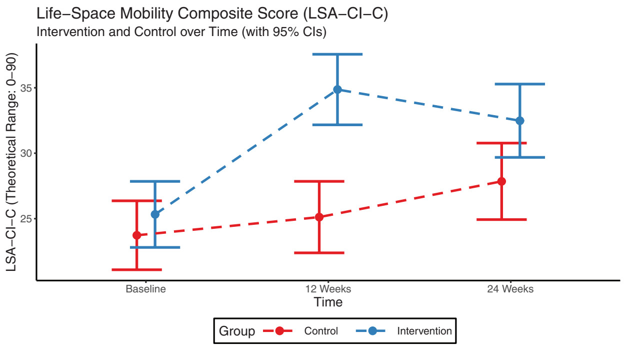

Figure 2. Life-space mobility (LSA-CI-C) results in the IG compared to the CG over time. *Note:* The model-based means for the life-space mobility composite score (LSA-CI-C) with 95% confidence intervals (CIs) in the IG compared to the CG over the measurements (baseline, postintervention, and after follow-up period) are presented. CG = control group; IG = intervention group; LSA-CI = Life-Space Assessment in Persons with Cognitive Impairment.

Table 3. Regression Model for Predictors of Change in Life-Space Mobility During the Intervention Period for the IG

Adjusted R^2			.218	
Variable	β	*B*	SE_B	95% CI for *B*
Baseline LSM (LSA-CI composite score)	−0.337*	−0.282	0.116	−0.516 to −0.049
Adherence (number of days with pedometer use)	0.296*	0.124	0.058	0.007 to 0.241

Notes: IG = intervention group; LSA-CI = Life Space Assessment in Persons with Cognitive Impairment; LSM = life-space mobility. Presented is linear regression analysis for the change in LSM (LSA-CI composite score of ΔT1–T2) with potential predictors for participants of the IG with completed intervention and complete adherence data (n = 53). The general fit of the model is reported by the adjusted coefficient of determination R^2. Effects are reported as unstandardized (*B*) and standardized regression coefficients beta (β).

Bold indicates statistically significant with $*p < .05$, $**p < .01$.

CI (18). Enrollment targets were achieved, despite the target group being difficult to reach and typically excluded from intervention trials (21,22). No adverse events were associated with the intervention, and the dropout rate was relatively low, considering the high age and impaired health status of the target population, indicating the feasibility of the intervention. Training adherence, as previously reported in detail (35), was slightly higher than in comparable RCTs on home-based training and LSM in predominantly cognitively intact persons (30,52), documenting the acceptance of the intervention in the study population. Previous RCTs evaluating LSM as an outcome measure reported no positive intervention effects (24–28,31,32), except for 3 RCTs specifically targeted at LSM improvements, which showed significant intervention-induced improvements in LSM (29,30,33). However, these RCTs did not focus on older people with CI (30,33) or were conducted in institutionalized settings (29). To the best of our knowledge, the present study is the first to demonstrate that LSM can also be increased by a home-based physical training and activity promotion program in cognitively impaired community-living older persons after geriatric rehabilitation. In all studies reporting positive intervention effects on LSM, the intervention was, as in the present study, implemented after a preceding acute medical event (29,30,33), resulting in an acute loss of LSM (17) with high opportunity for improvements in LSM. While this loss is associated with an urgent need to regain this highly relevant mobility domain, a low health status also represents a barrier to physical activity (53). A comprehensive intervention approach, with motivational strategies to encourage behavioral changes (eg, self-monitoring, goal setting, and barrier management) as applied in the present study, may be highly relevant to successfully promote LSM. Previous studies with similar intervention approaches also showed improvements in LSM (30,33). Studies without an individual specified motivational strategy (25,26,29,31) or with minimal individualized motivational strategies could not document such positive effects (24,27,28,32). This suggests that the successful implementation of CI-specific motivational strategies (35) was the key factor for the substantial benefits on LSM in the present study. None of the RCTs with LSM as a study outcome reported intervention effects on life space achieved with personal assistance, equipment, or independently, as represented by the LSA-CI subscores. Significant improvements in the IG, over the intervention period, for the independent life-space subscore underline the positive impact on the home-based training program. In line with previous research, assuming that the subscore for maximal life space (LSA-CI-M; with personal support and equipment) would not be sensitive to document intervention-induced changes (15), no significant benefits could be shown for this subscore, with a possible ceiling effect (54). For the equipment-assisted life space (LSA-CI-E), a significant effect could not be documented. However, the successful training of physical function can be reflected by the significant benefits in the independent life space (LSA-CI-I) after the intervention period. This indicates that the exercises of the home-based physical training program successfully improved physical function and autonomy. It can also be related to adaptive task modifications of walking, which has been shown to be a solution to postpone decline in outdoor mobility (55). Considering the health outcome priorities of multimorbid older persons, with independence cited as the most important outcome (6), the significance of independent life space as a relevant study outcome in this population becomes apparent. The additional analyses underline the positive impact on LSM induced by the intervention. The improvements in the IG with respect to clinically relevant categories (increased, decreased, or stable LSM or life space) compared to the slow recovery of LSM in the CG emphasize the trainability of LSM even in a multimorbid population. The IG program also led to advantages over the CG program regarding 2 clinically relevant thresholds. These are important, as the ability to be mobile beyond one's own neighborhood without personal assistance enables an individual to have independence in engaging in activities of everyday life or social participation (1). The ability to independently walk outside the home has been considered to be the minimum level of mobility to maintain physical function and mobility (8,13). Previous RCTs on LSM in older adults including long-term follow-up assessments of 12 weeks to 11 months showed no sustainable intervention effects on LSM in older adults (25,26,28,29). Similarly, benefits of the intervention also decreased in the present study with no significant differences in the IG and the CG after the 12-week follow-up period. Previous study results indicate that recovery of LSM after hospitalization is an ongoing process (17). The present study shows that recovery of LSM is modifiable, but suggests that ongoing support may be required to foster sustainable benefits on LSM.

The substantial increases of LSM and independent life space for large parts of the study population imply that the rehabilitation potential was not exploited—or not targeted—during ward-based rehabilitation. Our study results further suggest that LSM can be included as a crucial but also feasible objective for post-ward interventions to fully exploit rehabilitation potentials and to extend rehabilitation goals to activity behavior at home. This is particularly important, as maintaining mobility in and around the home has been shown to be of high personal relevance for vulnerable older persons (6,23).

Predictors of Training Effects

Lower LSM at baseline was identified as an independent predictor of improvement in LSM. This inverse relationship between the magnitude of benefits in LSM and the baseline LSM status is in accordance with the rate-dependency phenomenon and general training principles that indicate intervention response rates are highest in those individuals with the lowest baseline values (56,57). Because of their more restricted LSM, participants with the lowest LSM profit most, in cases where the inclusion and training of these most affected individuals are feasible.

High adherence as measured by pedometer monitoring was predictive for positive training response on LSM, which is in accordance with a previous study result on the influence of adherence on LSM change (32). The present study result adds to the evidence for the previously reported positive impact of pedometer monitoring as a successful motivational strategy on the mobility behavior of adults (58). Within the levels of mild-to-moderate CI, MMSE scores were not associated with the training response on LSM, which is in accordance with a previous study (30). In contrast to this previous study, which revealed an influence of frailty status on training response (30), surrogate markers for frailty, for example, physical impairment and multimorbidity, did not predict training response in the present study. Overall, our results suggest that a notable training response can be achieved despite relevant physical impairment and CI.

In spite of the evidence-based, comprehensive analysis of a wide range of potential predictors of training response, based on a complex mobility model (2) and a previous cross-sectional study of LSM determinants in the target population (18), identified predictors explain only parts of the total variance in the regression models.

Strengths and Limitations

The present study is the first to demonstrate the effectiveness of an activity promotion program for multimorbid older persons with functional and cognitive impairment, which are typically excluded, and difficult to reach. The feasibility of the intervention was the basis for its success and needs to be acknowledged with respect to the older, multimorbid study population. Influencing mobility behavior in this population is also difficult. The specific intervention, as well as the related assessment strategies, tailored to the multimorbid target population, enabled the complexities and challenges of this study population to be overcome, and lead to extended and more independent LSM. However, our study has limitations. The LSA-CI represents an assessment method relying on the self-reporting of participants. Although successfully validated in the multimorbid target group with motor and cognitive impairment (46), we cannot completely rule out incorrect responses despite methodological precautions such as the tailored development for the study sample and assessment by experienced and intensively trained assessors. The dropout rates of 11% for the intervention and 22% for the follow-up period might appear to be high; however, these are readily explained by the vulnerability of the study population with high age and impaired health status. Additionally, the groups of individuals who completed the training and those who dropped out were fairly comparable. The results were documented in a study population predefined by strict and transparent inclusion criteria. Although the intervention program could also be effective in other settings, the effectiveness and feasibility have shown to work in the described sample, limiting the overall representativeness of results.

Conclusions

The study results document the feasibility and effectiveness of the home-based training to improve LSM and independent life space in multimorbid older persons with both physical impairment and CI. Given the negative effects of restricted mobility on health, these results are highly relevant for the promotion of independence and social participation in such a vulnerable population. The results of the predictor analysis encourage the inclusion of persons with relevant LSM restrictions, as these persons have a great need of improvement alongside a high potential for a positive training response. The home-based training program can therefore represent an appropriate model for extended rehabilitation to fill the gap between ward-based rehabilitation and independent living. This can improve the transition from rehabilitation to the home in this vulnerable, older population with CI and an extraordinary high risk of activity restriction and loss of independence. Ongoing support seems to be required to sustain benefits on LSM.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki declaration and its later amendments. Written informed consent was obtained from all individual participants included in the study.

Conflict of Interest

None declared.

Author Contributions

P.U. drafted the manuscript. The primary analysis of the data was carried out by A.S. and P.U. Secondary analyses were carried out by P.U. C.W., K.H., B.A., and A.S. critically revised the article. K.H. is responsible for the conception of the study and study design. M.B., T.E., and R.B. participated in data collection. All authors read and approved the final manuscript.

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Promoting physical activity in geriatric patients with cognitive impairment after discharge from ward-rehabilitation: a feasibility study

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Promoting physical activity in geriatric patients with cognitive impairment after discharge from ward-rehabilitation: a feasibility study

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Abstract

The aim of the present study was to examine adherence and acceptance of a home-based program to promote physical activity (PA) in older persons with cognitive impairment (CI) following inpatient rehabilitation. Sixty-three older persons (≥ 65 years) with mild to moderate CI (Mini-Mental State Examination score 17–26), allocated to the intervention group of a randomized, controlled intervention trial underwent a 12-week home-based PA intervention including (1) physical training and outdoor walking to improve functional fitness and (2) motivational strategies (goal-setting, pedometer-based self-monitoring, social support delivered by home visits, phone calls) to promote PA. Training logs were used to assess adherence to physical training, outdoor walking and to motivational strategies (goal-setting, pedometer-based self-monitoring). Acceptance (subjective feasibility and effectiveness) of the program components was assessed by a standardized questionnaire. Mean adherence rates over the intervention period were 63.6% for physical training, 57.9% for outdoor walking, and between 40.1% (achievement of walking goals), and 60.1% (pedometer-based self-monitoring) for motivational strategies. Adherence rates significantly declined from baseline to the end of intervention (T1: 43.4–76.8%, T2: 36.1–51.5%, *p values*<.019). Most participants rated physical training, outdoor walking, goal-setting, and pedometer self-monitoring as feasible (68.2–83.0%) and effective (63.5–78.3%). Highest ratings of self-perceived effectiveness were found for home visits (90.6%) and phone calls (79.2%). The moderate to high adherence to self-performed physical training and motivational strategies proved the feasibility of the home-based PA program in older persons with CI following inpatient rehabilitation.

Keywords Adherence · Feasibility · Physical activity · Geriatrics · Transitional care · Cognitive impairment

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Introduction

Cognitive impairment (CI) is a crucial factor for rehabilitation success in geriatric patients, as individuals with CI are at a high risk for poor functional recovery during rehabilitation (McGilton et al. 2016) and experience more often caught in the downward spiral of decreased outdoor mobility after discharge (Brown et al. 2009), loss of autonomy, and functional independence (Portegijs et al. 2014). Despite the urgent necessity to increase functional fitness and to promote physical activity (PA), this vulnerable group is mostly excluded from interventions targeting care continuity in the community following ward-based rehabilitation (Chenoweth et al. 2015).

High adherence to exercise is a prerequisite of successfully implemented interventions in mobility impaired older adults (Fairhall et al. 2012; Taylor et al. 2017), but is reduced in persons with CI participating in home-based rehabilitation compared to their cognitively intact counterparts (Moseley et al. 2009). Nonetheless, high adherence to physical training was achieved in home-based and supervised programs with caregiver support in cognitively impaired elderly (Prick et al. 2016; Suttanon et al. 2013; Teri et al. 2003; Wesson et al. 2013). A previous home-based study demonstrated high adherence to autonomously performed physical training by cognitively and functionally restricted individuals following inpatient rehabilitation (Hauer et al. 2017), although deteriorating health is known to mitigate adherence to home exercise (Fairhall et al. 2012). Decreasing adherence to individually tailored training over time indicate the challenge of achieving a long-lasting increase in PA in this target group (Taylor et al. 2017). This may be hampered by CI-specific barriers, such as impaired executive function, reduced awareness of own deficits, and apathetic behavior (David et al. 2012; Jacus 2017).

With respect to these multiple barriers, interventions are needed that promote PA as part of daily routine (Heyn et al. 2004). To facilitate a change of activity-related behavioral patterns, behavioral change techniques (BCT; Abraham and Michie 2008) are implemented across PA interventions in diverse adult populations. Two reviews narratively synthesized the efficacy of a variety of BCT (named as motivational strategies in the following) on levels of PA in intervention studies among persons with CI (Nyman et al. 2018; van der Wardt et al. 2017). Within the audited studies, there is cautious evidence for the impact of goal-setting and self-monitoring in terms of high adherence to training and elevated levels of PA. Goal-setting and self-monitoring of own activity behavior led to gains of step counts among individuals without CI (Rosenberg et al. 2012), whereas both strategies were associated with limited efficacy and higher dropout in individuals with CI (Kerse et al. 2008; Vidoni et al. 2016). Home visits and phone calls provided by professionals are useful sources for social support and essential components for the success of activity promotion in elderly (Suttanon et al. 2012). Particularly, dementia-specific communication was beneficial in PA promotion among elderly with CI (Hauer et al. 2012).

Most of the interventions which aimed to change PA behavior using a motivational concept followed a continuously supervised approach. This supervision comprised either the use of caregivers as training partners (Taylor et al. 2017; Teri et al. 2003) or group-based sessions within a nursing care setting (Olsen et al. 2015; Phillips and Flesner 2013). Programs without continuous supervision, fostering the autonomous engagement in physical training and walking, were exclusively implemented in elderly with subjective memory complaints or very mild CI (Cox et al. 2013; Dannhauser et al. 2014; Lautenschlager et al. 2008). Interventions to promote PA in cognitively impaired individuals solely reported adherence to the exercise regimen, but did not provide information about the adoption of motivational strategies for PA promotion. Only Cox et al. (2013), examining the completion of worksheets, reported modest adherence to the general behavior counseling concepts to promote home-based PA in adults with memory complaints. This approach does not allow testing the feasibility of the unique motivational strategies.

By use of qualitative designs, a few studies conducted in cognitively impaired samples described participants' and coaches' experiences of participating in activity promotion programs rather than testing the feasibility of motivational strategies underlying the PA promotion (Olsen et al. 2015; Phillips and Flesner 2013; Suttanon et al. 2012). Within an intervention to promote independent walking intervention, elderly without CI were satisfied with motivational program components, also including pedometer-monitoring, as evaluated by use of a questionnaire (Rosenberg et al. 2012). However, none of those studies used quantitative methods in terms of evaluating adherence to autonomously performed training and motivational strategies over time as well as testing the subjective feasibility as a measure of participants' acceptance in a sample of individuals with motor and cognitive impairment. The measurement of adherence to PA promotion programs might help to understand participants' attitude toward exercise and PA (Hawley-Hague et al. 2016).

Therefore, the aim of this study was to examine the feasibility, adherence over time, and acceptance of a home-based program to promote PA in older persons with CI following geriatric rehabilitation.

Methods

Study design

This feasibility study is part of a blinded, randomized-controlled 12-week intervention trial (RCT) with a 12-week follow-up period to improve functional fitness and to promote PA in older persons with CI after discharge from ward-rehabilitation (ISRCTN82378327). The RCT was approved by the ethics committee of the Medical Department of the University of Heidelberg and was conducted according to the Declaration of Helsinki. The present study uses patient-reported data of adherence and feasibility from participants allocated to the intervention group (IG).

Participants

Participants were consecutively recruited from geriatric rehabilitation wards of a German geriatric hospital. Inclusion criteria were: age ≥ 65 years, a score of 17–26 on the Mini-Mental State Examination (MMSE; Folstein et al. 1975) indicating mild to moderate cognitive impairment (O'Bryant et al. 2008), ability to walk ≥ 4 m without a walking aid, residence within 30 km of the study center, discharge to the patient's home, no terminal disease, no delirium, German-speaking, and written informed consent.

Intervention

The home-based intervention program included (1) physical training to improve functional fitness and (2) a comprehensive motivational concept to promote PA behavior. The intervention was implemented by skilled trainers (sport scientists) within five home visits with decreasing frequency and weekly phone calls beginning after the second home visit.

Physical training

The physical training included strength (tiptoe stance, stair climbing, sit-to-stand transfers), static balance exercises (i.e., side by side, semi-tandem, tandem), and outdoor walking. During the first home visit, participants were introduced in the training program by the trainer. To set graded tasks, the physical exercises were adjusted to participants' individual needs and functional abilities. To remind and instruct participants to execute the physical training, a large poster, containing pictures of the exercises and advices about safety, was fixed in a central position of the home. Participants were encouraged to autonomously perform the physical training and outdoor walking each day. More detailed information about the study design and the physical training has been published previously (Bongartz et al. 2017).

Motivational concept

To increase motivation and adherence to PA, theory-based behavioral change techniques (Abraham and Michie 2008) have been adapted to a CI-specific comprehensive motivational approach, which encompassed following strategies:

1. Provision of information about the benefits of regular training and PA (manual, trainer)
2. Encouragement to engage in daily activity (CI-specific communication by trainer within home visits)
3. Provision of instructions about how and where to perform the exercises (given by the trainer during home visits, poster)
4. Setting graded tasks (tailoring of the intervention to participants' needs and functional abilities)
5. Goal-setting and planning of a walking path in participants' home environment to transfer activity goals in specific and measurable behavior (structured procedure to set indoor and outdoor walking goals; planning and realization of the walking path during home visits)
6. Self-monitoring of behavioral outcomes (pedometer, training log)
7. Regular review of goals (pedometer, training log)
8. Barrier identification and problem solving (home visits, phone calls)
9. Feedback and positive reinforcement (home visits, phone calls)

These nine specific motivational strategies were conflated to the three core motivational components of goal-setting, self-monitoring, and social support. Since the strategy of setting graded tasks is an inherent feature of the individually tailored physical training, this strategy was described as part of the physical training program.

Goal-setting

To involve participants in the goal-setting process, a blinded assessor performed a modified version of Talking Mats (Murphy et al. 2005), which is a semi-structured and pictorial measurement tool developed for cognitively impaired individuals with communication disability. To identify individual meaningful activity goals, each participant was asked to rank prescribed indoor (cooking; self-care; daily activities/homework; self-formulated activity) and outdoor activities (gardening/letterbox; doctor/pharmacy; grocery/bakery/post office; self-formulated activity), which were visualized by pictures.

Since key motor functions such as standing, walking, sit-to-stand transfer, and walking stairs are major prerequisites of mobility, participants additionally evaluated their importance, self-perceived competence, and chance of success on a visual analog scale with range of 0–100. The evaluation of importance refers to the individual value of the key motor function, and the perceived competence captures beliefs about own abilities to perform the corresponding function. The chance of success reflects participants' view to which degree they can improve based on the estimated levels of importance and competence.

Based on the evaluation of the predefined target activity (e.g., going to the bakery) and the key motor functions during the first home visit, trainer and participants collaboratively planned an individualized walking path in the environment around participants' home. As part of the training sessions, the walking path was practiced by participants under the supervision of the trainer and its feasibility was tested with respect to the distance, environmental characteristics (e.g., slippery ground, stairs), and participants' need for assistive devices.

Self-monitoring

To provide feedback about walking behavior and to increase the motivation to engage in daily walking, participants were encouraged to monitor daily step counts by use of simple pedometers (YAMAX Digiwalker CW 700). The trainer instructed participants how to use the pedometer and gave haptic support for attaching it on the waist. The training log was also applied to derive information about personal progress and daily execution of physical training and walking. If participants failed to achieve daily execution of training and the defined walking path, trainer and participant collaboratively tried to identify barriers hampering regular walking and solutions to overcome these barriers during the phone calls and home visits.

Social support

Social support in our study was delivered by trainers within the home visits and phone calls. The professionals served as credible source for information about benefits of regular training and PA by means of a CI-specific communication, which involved simple and repetitively used instructions, haptic support, and picturesque language to encourage persons to integrate training in daily routines (Hauer et al. 2012). Positive feedback was given by the trainer to reinforce participants to maintain their efforts (9). Participation in a local exercise group in a geriatric hospital was offered to each participant as an additional option for regular training and social support by peers.

Measurements

Outcome measures

Main outcomes of the present study were the a) feasibility of goal-setting and professional social support (home visits, phone calls), b) adherence to training and the motivational strategies of goal-setting and self-monitoring by pedometers, and c) patient-rated feasibility and effectiveness of the program.

Feasibility of social support and goal-setting

The feasibility of goal-setting was defined as the proportion of participants (in %), who were able to nominate at least one activity. Comprehensive feasibility was achieved, if participants nominated both indoor and outdoor goals. Partial feasibility was achieved, if participants nominated at least one activity goal. To determine the feasibility of professional social support provided by the research team, the number of performed home visits and phone calls were documented by trainers in standardized protocols.

Adherence to training and motivational strategies

Adherence was documented by participants throughout the 12-week intervention by use of training logs in a simple calendar format. Participants were instructed to daily record the execution of physical training sessions, outdoor walking sessions, achievement of walking goals, and execution of self-monitoring via the pedometer. The amount of step counts was not included as a measure of adherence due to possible inaccuracy regarding the detection of step counts by this simple piezoelectric pedometer. The training logs were returned at the end of the intervention period. The mean weekly adherence rates (in %) to physical training, outdoor walking, achieved walking goals, and pedometer-use were calculated as: number of sessions executed / number of possible sessions * 100. These adherence rates are reported at week 2, 12, and for the total intervention period. As in some cases, the introduction of the pedometer and the implementation of the walking path were performed in the second training session, we defined week 2 as the baseline reference of the intervention. Based on adherence rates, participants were classified as persons with (i) low adherence (0.0–33.3%), (ii) moderate adherence (33.4–66.6%), and (iii) high adherence (66.7–100%).

Acceptance

After the intervention, participants completed a questionnaire specifically designed to document participants' acceptance of the program components (training, outdoor walking, self-monitoring by pedometers, walking-related goal-setting, training group, home visits, phone calls) capturing the two subscales of perceived feasibility (e.g., "Were you able to use the pedometer?") and effectiveness (e.g., "Did the pedometer help you to improve yourself?"). Subjects responded on a 4-point Likert scale with a range of 1 ("not"), 2 ("rather not"), 3 ("rather yes"), and 4 ("yes"). The components' feasibility/effectiveness was classified according to the amount of participants with a score ≥ 3 for the respective component and expressed in percentage.

Descriptive variables

Socio-demographic and clinical characteristics including age, gender, body mass index (BMI), number of medications, number of diagnoses, and education were documented from patient charts or by standardized interviews. Education was categorized as primary school or none (low educational level), vocational or other secondary school (middle educational level), and university or vocational postsecondary school (high educational level). Functional fitness was assessed by the Short Physical Performance Battery (SPPB) (Guralnik et al. 1994). For PA behavior, the number of steps was measured within 48 h using an established, ambulatory sensor system (PAMSys™, BioSensics, Cambridge, MA, USA), based on an algorithm validated among older adults (Najafi et al. 2003). To capture different aspects of psychological status, apathy was assessed via the Apathy Evaluation Scale-Clinical Version (AES-C) (Marin et al. 1991) and depression by the 15-item Geriatric Depression Scale (GDS) (Allgaier et al. 2011; Greenberg 2007). To describe the proportion of persons with clinically relevant apathetic syndrome, a cutoff score (>40.5; range 18–72) was used which has been ascertained within a cognitively impaired sample of community-dwelling elderly (Clarke et al. 2007).

Statistical analyses

Descriptive data were presented as frequencies and percentages for categorical variables, means (*M*), and standard deviations (SD) or medians and interquartile ranges (IQR) for continuous variables. Unpaired *t* tests, Mann–Whitney *U*-tests, and Chi-square tests were used for baseline comparison between dropouts and completers according to the data distribution. Paired *t* tests were performed to test for differences regarding mean adherence rates between beginning (week 2) and end of intervention (week 12).

Results

Participant characteristics

Out of 1981 patients screened for eligibility, 118 individuals were enrolled to the original RCT according to predefined inclusion criteria, of whom 63 participants were allocated to IG (see Fig. 1). The present sample comprised multi-morbid, sedentary, cognitively, and physically impaired older adults with more than the half showing apathetic symptoms (for sample description see Table 1).

Fifty-four subjects completed the intervention program and were therefore eligible for analyses of adherence and acceptance of the program. Reasons for dropout were death, fall-related fractures, and other serious medical events unrelated to the intervention program. When dropouts ($n = 9$) were compared with those participants who stayed in the study until the end of the intervention ($n = 54$), no significant differences in baseline characteristics were found ($p >$ .05), except for age ($M = 86.2$, SD = 4.0 years [dropouts] vs. $M = 81.5$, SD = 5.9 years [completers]; $p < .025$) and physical performance (SPPB total score, $M = 4.0$, SD = 1.3 [dropouts] vs. $M = 5.7$, SD = 2.2 [completers]; $p < .030$).

Feasibility of social support and goal-setting

In those participants completing the study, in median 5 (IQR = 5–5) home visits and 9 (IQR = 8–10) telephone calls were conducted. Goal-setting was feasible for 62 participants. Comprehensive feasibility was achieved in 57 individuals and partial feasibility in 4 persons. Due to cognitive deficits, one participant was not able to engage in goal-setting. Mean time to complete goal-setting was 11.3 min (SD = 3.1), with a range of 6–19 min.

More than half of the participants ($n = 35$, 55.6%) rated "washing and having a shower" the most important indoor activity, followed by "cooking a meal" ($n = 21$, 33.3%) and "doing housework" ($n = 4$; 6.3%). Going to the "doctor/pharmacy" was the most rated out-of-home-activity ($n = 24$, 38.1%). Just slightly fewer participants ranked "doing shopping" the highest priority outdoor walking ($n = 18$, 28.6%). Key motor functions were rated as highly important, while the level of perceived competence was comparatively low. The chance of success to improve present abilities was in between the level of perceived competence and the level of importance (see Table 2).

Adherence

Of the 54 study completers, three subjects were excluded from analyses of adherence to training and motivational

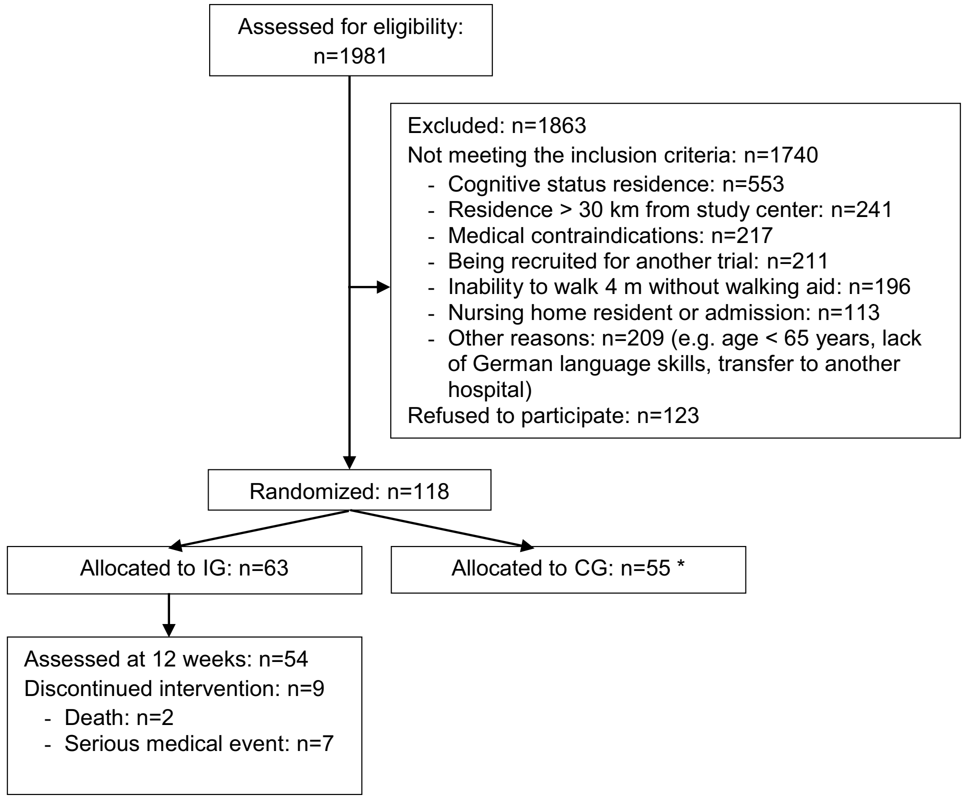


Fig. 1 Flowchart of the recruitment process and course of the intervention trial. *IG* intervention group. *CG* control group, *As the participants in the CG did not receive the physical training and motivational strategies to promote physical activity as the core of the present article, the CG was not included in the analysis

Table 1 Baseline characteristics of intervention group

Characteristics	Intervention group ($N = 63$)
Age (years), *M* (SD)	82.2 (5.8)
Sex, females, *n* (%)	48 (76.2)
Educational level (low/middle/high), %	33.3/47.6/19.0
MMSE, score (range 0–30), *M* (SD)	23.3 (2.7)
Number of diagnoses, *M* (SD)	11.3 (3.6)
Number of medication, *M* (SD)	9.4 (3.3)
SPPB, total score (range 0–12), *M* (SD)	5.4 (2.1)
Habitual gait velocity (m/s), *M* (SD)	0.50 (0.21)
Number of steps/day, *Mdn* (IQR)[a]	2662.5 (1175.1–4686.5)
Geriatric Depression Scale, score (range 0–15), *M* (SD)	5.2 (3.0)
The presence of apathetic symptoms (AES-C score > 40.5), *n* (%)	33 (52.4)

M mean, *SD* standard deviation, *Mdn* median, *IQR* interquartile range, *MMSE* mini-mental state examination; *SPPB* short physical performance battery; *m/s* meters per second, *AES-C* apathy evaluation score clinical version

[a]$n = 62$, missing sensor-based activity data for one person

strategies due to impaired vision ($n = 1$), not able to write in German language without support by others ($n = 1$), and loss of training log ($n = 1$).

Adherence to physical training and outdoor walking

Mean adherence rates over the total 12-week intervention period were 63.6% (SD = 33.8) for physical training and 57.9% (SD = 35.2) for outdoor walking, with about half of the participants exhibiting high (≥ 66.7%) adherence rates (physical training: $n = 26$, 51.0%; outdoor walking: $n = 23$, 45.1%). Adherence to physical training and outdoor walking was highest at the beginning of the intervention, showing significant declines over the intervention period ($p \leq .001–.019$) (see Fig. 1; see Table 3).

Adherence to motivational strategies

Mean adherence rates over the intervention period were 40.1% (SD = 38.5) for achievement of walking goals and 60.1% (SD = 37.7) for self-monitoring by pedometers, with half of the participants displaying high adherence to self-monitoring ($n = 26$, 51.0%) and 18 individuals (35.4%) highly adhering to goal achievement. Adherence rates to self-monitoring by pedometers ($M = 66.7\%$, SD = 41.8) and goal achievement ($M = 43.4$, SD = 40.7) were also highest at the intervention start and decreased over time, whereas the decline was significant for self-monitoring by pedometers ($p = .017$) and was close to level of significance for goal achievement ($p = .098$) (Fig. 2).

Table 2 Subjective importance, competence, and chance of success of key motor functions

	Importance (range 0–100)			Competence (range 0–100)			Chance of success (range 0–100)		
	n	*M*	(SD)	*n*	*M*	(SD)	*n*	*M*	(SD)
Standing	56	83.0	(17.2)	62	55.6	(22.0)	61	73.4	(20.2)
Walking	59	84.2	(20.4)	62	53.0	(23.0)	58	72.5	(19.2)
Sit-to-stand transfer	59	86.6	(13.4)	62	61.6	(21.4)	58	79.2	(17.4)
Walking stairs	59	82.7	(23.3)	62	52.0	(25.0)	58	72.1	(21.1)

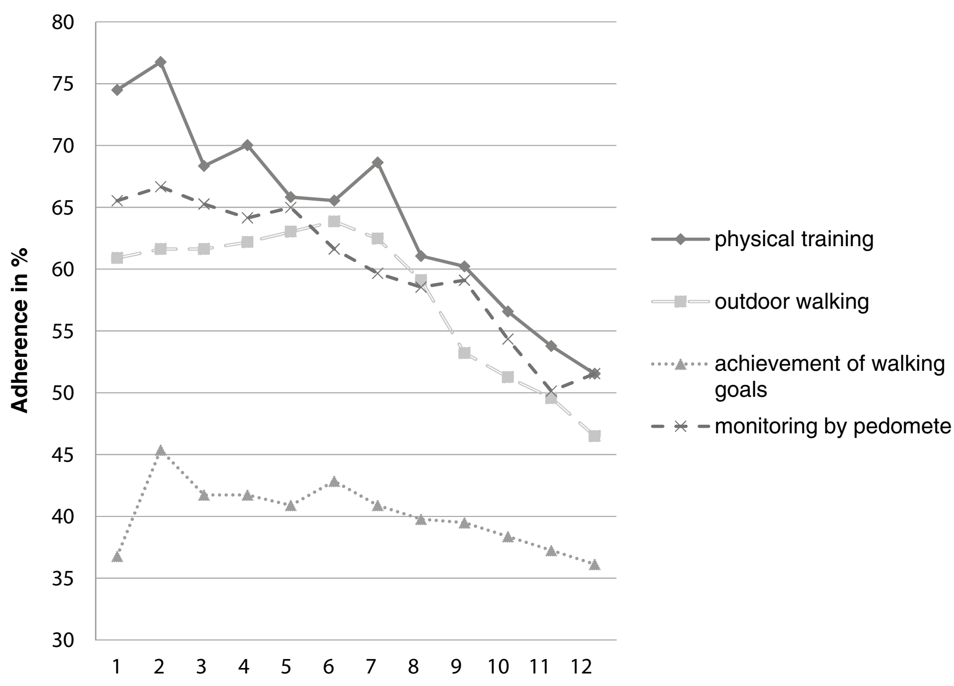
M mean, *SD* standard deviation

Table 3 Adherence to physical training, outdoor walking, and motivational strategies over the total intervention period, at week 2, and week 12

Adherence Parameters	Total (Week 1–12)	Week 2	Week 12	Difference week 2 vs. 12
	M % (SD)	*M* % (SD)	*M* % (SD)	*p* value
Training	63.6 (33.8)	76.8 (32.7)	51.5 (47.9)	< .001***
Outdoor walking	57.9 (35.2)	61.6 (38.2)	46.5 (45.1)	.019*
Achievement of walking goals	40.1 (38.5)	43.4 (40.7)	36.1 (46.4)	.098
Self-monitoring by pedometers	60.1 (37.7)	66.7 (41.8)	51.5 (49.5)	.017*

M mean, *SD* standard deviation; adherence as mean percentage during total intervention, week 2 and week 12 in intervention group with complete adherence data based on training log (n=51); *$p < .05$, **$p < .01$, ***$p < .001$ based on paired t tests to test for differences between week 2 and 12

Fig. 2 Weekly adherence to the home-based physical activity promotion program



Acceptance

Questionnaire data to evaluate the patient-rated acceptance of the program components were available for 53 participants, as one study completer did not send back the questionnaire. Regarding the feasibility, the highest rated program component was physical training (M = 3.3, SD = 0.9, 83%).

The components walking-related goal-setting (M = 3.0, SD = 1.2, 73.0%), self-monitoring by pedometers (M = 3.1, SD = 1.2, 68.2%), and outdoor walking (M = 2.9, SD = 1.1, 67.9%) were also rated to be feasible by the majority of the present sample. The participation in the training group was only rated as feasible by six persons (M = 1.3, SD = 1.0, 11.8%), but those who were able to participate in the center-based group rated this component as effective (M = 3.7, SD

= 0.8, 85.7%). Home visits (M = 3.6, SD = 0.8, 90.6%) and phone calls (M = 3.1, SD = 1.1, 79.2%), which were delivered by professionals, achieved highest rates for effectiveness. Self-monitoring by pedometers was the component rated as the least effective (M = 2.9, SD = 1.2, 63.5%) (see Table 4).

Discussion

The present results describe a successful home-based program to promote PA in cognitively and physically restricted community-dwelling older persons post-discharge from ward-rehabilitation. All program components achieved high acceptance leading to an initially high adherence to autonomously performed physical training, outdoor walking, and to the frequent uptake of the motivational strategies of goal-setting and self-monitoring which declined over time.

Physical training and outdoor walking

Adherence to home-based, self-performed physical training was initially high, indicating good feasibility of the individually tailored home-based approach. Within a previous home-based physical exercise program following discharge from rehabilitation including a mixed sample concerning cognitive status, the adherence in individuals with CI was lower compared to their cognitively intact counterparts (Moseley et al. 2009). This emphasizes the challenge to ensure high adherence to autonomously performed physical training in this vulnerable group.

Study results were comparable to the adherence rates of an exercise in sample of cognitively impaired and non-impaired individuals following discharge from rehabilitation (Salpakoski et al. 2014), to caregiver-supported functional training (Prick et al. 2016; Suttanon et al. 2013; Taylor et al. 2017), and walking programs in community-dwelling persons with CI (Lowery et al. 2014; McCurry et al. 2005).

We assume that the individual tailoring of the physical training and planning of a walking path respective to participants' physical abilities and environmental conditions as applied in the present study potentially facilitated high initial adherence. Study participants lived in the urban area in and around the city of Heidelberg, a university town with no major environmental barriers, easy access to public transportation and a wide variety of green areas. These environmental characteristics refer to a high perceived walkability which is associated with low concerns to fall and higher levels of PA (Harada et al. 2017). The initially high adherence to training declined over time simultaneously with the decreasing frequency of our home visits confirming decreasing adherence rates in previous PA studies in diverse samples of older adults (Cox et al. 2013; Taylor et al. 2017). This finding might indicate the need of continuous supervision of training especially in multi-morbid populations.

Motivational strategies

The autonomous engagement in PA without any external supervision has so far been promoted only in populations with subjective memory complaints, representing cognitively less affected individuals (Cox et al. 2013; Dannhauser et al. 2014; Lautenschlager et al. 2008). Only one of these studies tested the adherence to a comprehensive motivational approach by reporting the completion rate of worksheets in a PA promotion program, but not the adherence to the specific strategies, documenting a modest adoption of a motivational concept into participants' daily routines (Cox et al. 2013). In contrast, the present study allows a detailed insight into different motivational strategies, documenting a comparatively high feasibility and adherence considering the sample of sedentary older adults with low functional fitness,

Table 4 Subjective feasibility and efficacy of program components

Intervention component	*M* (SD) (range 1–4)	% of participants with feasibility score ≥ 3	*M* (SD) (range 1–4)	% of participants with effectiveness score ≥ 3
Physical training	3.3 (1.0)	83.0[a]	3.4 (1.0)	78.3[a]
Outdoor walking	2.9 (1.1)	67.9[a]	3.1 (1.1)	75.0[b]
Goal-Setting	3.0 (1.1)	73.0[c]	3.1 (1.1)	75.0[b]
Self-monitoring by pedometers	3.1 (1.2)	68.2[d]	2.9 (1.2)	63.5[d]
Training group	1.3 (1.0)	11.3[e]	3.7 (0.8)	85.7[f]
Home visits	n.a.	n.a.	3.6 (0.8)	90.6[b]
Phone calls	n.a.	n.a.	3.1 (1.1)	79.2[b]

Presented are mean scores and standard deviations on the feasibility and effectiveness of the implemented program components as well as the proportion of participants with scores ≥ 3

M mean, *SD* standard deviation, *n.a.* not applied

[a]$n = 53$; [b]$n = 52$, [c]$n = 48$; [d]$n = 50$, [e]$n = 47$; [f]$n = 7$

moderate depressive, and high apathetic symptoms. Deteriorating physical function was identified as main barrier for adherence to a PA program in older adults after discharge from ward-rehabilitation (Fairhall et al. 2012). Depressive symptoms and apathy are psychological correlates showing close associations with decreased levels of PA among individuals with CI (David et al. 2012; Yuenyongchaiwat et al. 2018). In consideration of these PA-related barriers in our vulnerable sample, the adherence to motivational strategies over the intervention period can be rated as high.

Goal-setting

The comprehensive approach of goal-setting, including the identification of goals as measure of feasibility and the achievement of goals as measure of adherence, showed heterogeneous results in the present study. The high rate of identified goals indicated feasibility of the structured goal-setting approach, while the rate of achieved goals was considerably lower. These results are in line with the studies testing the feasibility and the adherence of goal-setting in diverse older populations including persons with CI (Kerse et al. 2008) and without CI (Fairhall et al. 2012; Smit et al. 2018; van Seben et al. 2019).

The present positive results with respect to the identification of goals in the present study indicate that individuals with CI may have profited from the use of talking mats as previously demonstrated (Murphy et al 2005), representing a structured, nonverbal strategy, while more complex instruments have shown limited feasibility in patients with CI (Stevens et al. 2013). With the talking mat method also problems in goal-setting were avoided as experienced by stroke patients with communicative and cognitive problems, which reported the goal-setting process be driven by the therapist rather than participants (Smit et al. 2018). Considering those findings, it was remarkable that the participants of the present study were able to give reliable information about the priority of goals and the subjective importance, control, and chance of success of key motor functions. Study results contrast to a previous study which reported problems to formulate specific and realistic behavioral goals in reports of geriatric patients without CI (van Seben et al. 2019).

While the identification of subjective goals represents a relevant but not sufficient objective, it is the transfer into action which is crucial to test the effectiveness of motivational strategies. In the present study, the rate of achieved walking goals was moderate, confirming previous studies on adherence to walking goals in older adults without (Fairhall et al. 2012) and with CI (Kerse et al. 2008). The discrepancy between high rate of identified goals and a moderate rate of achieved walking goals may emphasize the difficulty to implement the initially set goals into daily routines due to the high physical restrictions in the group of geriatric patients with CI. The high presence of functional deficits in the transitional stage after admission to home environment may have led to a shift of goals over time, as some individuals tended to choose too ambitious long-term goals after discharge from ward-rehabilitation given their physical abilities (van Seben et al. 2019). These individuals may have set their activity goals based on their prior abilities to perform activities of daily living before hospitalization, which resulted in these goals being unrealistic in the stage post-discharge from ward-rehabilitation. This could also be true for some individuals in the present study who highly ranked outdoor goals (e.g., going to the doctor), which were not viable for them in consideration of their degree of functional restrictions.

The only moderate rate of adherence to walking goals over the intervention period might explain the limited effects of goal-setting on physical function during geriatric inpatient rehabilitation, as demonstrated by a recent meta-analysis (Smit et al. 2019). Therefore, future interventions might incorporate standardized instruments to continuously monitor the adaption of initially set goals, which could help to optimize strategies to realize walking goals into practice and therefore to increase adherence to goal-setting over time.

Self-monitoring by pedometers

In the present study, self-monitoring of activity behavior by pedometers was shown to be a useful tool to increase motivation to PA for most participants as indicated by high adherence and acceptance.

Previous pedometer-based interventions to promote PA in persons with CI showed heterogeneous results with respect to the impact on PA, albeit they did not test the daily adherence (Logsdon et al. 2009; Vidoni et al. 2016). In one study, a high rate of dropouts limited the efficacy of a technology-assisted pedometer driven intervention, also leading to limited efficacy (Vidoni et al. 2016). The study by Logsdon et al (2009) also reported a restricted manageability of such technical advices due the lack of fine motor skills and memory complaints in some participants with more severe CI, whereas usability was adequate for the majority of participants leading to increased PA-levels. Since the primary purpose of the pedometer was to provide feedback and to increase the participant's motivation rather than measuring the true walking distance, we selected simple to use and robust pedometers to achieve high self-perceived feasibility.

Social support

In the present study, professional social support as documented for home visits and telephone calls was highly appreciated in the vulnerable group of participants, confirming results from previous qualitative studies conducted in persons with

CI (Olsen et al. 2015; Phillips and Flesner 2013; Suttanon et al. 2012). The face-to-face contact within home visits was rated as the most effective program component in this PA program. This finding indicates that health care professionals may serve as a valuable source to provide information how to perform training and which benefits can be expected (Olsen et al. 2015). High subjective effectiveness of phone calls also supports previous results which also demonstrated high satisfaction with phone calls in older adults without CI (Rosenberg et al. 2012) and with subjective CI (Cox et al. 2013). The trainers in our program were skilled in CI-specific communication, which might be a key strategy of the successful implementation of home visits as rated by participants. Positively framed messages focusing on the benefits of PA behavior may have induced elevated motivation to PA compared to negatively framed messages informing about the risk of being non-active (Notthoff et al. 2016). Such supportive communication, including positive reinforcements, has the potential to strengthen the perceived competence to exercise in a group of cognitively impaired persons (Tortosa-Martínez et al. 2017).

The provision of frequent external sources of motivation as provided by a more continuous supervision might be a key factor for the maintenance of adherence to PA in this trial. The program implementation by peers or lay trainers as trustful training partners and motivators is recommended as a promising strategy to increase the participant's self-efficacy and to ensure maintenance of PA within older adults (Matz-Costa et al. 2019). A regular frequency of contact with professionals was effective in PA promotion in nursing home residents (Jansen et al. 2015) as well as in sedentary community-dwelling women (Poulsen et al. 2007).

Limitations

One limitation of the present study is the relatively small sample size explicitly including participants of the intervention group. As the control group was not included in the intervention program, no information about adherence was available in the control condition. Our analysis of adherence was based on self-reports which may represent a limiting factor for the accuracy of adherence to PA in elderly with CI (Visser et al. 2014). As adherence to training and outdoor walking only included the daily frequency of exercise, physical training, and outdoor activities executed several times per day were not considered, with the potential consequence of underreporting actually performed PA.

Conclusion

Study results indicated a comparatively high adherence to the present PA promotion program proving the feasibility of the individually tailored program in vulnerable, multi-morbid persons with relevant motor and cognitive impairment. Successful participation was further documented by high patient-rated feasibility and effectiveness of the program components. Continuous supervision delivered by professionals might constitute an essential ingredient for maintaining adherence to PA promotion in elderly with multiple restrictions, as this study revealed a decline of adherence to the intervention program concomitant with decreasing frequency of home visits.

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Compliance with ethical standards

Conflicts of interest The authors have no conflicts of interest to declare.

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