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Integration von Bewegung und Training in den Alltag: Entwicklung und Evaluation eines neuen Trainingskonzepts für ältere Menschen

vorgelegt von
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IN GEDENKEN AN MEINE MUTTER

„Nicht die Jahre in unserem Leben zählen, sondern das Leben in unseren Jahren.“

(Adlai Ewing Stevenson)

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Abkürzungsverzeichnis

SPPB	Short Physical Performance Battery
BBS	Berg Balance Skala
TUG	Timed Up-and-Go Test
FAB	Fullerton Advanced Balance Skala
CBM	Community Balance and Mobility Skala
IKT	Informations- und Kommunikationstechnik
LiFE	Lifestyle-integrated Functional Exercise
aLiFE	angepasstes Lifestyle-integrated Functional Exercise Programm
eLiFE	erweitertes Lifestyle-integrated Functional Exercise Programm

I Liste der wissenschaftlichen Veröffentlichungen zur publikationsbasierten Dissertation

Manuskript 1:

Bergquist R*, **Weber M***, Schwenk M, Ulseth S, Helbostad JL, Vereijken B, Taraldsen K (2018) Performance-based clinical tests of balance and muscle strength used in young seniors: A systematic literature review. *BMC Geriatrics (submited)*.

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Manuskript 2:

Weber M, Van Ancum J, Bergquist R, Taraldsen K, Gordt K, Mikolaizak S, Nerz C, Pijnappels M, Jonkman N, Maier AB, Helbostad JL, Vereijken B, Becker C, Schwenk M (2018) Concurrent validity and reliability of the Community Balance and Mobility scale in young-older adults. *BMC Geriatrics, 18*:156.

Manuskript 3:

Weber M, Belala N, Boulton E, Hawley-Hague H, Becker C, Schwenk M (2017) Feasibility and effectiveness of intervention programmes integrating functional exercise into daily life of older adults: a systematic review. *Gerontology,* DOI: 10.1159/000479965.

Manuskript 4:

Boulton E, **Weber M**, Hawley-Hague H, Bergquist R, Jonkman NH, Taraldsen K, Helbostad JL, Maier AB, Becker C, Todd C, Clemson L, Schwenk M (2018) Proof-of-concept of the adapted LiFE (aLiFE) programme developed for 60-70 year olds: perceptions of participants and trainers. Innovations of Aging *(submitted).*

II Kurzdarstellung

Bereits ab dem 30. Lebensjahr reduziert sich die motorische Leistungsfähigkeit, wobei vor allem die Gleichgewichtsfähigkeit und Kraft betroffen sind. Dieser Abbau beschleunigt sich nochmals rapide ab der siebten Lebensdekade, was in reduzierter Mobilität, Krankheit, Pflegebedürftigkeit und letztlich auch frühzeitigem Tod münden kann. Um dies zu vermeiden, besteht zunehmender Bedarf an präventiven Maßnahmen, vor allem vor dem Hintergrund des Bedeutungszuwachses der alternden Gesellschaft. Diese Maßnahmen sollen ein möglichst langes, selbstständiges Leben und gesundes Alter(n) ermöglichen. Bisher existieren keine Trainingskonzepte, welche spezifisch für die Prävention funktioneller Einschränkungen entwickelt wurden.

Darüber hinaus mangelt es vorhandenen Trainingsprogrammen an Nachhaltigkeit. Gerade strukturierte Formate, gekennzeichnet durch standardisierte Übungen mit vorgegebener Wiederholungszahl und Intensität (beispielsweise 4 Übungen mit 12 Wiederholungen an 3 Tagen/Woche). Ältere Menschen ziehen es vielmehr vor, Übungen in ihren Alltag integrieren zu können, was einerseits die Motivation steigert und dadurch gleichzeitig die Nachhaltigkeit verbessert, andererseits eine kostengünstige, zeitsparende und flexible Möglichkeit ist, zu jeder Zeit und an jedem Ort aktiv zu sein (beispielsweise Einbeinstand beim Zähneputzen oder auf den Zehenspitzen den Flur entlang zu gehen). Entsprechend ist die Entwicklung eines alltagsintegrierten Trainingsprogramms eine Alternative, welche spezifisch in einer jüngeren Zielgruppe (60-70 Jahre) eingesetzt werden könnte, um sowohl präventiv funktionellen Einschränkungen vorzubeugen als auch die Nachhaltigkeit und Effektivität zu erhöhen.

Um dies zu realisieren, bedarf es jedoch vorab der Entwicklung geeigneter Messinstrumente, welche spezifisch für die Erfassung der individuellen funktionellen Leistungsfähigkeit einer jüngeren, fitteren Zielgruppe geeignet sind. Einerseits können dadurch gezielt Personen mit einem erhöhten Risiko für funktionelle Einschränkungen identifiziert werden, andererseits sind solche Tests auch Voraussetzung für eine korrekte Evaluation des Trainingskonzepts, insbesondere mit Blick auf dessen Effektivität. Basierend auf diesen Überlegungen befasst sich die vorliegenden Arbeit mit der Entwicklung und Evaluation eines neuen alltagsintegrierten Trainingskonzepts für junge ältere Menschen (60-70 Jahre) sowie der Identifikation und Evaluation geeigneter Messinstrumente für diese Zielgruppe.

Manuskript 1 ist eine systematische Übersichtsarbeit der vorhandenen Tests zur Erfassung der Kraft und/oder Gleichgewichtsfähigkeit in der Zielgruppe gesunder, junger älterer Menschen (60-70 Jahre). Dabei zeigt sich, dass zahlreiche klinische Tests, welche ohne aufwendiges Laborequipment durchgeführt werden können, existieren. Jedoch fehlt es insbesondere an geeigneten Gleichgewichtstests, welche die Gleichgewichtsfähigkeit gesunder, junger älterer Menschen adäquat abbilden.

Aufbauend auf dem ersten Manuskript wird in Manuskript 2 die Eignung einer anspruchsvollen Skala zur Erfassung der Gleichgewichtsfähigkeit und Mobilität, die Community Balance & Mobility (CBM)-Skala, bei jungen älteren Menschen analysiert. Die CBM erweist sich dabei als valides Messinstrument mit exzellenter Test-Retest-Reliabilität und zeigt, im Gegensatz zu anderen Tests, keine Deckeneffekte (das heißt die maximal mögliche Punktzahl wurde nicht erreicht). Entsprechend empfiehlt sich die CBM-Skala zur Ermittlung von Gleichgewichts- und Mobilitätsdefiziten in dieser Zielgruppe, insbesondere vor dem Hintergrund der frühzeitigen Aufdeckung von funktionellen Einschränkungen.

Manuskript 3 ist eine systematische Übersichtsarbeit vorhandener Studien mit Fokus auf alltagsintegrierte Trainingsprogramme. Im Ergebnis zeigt sich, dass das „Lifestyle-integrated Functional Exercise“ (LiFE) Programm bislang das am besten evaluierte Trainingsprogramm ist. Andere Studien kombinieren alltagsintegriertes und strukturiertes Training, vorwiegend im institutionellen Bereich (beispielsweise Pflegeheime). In Bezug auf die Nachhaltigkeit des Trainings erweisen sich beide Ansätze als effektiver verglichen mit einem strukturierten Training. Trotz dieser vielversprechenden Befunde fehlt es an umfassend angelegten Studien zur Durchführbarkeit als auch Effektivität des alltagsintegrierten Trainings in verschiedenen Zielgruppen.

Basierend auf den Befunden aus Manuskript 3 wird in Manuskript 4 die Durchführbarkeit eines an junge ältere Menschen angepassten LiFE (aLiFE)-Programms überprüft. Dabei zeigt sich, dass sowohl die Teilnehmenden als auch Trainer/innen aLiFE positiv beurteilten. Die Teilnehmenden schätzten insbesondere den individuellen Ansatz, den präventiven Fokus und die Unterstützung seitens der Trainer/innen. Die Trainer/innen betonten ebenfalls die Flexibilität des Programms. Dennoch bemängelten sowohl Teilnehmende als auch Trainer/innen die umfangreiche Papierarbeit. Nichtsdestotrotz berichteten die Teilnehmenden von einer Verinnerlichung einzelner Übungen innerhalb des kurzen 4-wöchigen Zeitraums, auch ohne kontinuierliche Selbstkontrolle. Aufgrund dieser Befunde empfiehlt sich die Testung der Durchführbarkeit und Effektivität von aLiFE im Rahmen einer randomisiert-kontrollierten Studie.

Insgesamt belegen die Studienergebnisse die Durchführbarkeit und hohe Akzeptanz des neu entwickelten aLiFE-Programms. Zudem erweist sich die CBM als geeignetes Messinstrument zur Erfassung der Gleichgewichtsfähigkeit und Mobilität bei jungen Älteren. Weitere Forschung ist notwendig, um die Ergebnisse in größeren randomisiert-kontrollierten Studien zu evaluieren sowie alternative Vermittlungsformen des Programms zu testen.

Abstract

Motor performance already starts to decline at the age of 30, with balance and muscle strength mostly affected. This decline accelerates dramatically in the seventh decade of life, resulting in reduced mobility, illness, care dependency and early mortality. In avoidance of these negative impacts and with regard to the increasing importance of the aging population, there is a growing need for preventive approaches. Such approaches should lead to a long, independent life and promote healthy aging. So far, no training approaches exist which specifically focus on the prevention of functional decline in older adults.

Moreover, existing programs lack of sustainability. Especially structured approaches, characterized by standardized exercises with predefined number of repetitions and intensity (e.g. 4 exercises with 12 repetitions, 3 times a week). Older adults prefer to integrate physical activity into daily life. This, in turn, increases their motivation as well as the sustainability of the program. On the other hand, integrated activities are more cost-effective, time-saving and more flexible since older adults can perform the exercises at any time and any place (e.g. one-leg stand while brushing teeth or walking on toes along the hallway). Accordingly, the development of a lifestyle-integrated exercise program would be a promising alternative which could be specifically implemented for young-older adults (60-70 years) in order to prevent functional decline and increase the effectiveness and sustainability of the program.

To realize this, appropriate measurement instruments are needed in advance which are able to adequately assess functional capacity of higher-functioning young-older adults. This allows on the one hand the identification of older adults with an increased risk for functional decline and on the other hand, these tests are essential to adequately evaluate the training concept, especially with regard to its effectiveness. Based upon these considerations, the aim of this doctoral thesis is to develop and evaluate a new lifestyle-integrated training concept for young-older adults (60-70 years) as well as to identify suitable measurement instruments for this specific population.

Manuscript 1 summarizes the current evidence on physical performance measures in young-older adults aged 60-70. Many tests exist which measure balance and strength in young-older adults and can be performed without advanced laboratory equipment. However, there is a lack of suitable balance tests which are challenging enough to reflect young-older adult's balance performance adequately.

Based on the results of manuscript 1, the second manuscript analyzed the applicability of a challenging balance and mobility test, the Community Balance & Mobility (CBM) scale, in healthy young-older adults. The CBM shows good validity, excellent test-retest reliability, and most importantly, did not show ceiling effects (i.e., non-achievement of maximum obtainable score) in contrast to other scales. The CBM can therefore be recommended to measure balance and mobility in young-older adults, particularly in the context of an early detection of functional decline.

Manuscript 3 summarizes the current evidence on lifestyle-integrated functional exercise programs. The "Lifestyle-integrated Functional Exercise" (LiFE) program turned out to be the most frequently evaluated program. Other studies combined integrated and structured training, mainly in institutional settings (e.g. nursing homes). Both approaches turned out to be more effective regarding their sustainability as compared to structured training programs. Despite these promising results, larger studies analyzing the feasibility and effectiveness of integrated training in different target populations are needed.

Based on the results of manuscript 3, the fourth manuscript analyzed the proof-of-concept of an adapted LiFE (aLiFE)-program in young-older adults. As a result, both trainers and participants were positive about aLiFE. Participants acknowledged the individual approach, preventive focus and the support by the trainers. Trainers also highlighted the flexible approach. However, both dislike the extensive paperwork. Nonetheless, participants reported habitualization of some of the exercises within the short, 4-weeks pre-post pilot study, even without continuous self-monitoring. Due to these findings, the feasibility and effectiveness of aLiFE should be tested in a randomized controlled trial.

In summary, study results demonstrate the feasibility and high acceptance of the newly developed aLiFE-program. Moreover, the CBM has proven its suitability for assessing balance and mobility in higher functioning young-older adults. However, further research is needed to confirm these findings in larger study samples as well as to proof the feasibility of more advanced delivery modes.

1 Einleitung

Körperliche Aktivität gilt als der wichtigste Faktor für die Selbstständigkeit und Unabhängigkeit im Alter, erhält die körperliche Leistungsfähigkeit, schützt vor Krankheiten und wirkt sich positiv auf die Mobilität, das psychische Wohlbefinden und auch die kognitive Leistungsfähigkeit aus. Ein ausreichendes Maß an körperlicher Aktivität, insbesondere im höheren Erwachsenenalter, kann vor funktionellen Einschränkungen schützen und ein selbstständiges, gesundes Alter(n) ermöglichen.

Wenngleich die positiven Effekte, speziell im höheren Erwachsenenalter, weit verbreitet und bekannt sind, fehlt es dennoch an effektiven, nachhaltigen Ansätzen, welche ein überdauerndes, kontinuierliches Training in der älteren Bevölkerung begünstigen. Dieses ist insbesondere vor dem Hintergrund des rapiden Anstiegs älterer Menschen an der Gesamtbevölkerung relevant, wobei vor allem die derzeitig stark besetzten mittleren Jahrgänge (Baby-Boomer-Generation) zu einer dramatischen Verschiebung der Altersstruktur und Revolutionierung des Alter(n)s beitragen. Es gibt bereits eine Vielzahl an strukturierten Trainingsprogrammen, welche gezielt für ältere Menschen entwickelt wurden und den Fokus speziell auf elementare Defizite im Bereich der Kraft und Gleichgewichtsfähigkeit legen. Dabei dient ein vorgegebenes Format als Basis, insbesondere gekennzeichnet durch eine festgelegte Trainingsdauer (beispielsweise 3x30 Minuten pro Woche), Wiederholungszahlen (beispielsweise 8 Wiederholungen pro Übung) und Trainingssätze (beispielsweise 3x8 Wiederholungen pro Übung). Jedoch erweisen sich diese Programme als unzureichend, sowohl hinsichtlich der Motivation zur Teilnahme an diesen Programmen als auch der Effektivität. Dieses gründet sich möglicherweise auch darin, dass strukturierte Trainingsprogramme im Allgemeinen keinen Ansatz zur Verhaltensänderung beinhalten und es folglich es vor allem an langfristiger Teilnahme mangelt.

In jüngster Zeit haben sich Studien mit einem neuen Trainingsansatz befasst, welcher darauf abzielt, spezifische funktionelle Kraft- und Gleichgewichtsübungen in den Alltag älterer Menschen zu integrieren. Hierfür dienen Routinetätigkeiten wie das tägliche Zähneputzen, das Zubereiten von Mahlzeiten oder der Gang über den Flur als Gelegenheiten, bei denen gleichzeitig funktionelle Übungen wie Einbeinstand, Kniebeuge oder Tandemstand/-gang (das heißt beim Stehen/Gehen den einen Fuß direkt vor den anderen Fuß setzen) ausgeführt werden können.

Dieser neue Ansatz soll einerseits die Barrieren für körperliche Aktivität reduzieren, andererseits die Aufrechterhaltung und somit insbesondere auch die Nachhaltigkeit des Trainings verbessern. Allerdings haben sich die bisherigen Studien auf eine ältere, gebrechlichere Zielgruppe fokussiert, in der bereits erste funktionelle Einschränkungen vorliegen. Aufgrund der demografischen Alterung sollte der Fokus jedoch verstärkt auf präventive Aspekte gelegt werden, um die funktionelle Leistungsfähigkeit bestmöglich zu erhalten, damit das Alter(n) primär von Selbstständigkeit, Unabhängigkeit und Gesundheit und nicht von funktionellen Einschränkungen, Krankheit und Pflegebedürftigkeit geprägt ist.

Für die Entwicklung eines neuen Trainingskonzepts ist zudem auch die Ausarbeitung gezielter psychologischer Strategien erforderlich, welche eine nachhaltige Verhaltensänderung hin zu einem aktiv(er)en Lebensstil begünstigen. Diese müssen spezifisch für die Zielgruppe der jungen Älteren zugeschnitten sein, um einerseits die ausgeprägte Heterogenität junger Älterer angemessen zu berücksichtigen. Andererseits lassen sich diese aufgrund eines hohen Aktivitäts- und Vitalitätsbestreben durch andere Faktoren motivieren als es bei älteren Personen mit fortgeschrittenem altersbedingtem funktionellem Abbau der Fall ist. Zudem bedarf es der Identifikation geeigneter Messinstrumente, da keine andere Zielgruppe eine solche Heterogenität aufweist wie die der jungen Älteren. Um das Training und die Strategien zur Verhaltensänderung bestmöglich auf den/die jeweilige/n Teilnehmende/n zuschneiden zu können, sind geeignete Messinstrumente erforderlich, welche die individuelle Leistungsfähigkeit adäquat abbilden können. In einem ersten Schritt können so diejenigen Personen identifiziert werden, welche ein höheres Risiko für funktionelle Defizite aufweisen und somit besonders von dem Trainingsprogramm profitieren. Zum anderen können nur ausreichend anspruchsvolle Tests die Effektivität des Trainings hinreichend erfassen und auch bereits kleinste Veränderungen aufdecken.

Die hohe Relevanz dieser Thematik wird auch durch die limitierte Studienlage zu jungen Älteren (60-70 Jahre) verdeutlicht. So existieren kaum Studien, die sich spezifisch mit der Prävention funktioneller Einschränkungen in dieser Altersgruppe auseinandergesetzt haben. Entsprechend ist das Ziel der vorliegenden Dissertation, ein neues Trainingskonzept zu entwickeln und zu evaluieren, welches, im Gegensatz zu zahlreichen existierenden strukturierten Trainingsprogrammen, gezielt Übungen in den Alltag älterer Menschen integriert. Mit Blick auf die alternde Bevölkerung soll hierbei der Fokus auf der Prävention funktioneller Einschränkungen bei jungen Älteren (60-70 Jahre) gelegt werden. Junge Ältere kennzeichnen sich in diesem Kontext vor allem durch einen aktiven Lebensstil, sind generell fitter und streben nach einem möglichst langen selbstständigen Alter(n). Insbesondere vor dem Hintergrund der zunehmenden Ausdifferenzierung der Lebensphase Alter(n) gilt es umso mehr, diese Zielgruppe mit Blick auf präventive Maßnahmen in den Fokus zu stellen. Hierzu soll ein neues, alltagsintegriertes Kraft- und Gleichgewichtstraining die 60-70-Jährigen dazu befähigen, selbstständig für ihre Gesundheit und ihre allgemeine körperliche Leistungsfähigkeit vorzusorgen mit dem Ziel eines gesunden und aktiven Lebensstils.

Dabei gilt es einerseits zu untersuchen, wie ein speziell für junge Ältere entwickeltes funktionelles, alltagsintegriertes Training gestaltet sein muss, um eine hohe Akzeptanz und Nachhaltigkeit in dieser Zielgruppe zu begünstigen. Ergänzend ist es notwendig zu identifizieren, welche Messinstrumente zur Erfassung der funktionellen Leistungsfähigkeit junger Älterer existieren und ob diese anspruchsvoll genug sind, um die individuelle funktionelle Leistungsfähigkeit junger Älterer abzubilden. Letzteres ist vor allem für die individuelle Anpassung des Trainings Voraussetzung, da dieses auf Basis der jeweiligen Defizite zugeschnitten wird. Darüber hinaus ist eine Aussage über die Effektivität des Trainings nur anhand ausreichend fordernder Messinstrumente möglich, welche die Heterogenität der jungen Älteren adäquat abbilden.

Die vorliegende Arbeit ist wie folgt gegliedert: Zunächst wird die demografische Alterung und die zunehmende Bedeutung der jungen Älteren (60-70 Jahre) thematisiert, welche Ausgangspunkt für die weiteren Überlegungen und Analysen sind. Anschließend folgt die Erörterung der altersbedingten Veränderungen in der funktionellen Leistungsfähigkeit (vor allem Gleichgewicht, Kraft und Mobilität) und die Analyse existierender Messinstrumente, welche bisher eingesetzt wurden, um die funktionelle Leistungsfähigkeit junger älterer Menschen abzubilden. Mit Blick auf die Entwicklung eines neuen alltagsintegrierten Trainingskonzepts wird in einem weiteren Abschnitt die Bedeutung körperlicher Aktivität im Alter veranschaulicht und die Relevanz neuer, alltagsintegrierter Trainingskonzepte thematisiert. Anschließend werden die Forschungsfragen formuliert sowie die methodische Einbettung dieser Dissertation erläutert, das heißt das europäische Projekt, aus dem diese Dissertation unter anderem hervorgeht. Es folgt die Zusammenfassung der dissertationsrelevanten Manuskripte (1-4), welche sowohl die Entwicklung und Evaluation geeigneter Messinstrumente als auch die Entwicklung und Evaluation eines geeigneten alltagsintegrierten Trainingskonzepts für junge Ältere beschreiben. Abschließend werden die Studienergebnisse in den Forschungszusammenhang eingeordnet und ein Ausblick für zukünftige Forschungsansätze sowie praktische Implikationen gegeben.

2 Theoretischer Hintergrund

2.1 Demografische Alterung und die Bedeutung der jungen Älteren

Der kontinuierliche Anstieg der Weltbevölkerung und der zeitgleich zu beobachtende Rückgang der Fertilität führen weltweit zu gravierenden Veränderungen in der Altersstruktur der Bevölkerung. Global ist eine deutliche Zunahme des Anteils der alternden Bevölkerung zu verzeichnen. Dabei ist vor allem der Geburtenrückgang, bei gleichzeitigem Anstieg der Lebenserwartung weltweit ausschlaggebend dafür, dass sich der Anteil der über 60-Jährigen von 2000 bis 2050 Schätzungen zufolge mehr als verdreifacht auf rund 2,1 Billionen Menschen, im Vergleich zu 607 Millionen in 2000 bzw. 900 Millionen in 2015. Dabei steigt der Anteil der über 60-Jährigen von heute 12,3% auf 21,5% in 2050. Keine andere Altersgruppe verzeichnet einen solch rasanten Zuwachs, sowohl was die absoluten Zahlen als auch den prozentualen Anteil an der Weltbevölkerung betrifft (United Nations Department of Economic and Social Affairs Population Division, 2015).

Die Alterung der Bevölkerung hat zur Folge, dass sich die Altersstruktur deutlich nach oben verschiebt. Bereits 2030 wird der Anteil der über 60-Jährigen den der Kinder im Alter von 0-9, im Jahr 2050 auch den der Jugendlichen und jungen Erwachsenen im Alter von 10-24 Jahren, übersteigen (United Nations Department of Economic and Social Affairs Population Division, 2015). Für Europa liegt dabei der Anteil der über 60-Jährigen bei mehr als 25% im Jahr 2030, in Deutschland wird im Jahr 2030 sogar mehr als ein Drittel (35,2%) älter als 60 Jahre sein (verglichen zu 27,2% in 2013) (Statistisches Bundesamt, 2015) und der Anstieg schreitet mit zunehmender Geschwindigkeit voran (United Nations Department of Economic and Social Affairs Population Division, 2015). Diese demografische Alterung, auch als Gerontokratie betitelt, geht mit einem zunehmenden Bedeutungszuwachs der alternden Bevölkerung einher, insbesondere aufgrund der daraus resultierenden enormen sozial-strukturellen Veränderungen und dem steigenden Druck auf das Gesundheitssystem (Hartmann-Tews, Tischer, & Combrink, 2012; Wurm, Berner, & Tesch-Römer, 2013).

Die deutliche Verlängerung der Lebensphase Alter(n) schlägt sich vor allem in steigenden Gesundheitsausgaben nieder, insbesondere durch den altersbedingten Funktionsverlust und die abnehmende Selbstständigkeit, resultierend in potenziell längeren Krankheitsphasen und Pflegebedürftigkeit (Cooper, Hardy, Sayer, & Kuh, 2014; Justice et al., 2016; Perera et al., 2015; Studenski et al., 2011). Entsprechend entsteht ein zunehmender Druck für das Gesundheitssystem, Maßnahmen zu ergreifen, die gezielt die ältere beziehungsweise alternde Bevölkerung in den Fokus stellt (Rowe, Fulmer, & Fried, 2016). Vor allem aufgrund der derzeitig stark besetzten mittleren Jahrgänge (*Baby-Boomer*) sollte der Fokus zunehmend auf präventive Aspekte gelegt werden, mit dem Ziel, die Entstehung von Krankheiten und anderer funktioneller Beeinträchtigungen so gut wie möglich zu verhindern. Die hohe Zahl an Nachkommen der Nachkriegsgeneration sind das Resultat steigender Geburtenraten nach dem zweiten Weltkrieg, speziell zwischen den Jahren 1946 und 1965 (Oertel, 2014). Der *Baby-Boom* aus diesen Jahren trägt wesentlich zu der Verschiebung der Altersstruktur bei, einhergehend mit einer kontinuierlich steigenden *fernen Lebenserwartung* älterer Menschen (28,4 Jahre für 60-jährige Frauen beziehungsweise 24,9 Jahre für Männer in 2030 verglichen zu 25,8 Jahre beziehungsweise 21,7 Jahre in 2000) (Statistisches Bundesamt, 2017).

Die Folge dieser Langlebigkeit ist bereits heute sichtbar und spiegelt sich in der Ausdifferenzierung der Lebensphase Alter(n) in ein drittes und viertes Lebensalter wieder. Geläufiger hierfür ist im Allgemeinen die Bezeichnung *junge Alte und alte Alte*, welche synonym für die Beschreibung angewandt werden (Höpflinger, 2017). Dabei sind die jungen Älteren vor allem durch Aktivität, Vitalität und Konsumfreudigkeit gekennzeichnet (Hartmann-Tews, 2010). In dieser Phase geht es in erster Linie um ein erfolgreiches Altern, das heißt die physische als auch psychische Gesundheit bestmöglich zu erhalten, seine Selbstständigkeit und Funktionalität möglichst bis ins hohe Alter aufrecht zu erhalten, einhergehend mit einem hohen Maß an Lebenszufriedenheit. Dieses jedoch kollidiert auf der anderen Seite mit der ausgeprägten Heterogenität dieser spezifischen Altersgruppe hinsichtlich des Gesundheitszustands und dem Wohlbefinden, verglichen zu den alten Älteren (Hartmann-Tews, 2010).

Aufgrund dieser Heterogenität ist letztlich auch keine konkrete Festlegung der Altersspanne für junge Ältere beziehungsweise alte Ältere möglich. Großer Konsens besteht darin, die untere Grenze bei 60 Jahren zu ziehen (United Nations Department of Economic and Social Affairs Population Division, 2015; World Health Organization, 2015). Aufgrund der derzeitigen fernen Lebenserwartung von 20,2 Jahren für die 60-Jährigen (2010/2015) (United Nations Department of Economic and Social Affairs Population Division, 2015) wird für die vorliegende Arbeit im Kontext der jungen Älteren die Altersspanne 60-70 Jahre definiert, welche die Zielgruppe für präventive Ansätze darstellen, insbesondere aufgrund des dramatischen Zuwachses in den kommenden Jahren durch die Baby-Boomer Generation. Diese Entwicklung verschärft den Druck auf das Gesundheitssystem und die Gesellschaft, sich mit der alternden

Bevölkerung, der jungen Älteren im Speziellen, auseinanderzusetzen. Bisherige Maßnahmen, vor allem im medizinischen Bereich, haben den Fokus primär auf die Reduktion der Sterblichkeit gelegt, insbesondere durch die Behandlung bereits vorhandener Krankheiten und deren Symptome, beispielsweise durch den Einsatz von Insulininjektionen bei Diabetes, Grippeschutzimpfungen und Antibiotika zur Minderung bakterieller Infektionen (Swartz, 2008). Entsprechend gilt hier vor allem die betagte Generation (≥70 Jahre) mit fortgeschrittenen Abbauprozessen als Zielgruppe. Auch die Alternsforschung hat sich bisher primär auf die alten Älteren fokussiert, bei denen bereits Einschränkungen in der Alltagskompetenz oder aber Gebrechlichkeit vorliegen (Crimmins, Kim, & Vasunilashorn, 2010).

Auch wenn dieser Ansatz dazu beiträgt, die Lebenserwartung zu erhöhen und das Leiden zu mindern, wird dadurch die Lebensphase Alter(n) beziehungsweise der Eintritt altersbezogener Krankheiten weder verhindert noch hinausgezögert (Ben-Haim et al., 2017). Es wird dadurch lediglich das Eintreten des Todes hinausgezögert und somit unter Umständen die Lebensspanne in Krankheit verlängert. Diese Erkenntnis hat in den vergangenen Jahren zunehmend an Bedeutung gewonnen und das Bewusstsein für ein gesundes Altern und die Notwendigkeit präventiver Ansätze ist deutlich gestiegen (World Health Organization, 2012). Neuere Ansätze sind nunmehr darauf ausgerichtet, die individuelle Lebensspanne in guter Gesundheit zu verlängern, sodass Krankheiten und unvermeidbare altersbedingte funktionelle Beeinträchtigungen hinausgezögert oder gar verhindert werden können. In diesem Kontext gilt Fries (1980) als Pionier auf dem Gebiet des gesunden Alter(n)s, der durch seine These der „compression of morbidity“ betont, dass präventive Maßnahmen dazu beitragen, die Lebensphase Alter(n) durch gesunde Lebensjahre zu prägen. Gleichzeitig ist so auch nur eine sehr kurze, komprimierte Zeit kurz vor dem Tod von Krankheit und Funktionsverlust geprägt (Fries, 1980). Dies hat nicht nur positive Auswirkungen auf das Individuum (unter anderem weniger Krankheiten/Leiden, gesteigertes Wohlbefinden) und die Gesellschaft (unter anderem aktive Lebensführung, Integration, Teilhabe), sondern mindert auch maßgeblich den Druck auf das Gesundheitssystem (unter anderem durch reduzierte Gesundheitskosten). Dafür ist es jedoch erforderlich, frühestmöglich die Risikofaktoren für altersbedingte funktionelle Beeinträchtigungen zu identifizieren. Diese Identifikation ermöglicht es dann, zielgerichtete, geeignete Maßnahmen für die Personengruppen zu entwickeln, die ein erhöhtes Risiko für funktionelle Beeinträchtigungen aufweisen, und diesen dann präventiv entgegenzuwirken.

2.2 Risikofaktoren für altersbedingte, funktionelle Einschränkungen

Wie bereits beschrieben, unterliegt der Alterungsprozess unvermeidbaren altersbedingten funktionellen Einschränkungen. Es finden Abbauprozesse statt, wobei vor allem die abnehmende motorische Leistungsfähigkeit das Alter(n) kennzeichnet (Spirduso, Francis, & MacRae, 2005). Bereits ab dem frühen Erwachsenenalter (18-30 Jahre) sich die motorische Leistungsfähigkeit, jedoch nur in unwesentlichem Ausmaß verschlechtert (Meinel & Schnabel, 2007). Die motorischen Einschränkungen verstärken sich in der vierten Lebensdekade (30-39 Jahre) und tragen dabei nicht nur zu einem funktionellen Abbau und Krankheiten bei, sie stellen auch ein wesentliches Risiko für eine abnehmende Lebensqualität dar (Justice, Cesari, Seals, Shively, & Carter, 2016). Ab dem 60. Lebensjahr nimmt die motorische Leistungsfähigkeit nochmals deutlich schneller ab und altersbedingte funktionelle Abbauprozesse schreiten beschleunigt voran (Granacher & Hortobágyi, 2015). Von besonderer Relevanz sind hierbei das Gleichgewicht, die Muskelkraft und -ausdauer sowie die Gehfähigkeit, welche mit fortschreitendem Alter deutliche Leistungseinbußen verzeichnen (Spirduso et al., 2005). Diese Funktionen sind jedoch wesentliche Voraussetzungen für ein selbstständiges und unabhängiges Leben im Alter und beeinflussen die Lebensqualität nachhaltig.

Die negativen Auswirkungen dieses Funktionsverlustes beeinflussen dabei nicht nur das körperliche, sondern auch das psychische Wohlbefinden im Alter. Das geminderte Wohlbefinden wiederum verstärkt andere Faktoren, beispielsweise eine zunehmende Reduzierung der allgemeinen Aktivität. Eine geminderte Aktivität ist insofern kritisch zu betrachten, da diese sowohl psycho-soziale Konsequenzen (unter anderem sozialer Rückzug, Isolation, Depression) als auch körperliche Konsequenzen (unter anderem erschwerte Ausführung alltäglicher Aufgaben wie zum Beispiel längere Strecken gehen, eine Flasche selbsttätig öffnen oder während der Busfahrt sicher stehen bleiben) nach sich ziehen kann (Bauman, Merom, Bull, Buchner, & Fiatarone Singh, 2016). Letztlich kann daraus eine Art Abwärtsspirale resultieren, bei der sich die Risikofaktoren und deren Konsequenzen gegenseitig bedingen und verstärken. Das wiederum kann sowohl Folgen für die Ausgaben im Gesundheitssystem (vor allem durch Hüftfrakturen und undifferenzierte Knochenbrüche als Sturzfolge) als auch für das Individuum haben (vor allem durch funktionellen Abbau, Inaktivität, Verlust der Selbstständigkeit und Depressionen) (Terroso, Rosa, Marques, & Simoes, 2014). Entsprechend sollte das Ziel sein, frühzeitig, das heißt bereits bei der Aufdeckung von Risikofaktoren, zu intervenieren, um frühestmöglich präventiv einwirken zu können.

Bei der gesonderten Betrachtung der kritischen Faktoren zeichnen sich für die Gleichgewichtsfähigkeit bereits bei jungen Erwachsenen ab einem Alter von 30 Jahren erste altersbedingte Veränderungen ab, welche sich ab der siebten Lebensdekade nochmals beschleunigen (Era et al., 2006). Diese Beschleunigung kann unter anderem auf eine kompensatorische Gegenreaktion des Körpers zurückgeführt werden, die durch das altersbedingte abnehmende Sehvermögen ausgelöst wird (Schwesig, Lauenroth, Becker, & Hottenrott, 2006). Das wird umso deutlicher durch die aktuelle Studienlage, die aufzeigt, dass das visuelle System für ein intaktes Gleichgewicht von größter Bedeutung ist (Ekdahl, Jarnlo, & Andersson, 1989; Era et al., 2006; Hytönen, Pyykkö, Aalto, & Starck, 1993; Teixeira et al., 2014) . Neben dem visuellen System führen auch altersbedingte Veränderungen im propriozeptiven System (Ekdahl et al., 1989; Goble, Coxon, Wenderoth, Van Impe, & Swinnen, 2009; Teixeira et al., 2014) sowie im vestibulären System (Teixeira et al., 2014) zu Veränderungen im Gleichgewicht, die vor allem ab dem 60. Lebensjahr nochmals an Bedeutung gewinnen (Ekdahl et al., 1989; Era et al., 2006). Das erklärt sich durch die Notwendigkeit, dass eine Koordination zwischen dem sensorischen und neuralen System sowie dem Bewegungsapparat stattfinden muss, um Gleichgewicht herstellen und aufrechterhalten zu können. Kommt es wiederum zu einer Abnahme in einem oder mehreren dieser Systeme, wirkt sich dieses negativ auf das Gleichgewicht aus, was letztlich eine sichere Fortbewegung beeinträchtigt, das Sturzrisiko erhöht und damit die Lebensqualität negativ beeinflussen kann.

Ein ähnliches Bild zeigt sich für die Muskelkraft. Nach Erreichen von Spitzenleistungen in der vierten Lebensdekade nimmt die Muskelkraft langsam ab, wobei diese Abnahme sich, wie bereits beim Gleichgewicht, in der siebten Lebensdekade nochmals beschleunigt (Ekdahl et al., 1989; Perna et al., 2016; Peterson & Krishnan, 2015). Dies zeigt sich beispielsweise in einem Verlust von rund 60% der Muskelkraft im Alter von 75 Jahren (Landi et al., 2017). Für die Muskelmasse und -ausdauer sind erste Abbauprozesse im mittleren Erwachsenenalter (≥45 Jahre) zu verzeichnen, wobei die Muskelausdauer bereits zu einem früheren Zeitpunkt und stärker betroffen ist (lineare Abnahme ab dem 45. Lebensjahr) als die Muskelmasse (leichte Abnahme ab dem 50. Lebensjahr) (Landi et al., 2017). Insbesondere der Abbau an Muskelkraft und -ausdauer wirkt sich negativ auf die Mobilität im Alter aus. Beide Faktoren stehen in einem engen Zusammenhang mit alltagsrelevanten Schlüsselfunktionen wie Stehen und Gehen (Hardy et al., 2013), wobei die abnehmende Muskelausdauer nochmals bedeutsamer ist als die abnehmende Muskelkraft (Justice et al., 2016).

Die Relevanz dieser Auswirkungen ist insofern bedeutsam, da die Mobilität im Alter auch als „key hallmark of functional aging“ (Ferrucci et al., 2016, S. 1185) gilt. Mobilität ist ein zentrales Merkmal für die Lebensqualität im Alter und gilt als Prädiktor für potentielle körperlichen Einschränkungen und Sterblichkeit (Ferrucci et al., 2016). Dabei kommt insbesondere der Gehfähigkeit eine große Bedeutung zu, vor allem im klinischen Kontext. Wichtig hierbei ist zu beachten, dass auch hier erste Veränderungen bereits ab der fünften Lebensdekade sichtbar werden, mit einer deutlichen Beschleunigung in der achten Lebensdekade. Eine frühzeitige Testung der Gehfähigkeit (beispielsweise durch einen Test der Ganggeschwindigkeit) ist entsprechend sinnvoll, da dieser auch Aufschluss über spätere funktionelle Defizite geben kann (Ferrucci et al., 2016). Mit Fokus auf den zum Teil doch schon früh auftretenden altersbedingten Abbauprozessen bezüglich Gleichgewicht, Kraft und Mobilität wird deutlich, dass Interventionen bereits in jüngeren Jahren notwendig sind, um Risikofaktoren für potentielle Einschränkungen im höheren Erwachsenenalter zu reduzieren und dem funktionellen Abbau vorzubeugen beziehungsweise diesen hinauszuzögern. Systematische Übersichtsarbeiten zeigen in diesem Kontext übereinstimmend, dass Gleichgewicht, Kraft und die Gehfähigkeit höchstrelevante Risikofaktoren sind und entsprechend im Zentrum intervenierender Maßnahmen stehen sollten (Ferrucci et al., 2016; Sousa et al., 2016; Sturnieks, St George, & Lord, 2008; Terroso et al., 2014).

Auch wenn nur circa ein Fünftel (19,6%) der Älteren eine funktionelle Abhängigkeit aufweisen, tragen diese zu beinah der Hälfte (46,3%) der gesamten Gesundheitsausgaben bei (Fried, Bradley, Williams, & Tinetti, 2001). Entsprechend besteht dringender Handlungsbedarf, frühestmöglich zu intervenieren, insbesondere vor dem Hintergrund der Baby-Boomer-Generation, welche die gesamtheitlichen Gesundheitskosten nochmals stark ansteigen lassen kann. Trotz dieses Wissens befassen sich Studien in erster Linie mit der Zielgruppe der über 70-Jährigen, bei denen der altersbedingte funktionelle Abbau bereits beschleunigt eingesetzt hat und sich im fortgeschrittenen Stadium befindet (O'Caoimh et al., 2015). Neueste Entwicklungen in der Forschung deuten jedoch darauf hin, dass das Bewusstsein steigt, auch jüngere Zielgruppen in Studien zu integrieren (Jonkman, Del Panta, et al., 2018). Vor dem Hintergrund der rasanten demografischen Alterung stehen dabei vor allem präventive Maßnahmen im Fokus. Von besonderem Interesse ist hierbei die Baby-Boomer-Generation, da diese zum Teil schon das kritische Alter von 60 Jahren und älter erreicht haben, welches im engen Zusammenhang mit beschleunigter altersbedingter funktioneller Beeinträchtigungen steht (Ekdahl et al., 1989; Era et al., 2006; Meinel & Schnabel, 2007; Perna et al., 2016; Peterson & Krishnan, 2015).

So befasst sich beispielsweise eine Studie explizit mit den 60-70-Jährigen und deren Risikofaktoren für funktionelle Abbauprozesse (Jonkman, Del Panta, et al., 2018). Dabei zeigte sich im Rahmen dieser 3-jährigen Längsschnittstudie, dass insbesondere die Veränderung der Ganggeschwindigkeit einen bedeutsamen Risikofaktor für einen funktionellen Abbau darstellt. Bei Männern wurden zudem Sturzangst und Alkoholkonsum als weitere Risikofaktoren identifiziert, bei Frauen das Alter, Alleinleben und geringe finanzielle Ressourcen. Die Studie kommt zu dem Schluss, dass vor allem die Heterogenität der jungen Älteren zu sehr unterschiedlichen Entwicklungen im funktionellen Abbau beiträgt und diejenigen Personen, welche bereits Einschränkungen zu Beginn der Studie aufwiesen, auch deutlich schneller und intensiver von einem weiteren Abbau betroffen waren. Dieser Befund zeigt, dass sobald funktionelle Einschränkungen vorliegen, sich der Gesundheitszustand auch mit beschleunigter Geschwindigkeit verschlechtert. Entsprechend würden besonders stark eingeschränkte Personen von präventiven Interventionen profitieren, da sich so das beschleunigte Voranschreiten der oben erwähnten Abbauprozesse hinauszögern ließe (Jonkman, Del Panta, et al., 2018).

2.3 Messverfahren zur Identifikation von Risikofaktoren bei jungen Älteren

Aus dem vorherigen Abschnitt geht hervor, dass das Alter(n) stark von abnehmender körperlicher Leistungsfähigkeit, insbesondere abnehmendem Gleichgewicht, reduzierter Kraft und Gehfähigkeit, geprägt sein kann. Frühzeitige Präventionsmaßnahmen respektive eine frühzeitige Aufdeckung von funktionellen Einschränkungen sowie deren zugrunde liegenden Ursachen können dazu beitragen, den altersbedingten Verlusten im späteren Leben vorzubeugen.

Tests zur Erfassung des physischen Gesundheitszustands, vor allem Messungen des Gleichgewichts, der Kraft und der Gehfähigkeit, sind wesentliche Indikatoren beziehungsweise Prädiktoren für das Wohlbefinden und die Lebensqualität älterer Menschen. Diese Tests geben nicht nur Aufschluss über den aktuellen, sondern auch über die Veränderung des körperlichen Gesundheitszustands über einen bestimmten Zeitverlauf hinweg. Ferner kann anhand der Daten auch prädiktiv das Risiko für verschiedene, sich negativ auf die Gesundheit auswirkende Faktoren abgeschätzt werden, darunter Multimorbidität, Einschränkungen bei Alltagstätigkeiten, Stürze, Krankenhausaufenthalte, Pflegebedürftigkeit sowie eine frühere Sterblichkeit (Cooper, Hardy, Sayer, & Kuh, 2014; Justice et al., 2016; Perera et al., 2015; Studenski et al., 2011). Entsprechend gelten diese Tests auch als einzigartige Biomarker zur Identifikation von Phänotypen in Bezug auf den individuellen Funktionsstatus (Justice et al., 2016). Dies ist insofern von besonderer Bedeutung, da Interventionen entsprechend zugeschnitten und individualisiert werden können, sodass Teilnehmenden das jeweils passende Format bereit gestellt werden kann (zum Beispiel Phänotyp Gleichgewicht: Fokus auf Gleichgewichtstraining, gegebenenfalls begleitet von Kraft- und Gehtraining).

Darüber hinaus ist durch die Identifikation von Defiziten und möglichen zugrunde liegenden Ursachen die Entwicklung von adäquaten Präventionsstrategien möglich, die sowohl auf individueller als auch gesellschaftlicher Ebene dazu beitragen, funktionellen Einschränkungen entgegenzuwirken (Ferrucci et al., 2016). Wichtig zu beachten ist hierbei für die Zielgruppe der jungen Älteren, dass die Tests anspruchsvoll genug gestaltet sind, um die zunehmende Heterogenität dieser Bevölkerungsgruppe adäquat abbilden zu können. Es bedarf provokativer Tests, die die spezifischen Funktionsbereiche hinreichend fordern, um auch bereits kleinste Veränderungen im Funktionsstatus sichtbar zu machen. Ist ein Test sensitiv genug, kann dieser sowohl den Schweregrad der Einschränkungen als auch subklinische Einschränkungen, das heißt noch nicht klinisch diagnostizierbare und zum Zeitpunkt der Messung vollständig kompensierbare Defizite, die noch keine erkennbaren Probleme bereiten, aufdecken (Ferrucci et al., 2016). Gleichzeitig sollte der Test dabei auch spezifisch genug sein, um das Risiko falsch-positiver Befunde möglichst gering zu halten. Dabei ist zu beachten, dass der Fokus auf der Identifikation des schwächsten physiologischen Funktionsbereichs liegt, um dieses vor einem späteren Funktionsverlust zu schützen oder um diesen zumindest hinauszuzögern (Ferrucci et al., 2016).

Zahlreiche Studien haben die Eignung diverser Tests zur Erfassung der körperlichen Leistungsfähigkeit speziell bei älteren Personen analysiert. Dabei zeigen jüngste systematische Übersichtsarbeiten, dass der Timed Up and Go (TUG) Test zur Überprüfung der Mobilität sowie die Berg Balance Skala (BBS) zur Testung des Gleichgewichts die am weitesten verbreiteten und am intensivsten getesteten Messverfahren in dieser Zielgruppe sind (Langley & Mackintosh, 2007; Power, Van De Ven, Nelson, & Clifford, 2014). Jedoch wird bei genauerer Betrachtung der Effektivität einzelner Tests für die Prädiktion von funktionellen Einschränkungen deutlich, dass sich die Studien bisher fast ausschließlich auf die über 70-Jährigen fokussiert haben (O'Caoimh et al., 2015). Dies ist insofern problematisch, da in dieser Zielgruppe die funktionellen Defizite bereits vorhanden bzw. deutlich fortgeschritten sind.

Mit Blick auf selbstständig lebende, gesunde ältere Menschen sind solche weit verbreiteten Tests wie der TUG und die BBS als auch andere geläufige Tests wie die Short Physical Performance Battery (SPPB; Gleichgewichtstest) oder der Dynamic Gait Index (DGI; Test der Gehfähigkeit) nicht in der Lage, die individuelle körperliche Leistungsfähigkeit adäquat abzubilden (Barry, Galvin, Keogh, Horgan, & Fahey, 2014; Langley & Mackintosh, 2007; Mancini & Horak, 2010; Pardasaney et al., 2012; Power et al., 2014; Schoene et al., 2013). Besonders die fehlende Komplexität stellt die größte Herausforderung für eine adäquate Abdeckung der Heterogenität dieser spezifischen Zielgruppe dar. Dies ist insofern besonders problematisch, da diese Zielgruppe im Zuge der demografischen Alterung und der Veränderung der Lebensphase Alter(n) durch die Baby-Boomer-Generation noch weiter zunehmen wird. Entsprechend steigt der Bedarf an geeigneten, ausreichend differenzierten Messmethoden.

Bezüglich der eingangs erwähnten geläufigsten Tests zeigt sich, dass beispielsweise der TUG zwar zur Erfassung der grundlegenden Mobilität geeignet ist und eine allgemeine Aussage über Kraft- und/oder Gleichgewichtsdefizite machen kann (Aufstehen vom Stuhl, gehen, drehen), jedoch keine Aussage darüber getroffen werden kann, welche Subkomponenten (Gang, Gleichgewicht) betroffen sind (Barry et al., 2014; Mancini & Horak, 2010). Darüber hinaus hat die fehlende Berücksichtigung weiterer Faktoren wie Sehen, Kognition oder auch Medikamenteneinfluss zur Folge, dass der TUG keine prädiktive Aussagekraft für Stürze aufweist (Barry et al., 2014; Schoene et al., 2013). Da der Test dazu befähigt, Aussagen über die Schwere von Defiziten tätigen zu können, beispielsweise hinsichtlich einer Diskriminierung von einfach und mehrfach Gestürzten, eignet sich dieser für weniger fitte, gebrechlichere ältere Menschen (Schoene et al., 2013). Dennoch ist der TUG nicht für den Einsatz bei fitteren, gesunden Älteren geeignet, da dieser in dieser Zielgruppe weder eine adäquate Diagnose stellen noch die Heterogenität dieser abdecken kann (Schoene et al., 2013).

Dies wird auch durch andere Studienergebnisse bestätigt (Viccaro, Perera, & Studenski, 2011). Trotz zusätzlichem Drehen, Stehen und Sitzen konnte kein Zusatznutzen für die Prädiktion von Stürzen nachgewiesen werden im Vergleich zu einfachen Messungen der Ganggeschwindigkeit (Viccaro et al., 2011). Vielmehr sind Messungen der Ganggeschwindigkeit bei gesunden, fitten älteren Personen sogar von größerem Nutzen für die Sturzprädiktion (Viccaro et al., 2011) sowie auch für die allgemeine Prognose hinsichtlich der Entwicklung funktioneller Einschränkungen in späteren Jahren (den Ouden, Schuurmans, Arts, & van der Schouw, 2011). Allerdings ist Vorsicht geboten, denn vereinzelte Tests weisen auch hier Deckeneffekte und eine geringe Sensitivität auf (Pardasaney et al., 2012). Vor allem, wenn nur Ränge vergeben werden (das heißt ordinal skaliert), wie es beispielsweise bei dem DGI der Fall ist, jedoch keine Aussagen über die tatsächliche Leistung (zum Beispiel Zeit, Distanz, Geschwindigkeit) vorliegen (Pardasaney et al., 2012).

Ein ähnliches Bild zeigt sich für „den Goldstandard“ der Gleichgewichtstests, die BBS (Langley & Mackintosh, 2007; Power et al., 2014). Systematische Übersichtsarbeiten berichten übereinstimmend, dass dieser Test zwar eine hohe Validität und Reliabilität für die Anwendung in älteren Zielgruppen aufweist (Langley & Mackintosh, 2007; Power et al., 2014), die Ergebnisse jedoch in Frage gestellt werden sollten aufgrund von Deckeneffekten und fehlender Sensitivität (Langley & Mackintosh, 2007; Mancini & Horak, 2010; Pardasaney et al., 2012; Power et al., 2014). Dies ist in erster Linie auf fehlende Komplexität zurückzuführen, die selbst die Entwickler/innen der BBS bereits kritisch angemerkt haben (unter anderem fehlende Erfassung des dynamischen Gleichgewichts) (Berg, Wood-Dauphine, Williams, & Gayton, 1989). Ähnlich wie für den TUG kann auch für die BBS entsprechend geschlussfolgert werden, dass diese zwar für stark eingeschränkte älterer Personen geeignet ist, jedoch die Eignung aufgrund der fehlenden Komplexität als auch der Länge der Testung (45-50 Minuten) und der auftretenden Probleme in der Interpretation der Kriterien zur korrekten Beurteilung der Gleichgewichtsfähigkeit in Frage gestellt werden sollte (Langley & Mackintosh, 2007).

Andere Studien verweisen in diesem Kontext auf die SPPB, die besser geeignet sei, um die Gleichgewichtsfähigkeit älterer Menschen adäquat zu erfassen. Dabei zeigen diese Studien, dass die SPPB nicht nur prädiktiv für funktionelle Einschränkungen geeignet ist, sondern auch für Mobilitätsdefizite und eine frühere Sterblichkeit bei älteren Personen (Minneci et al., 2015). Allerdings zeigen sich auch hier Deckeneffekte, wenn die SPPB in einer jüngeren, fitteren Zielgruppe unter 70 Jahren angewandt wird (Fleig et al., 2016). Eine speziell für fittere, selbstständig lebende Ältere entwickelte Skala, die Fullerton Advanced Balance (FAB) Skala verfolgt das Ziel, neben der reinen Identifikation von Gleichgewichtsdefiziten auch deren Schweregrad zu identifizieren, indem mehrere Systeme (sensorisch, muskuloskeletal, neuromuskulär) berücksichtigt werden sowie das statische als auch das dynamische Gleichgewicht getestet werden (Rose, Lucchese, & Wiersma, 2006). Wenngleich die FAB in der Originalstudie (≥65 Jahre; 75 ± 6,2 Jahre) eine hohe Reliabilität und Validität aufzeigt, ist diese Skala noch zu wenig erforscht. Zudem können aufgrund fehlender Anführung der erreichten Punktezahl keine Aussagen über potenzielle Boden- oder Deckeneffekte getroffen werden (Langley & Mackintosh, 2007).

Weit verbreitete Tests zur Erfassung der Muskelkraft sind in erster Linie der Aufstehtest (*Five times Sit-to-Stand*) und die Messung der Handgreifkraft (den Ouden et al., 2011; Power et al., 2014). Dabei gibt der Aufstehtest nicht nur Aufschluss über die Muskelkraft der unteren Extremitäten, er gilt auch als Prädiktor für ein erhöhtes Sturzrisiko (Power et al., 2014) und die Entwicklung funktioneller Einschränkungen im Allgemeinen (den Ouden et al., 2011). Letzteres lässt sich zudem auch anhand der Handgreifkraft ermitteln, welche als exzellenter Prädiktor für die Funktionalität als auch die Mobilität im Alter gilt (den Ouden et al., 2011; Minneci et al., 2015). Für beide Tests liegen keine Studien vor, die die Eignung in jüngeren, fitten Zielgruppen prüfen. Insbesondere die Messung der Handgreifkraft ist ein geläufiges Messverfahren, welches durch standardisierte Instrumente eine adäquate Erfassung der Muskelkraft ermöglicht und sich folglich auch für präventive Ansätze und eine möglichst frühzeitige Identifikation eines erhöhten Risikos für Kraft-, Funktionalitäts- und/oder Mobilitätsdefizite eignet.

Zusammenfassend zeigt sich, dass die derzeitigen Tests zur Erfassung von Gleichgewicht, Kraft und Mobilität vor allem in älteren Zielgruppen intensiv untersucht wurden, wobei das Durchschnittsalter meist über 70 Jahren liegt. Diese Tests können zwar vorhandene Defizite bei älteren, eher gebrechlichen Personen aufdecken, jedoch weder zwischen verschiedenen Subkomponenten unterscheiden noch die zunehmende Heterogenität der älteren Bevölkerung adäquat abbilden. Dabei stellen Deckeneffekte die größte Limitation dar, vor allem bei der Anwendung bei fitten, jungen Älteren (60-70 Jahre). Das ist insofern kritisch zu sehen, da Verbesserungen infolge von Interventionen nicht adäquat wiedergespiegelt werden können, was schließlich zur Folge hat, dass das Ausmaß der Interventionseffekte fälschlicherweise schwächer interpretiert wird als es tatsächlich der Fall ist (Fleig et al., 2016; Hackney & Earhart, 2010).

2.4 Körperliche Aktivität im Alter

Neben den unabdingbaren altersbedingten körperlichen Abbauprozessen (primäres Altern) wirken sich weitere, externe Faktoren auf die Lebenserwartung aus (sekundäres Altern). Von besonderer Bedeutung ist in diesem Zusammenhang die körperliche (In-)Aktivität. Weltweit können rund 6% der Todesfälle auf körperliche Inaktivität zurück geführt werden (World Health Organization, 2018). Die Weltgesundheitsorganisation stuft körperliche Inaktivität daher auch als viertwichtigsten Risikofaktor für eine verkürzte Lebenserwartung ein, nach Rauchen, Bluthochdruck und Blutzucker (World Health Organization, 2018). Dabei fällt bei genauerer Betrachtung auf, dass die zwei letztgenannten Faktoren als auch Übergewicht als fünftwichtigster Risikofaktor in engem Zusammenhang mit körperlicher Inaktivität stehen und folglich mit einem Fokus auf die körperliche (In-)Aktivität drei weitere Risikofaktoren positiv beeinflusst werden können. Dabei sollte vor allem die Prävention von Funktionsverlusten im Mittelpunkt stehen, welche aus körperlicher Inaktivität resultieren können. Ein unzureichendes Maß an körperlicher Aktivität trägt sowohl zu einem Verlust an Muskelmasse und –kraft bei, als auch zu einer Verminderung der Gleichgewichtsfähigkeit und Ausdauer und führt zudem zu einem erhöhten Risiko für kognitive Defizite (Jonkman, Del Panta, et al., 2018; Taylor, 2013; Terroso et al., 2014).

Obwohl die positiven Effekte körperlicher Aktivität hinreichend bekannt und durch zahlreiche Studien belegt sind, hält sich nur ein Bruchteil der über 60-Jährigen an die in den Leitlinien festgehaltenen Bewegungsempfehlungen (Keadle, McKinnon, Graubard, & Troiano, 2016; Sun, Norman, & While, 2013; Taylor, 2013). Systematische Übersichtsarbeiten zeigen, dass die Einhaltung der Leitlinien (150 min. moderate beziehungsweise 75 min. intensive körperliche Aktivität pro Woche) stark variiert (2,4-83%) (Sun et al., 2013), wobei die Studien mehrheitlich zwischen 20-60% liegen (Keadle et al., 2016; Sun et al., 2013). Hinzu kommt, dass dieser Prozentsatz mit zunehmendem Alter nochmals sinkt. So zeigt zum Beispiel die systematische Übersichtsarbeit von Sun und Kolleg/innen (2013) zur körperlichen Aktivität älterer Menschen ab 60 Jahren, dass sich 60-64-Jährige mehr als dreimal so häufig an die Bewegungsempfehlungen halten als über 85-Jährige (50,8% versus 15,4%) (Sun et al., 2013). Diese altersbedingte Abnahme ist jedoch vor allem durch Krankheiten, zunehmende Schmerzen und Verletzungen bedingt (Taylor, 2013).

Dabei ist körperliche Aktivität insbesondere im höheren Alter der wichtigste Faktor für die körperliche Funktionalität und Aufrechterhaltung der körperlichen Leistungsfähigkeit (Artaud et al., 2013; Granacher & Hortobágyi, 2015; Tak, Kuiper, Chorus, & Hopman-Rock, 2013; Taylor, 2013; Wang, Ramey, Schettler, Hubert, & Fries, 2002), sie schützt vor Krankheiten (Bauman et al., 2016) und wirkt sich positiv auf die Mobilität, das psychologische Wohlbefinden, die kognitive Leistungsfähigkeit sowie soziale Integration im Alter aus (Bauman et al., 2016; Granacher & Hortobágyi, 2015; Taylor, 2013). Dies wird auch durch neueste Studienergebnisse belegt, die aufzeigen, dass das Auftreten funktioneller Einschränkungen bei älteren Menschen im Alter von durchschnittlich 74 Jahren (Artaud et al., 2013) beziehungsweise 58 Jahren (Wang et al., 2002) durch körperliche Aktivität um bis zu 12 (Artaud et al., 2013) beziehungsweise 13 Jahre (Wang et al., 2002) hinausgezögert werden kann. Entsprechend gilt körperliche Aktivität auch als *der* Schlüsselfaktor zur Kompression der Morbidität (Fries, 1980).

Bereits ein moderates Level an körperlicher Aktivität ist ausreichend, um das Risiko für einen vorzeitigen Tod, die Entstehung von Krankheiten und Entwicklung funktioneller Einschränkungen zu reduzieren (Rillamas-Sun et al., 2017; Taylor, 2013). Protektive Effekte konnten bereits bei einem Aktivitätsniveau unterhalb der Leitlinien (bei circa 50%-iger Einhaltung) nachgewiesen werden (Bauman et al., 2016). Wichtig hierbei ist jedoch zunehmend das Bewusstsein für die Wichtigkeit der Reduktion von zu langem Sitzen, unabhängig vom individuellen Aktivitätsniveau, zu stärken und nicht nur den Fokus auf die Steigerung der körperlichen Aktivität zu legen. So gilt langes Sitzen mittlerweile als das neue Rauchen in Bezug auf die daraus resultierenden negativen gesundheitlichen Konsequenzen für das kardiovaskuläre System (Predel & Nitschmann, 2017). Zahlreiche Studien haben sich in jüngster Zeit mit dieser Problematik auseinandergesetzt (Bauman et al., 2016; den Ouden et al., 2011; Predel & Nitschmann, 2017; Rillamas-Sun et al., 2017) und zeigen unter anderem auf, dass langes Sitzen (>10 Stunden pro Tag) bei älteren Menschen (M=70,2 Jahre) das Risiko für Mobilitätseinschränkungen und einen frühzeitigem Tod deutlich erhöht (Rillamas-Sun et al., 2017).

Insbesondere für die Lebensphase Alter(n) sind neben körperlicher Aktivität und der Reduktion von zu langem Sitzen vor allem Kraft und Gleichgewicht zentrale Schlüsselkomponenten für ein gesundes und erfolgreiches Altern (Bauman et al., 2016; Hartmann-Tews, 2010). So trägt ein spezifisches Kraft- und Gleichgewichtstraining maßgeblich dazu bei, die Mobilität und Selbstständigkeit im Alter zu erhalten und vor schwerwiegenden negativen Konsequenzen wie Stürzen, Pflegebedürftigkeit und frühzeitigem Tod zu schützen (Era, Heikkinen, Gause-Nilsson, & Schroll, 2002; Gillespie et al., 2012; Sherrington et al., 2016; Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011). Wenngleich ein gezieltes Kraft- und Gleichgewichtstraining bedeutsam für die Selbstständigkeit und Unabhängigkeit im Alter ist, üben nur 12% der über 65-Jährigen regelmäßig Krafttraining (≥2 Mal pro Woche) aus, für Gleichgewichtstraining ist der Anteil nochmals deutlich geringer (5,9%) (Merom et al., 2012). Zudem besteht die Herausforderung darin, ältere Menschen zur Ausübung von mehr als einer körperlichen Aktivität zu animieren, das heißt neben aeroben Training wie Spazieren gehen oder Laufen als am weitesten verbreitete Form (rund 81%) (Merom et al., 2012), auch noch eine zweite und/oder dritte Aktivität wie Gleichgewichts- und/oder Krafttraining auszuüben (Merom et al., 2012).

Dies wird auch an dem geringen Anteil (27%) der über 65-Jährigen, die mehr als einer körperlichen Aktivität, gemessen an den vergangenen 12 Monaten, nachgehen, deutlich (Merom et al., 2012). Dabei kann vor allem eine Kombination aus spezifischen Kraft-, Gleichgewichts-, Koordinations- und Agilitätsübungen (sogenanntes neuromotorisches Training) zur Steigerung der funktionellen Fitness und Reduktion negativer Konsequenzen wie ein erhöhtes Sturzrisiko beitragen (Garber et al., 2011). Denn entgegen der weit verbreiteten Ansicht älterer Menschen, im Alter keinen gesundheitlichen Nutzen mehr aus körperlicher Aktivität heraus generieren zu können (Schutzer & Graves, 2004), bleibt die Trainierbarkeit, das heißt die bewegungs- und trainingsinduzierte Anpassung, auch im Alter erhalten (Behrens, Borchert, & Kress, 2018). Entsprechend kann sich eine Veränderung hin zu einem aktiv(er)en Lebensstil nicht nur positiv auf den Alterungsprozess auswirken, es ermöglicht auch eine selbstständige Lebensführung und eine größtmögliche Hinauszögerung des körperlichen Verfalls (sogenanntes *frailility*-Syndrom) (Sherrington et al., 2016; Sherrington et al., 2011).

Allerdings stammen die Befunde zu körperlicher Aktivität primär aus strukturierten Trainingsinterventionen, die mangels konkreter Strategien zur Verhaltensänderung wenig Fokus auf eine langfristige und regelmäßige Ausführung des Trainings legen (Burton, Khan, & Brown, 2012; Chao, Capri, & Farmer, 2000; Clemson et al., 2004). Dazu zählt unter anderem auch das weit verbreitete Otago-Programm, welches zur Sturzprävention bei selbstständig lebenden älteren Menschen (≥65 Jahre) entwickelt wurde (Campbell & Robertson, 2003). Das Otago-Programm richtet sich dabei in erster Linie an Personen, die ihr Zuhause kaum oder gar nicht mehr verlassen, indem das Training im jeweiligen Zuhause durchgeführt werden kann (Scherfer, Freiberger, Stranzinger, & Becker, 2013). Wichtig ist, dass die Teilnehmenden über das benötigte

Equipment (unter anderem Einsatz von Gewichtsmanschetten) verfügen und sich dreimal wöchentlich 30 Minuten Zeit frei halten, um die Übungen durchzuführen. Durch die vorgegebene Standardisierung sind Trainingsansätze wie das Otago-Programm sehr zeitaufwändig und unflexibel. Das hat den Nachteil, dass solche Programme keinen direkten Bezug zum Alltag aufbauen und folglich wenig Kenntnis über die Aufrechterhaltung und Nachhaltigkeit solcher strukturierter Trainingsprogramme geliefert werden kann. Der fehlende Nachweis der Nachhaltigkeit wird bereits in der Forschung kritisiert (Hawley-Hague et al., 2014). Dabei ist eine mögliche Erklärung für diese Forschungslücke, dass keine Evidenz über einen Zeitraum von mehr als 12 Monaten vorliegt. Studien beinhalten bisher keine längerfristigen Folgemessungen und somit fehlt es schlicht an Informationen über die tatsächliche Adhärenz (Einhaltung des Trainings, vor allem über die Intervention hinaus). Eine andere mögliche Erklärung gründet sich hingegen vielmehr in der mangelnden Motivation älterer Menschen (N. W. Burton et al., 2012; Costello, Kafchinski, Vrazel, & Sullivan, 2011).

So zeigen jüngste Studien, dass Ältere es vorziehen würden, körperliche Aktivität und/oder gezieltes neuromotorisches Training in ihren Alltag zu integrieren (zum Beispiel im Haushalt, während der Gartenarbeit oder beim Einkaufen) (N. W. Burton et al., 2012) und weniger Gefallen an den weit verbreiteten, standardisiert-strukturierten Ansätzen mit vorgegebener Intensität, Wiederholungszahl und Trainingssätzen finden (Boulton, 2014; Costello et al., 2011). Dies gründet sich vor allem darin, dass es im Rahmen strukturierter Trainingsprogramme oft an Transportmöglichkeiten und Zugang zu entsprechenden Einrichtungen (Schutzer & Graves, 2004) sowie der Bereitschaft, in einer Gruppe zu trainieren, mangelt (N. W. Burton et al., 2012) und der zeitliche Aufwand für die Teilnahme zu hoch ist (N. W. Burton et al., 2012; Chao et al., 2000; Cohen-Mansfield, Marx, & Guralnik, 2003). Zudem sehen sich ältere Menschen oftmals selbst nicht als sportliche Person und lehnen Sport daher generell ab (Boulton, 2014). Ein weiterer Faktor ist, dass es bisher auch noch an psychologischen Konzepten innerhalb strukturierter Trainingsprogramme mangelt, um das körperliche Aktivitätsverhalten nachhaltig beeinflussen zu können (Chao et al., 2000). Entsprechend besteht ein hoher Bedarf an neuen alltagsintegrierten Trainingskonzepten als Alternative und/oder Ergänzung zu strukturierten Trainingsprogrammen sowie der Entwicklung fundierter psychologischer Ansätze zur Verhaltensmodifikation hin zu einer Verinnerlichung eines aktiven Lebensstils (Chao et al., 2000; Clemson et al., 2004; Clemson et al., 2010).

2.5 Alltagsintegriertes, funktionelles Training

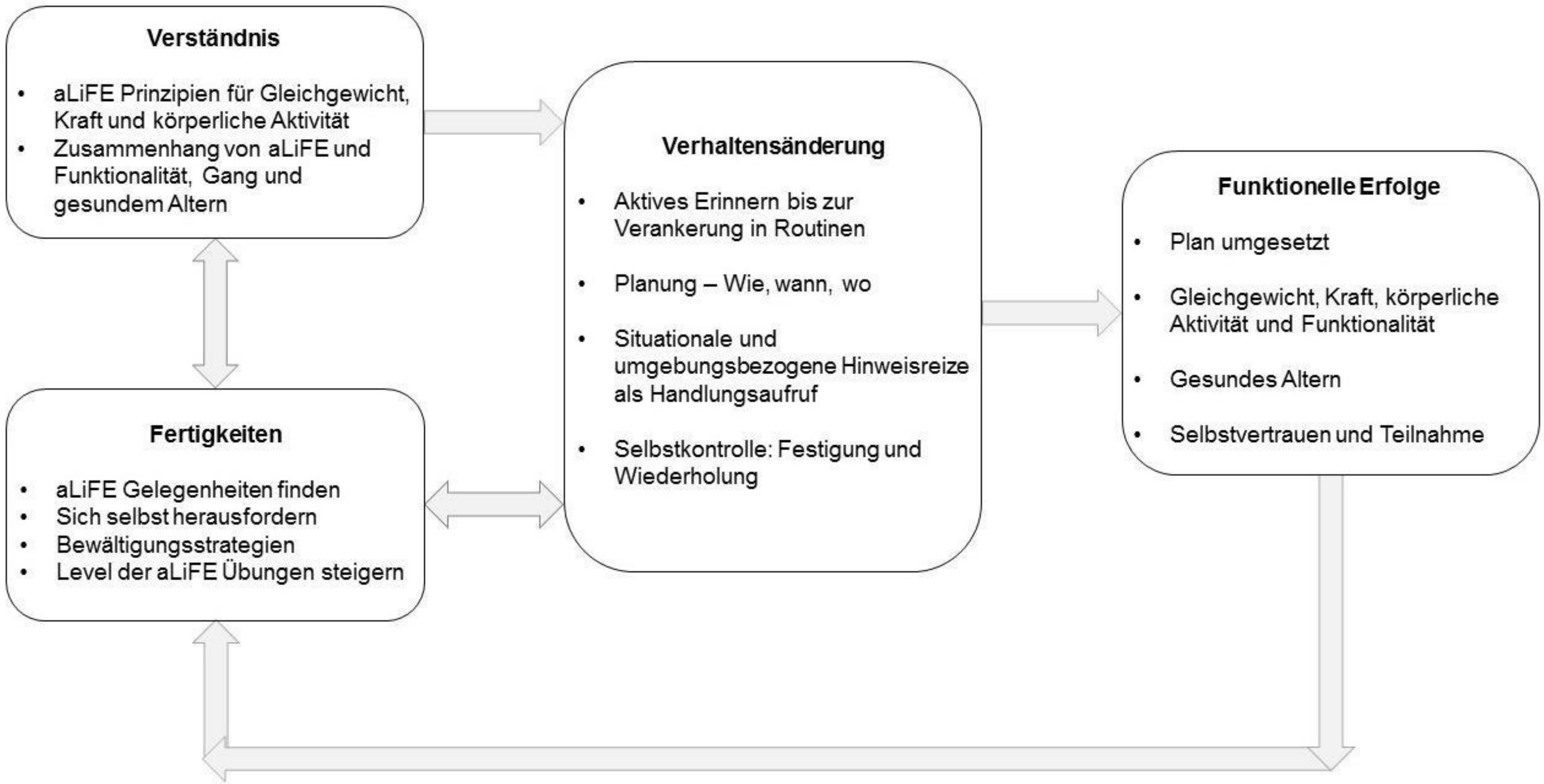
In den vergangenen Jahren hat vor allem das alltagsintegrierte Training deutlich an Bedeutung gewonnen (Bauman et al., 2016), hauptsächlich resultierend aus den bereits genannten Barrieren älterer Menschen zur Aufnahme beziehungsweise (längerfristigen) Aufrechterhaltung eines herkömmlichen strukturierten Trainings. Dabei liegt der Vorteil dieses alltagsintegrierten Trainings vor allem in der Zugänglichkeit (das heißt im/nahe dem eigenen Zuhause sowie geringe/keine Kosten). Gemäß zahlreichen Studien und systematischen Übersichtsarbeiten zufolge beeinflusst die Zugänglichkeit besonders stark die Motivation, sowohl zur Aufnahme als auch Aufrechterhaltung körperlicher Aktivität (Costello et al., 2011; Devereux-Fitzgerald, Powell, Dewhurst, & French, 2016; Franco et al., 2015; Schutzer & Graves, 2004).

In den letzten Jahren hat sich in diesem Zusammenhang ein neuer Trainingsansatz herausgebildet, der sich auf die Integration von funktionellem Training in den Alltag älterer Menschen fokussiert (Clemson et al., 2012; 2010). Dabei wird funktionelles Training als „any type of training that is performed with purpose to enhance a certain movement or activity" definiert (Liu, Shiroy, Jones, & Clark, 2014, S. 96), basierend auf dem Prinzip der Trainingsspezifität. Von diesem Prinzip ausgehend wird angenommen, dass das Training umso effektiver ausfällt, je konkreter es auf die jeweilig angestrebten Resultate zugeschnitten ist (Chou, Hwang, & Wu, 2012; Liu et al., 2014). Ein Beispiel hierfür wäre der Tandemstand während des Zähneputzens, um das Gleichgewicht zu trainieren oder eine Kniebeuge zu machen, wenn etwas vom Boden aufgehoben werden muss. Ziel dieses neuen Trainingsansatzes ist es, durch funktionelles, alltagsintegriertes Training gezielt die funktionelle Leistungsfähigkeit älterer Menschen zu trainieren und deren allgemeines körperliches Aktivitätsniveau zu steigern (Chou et al., 2012; Liu et al., 2014). Dabei liegt der Fokus auf gezielten Kraft- und Gleichgewichtsübungen, welche zentral für die Funktionalität und Aufrechterhaltung der Selbstständigkeit im Alter sind (Era et al., 2002; Gillespie et al., 2012; Sherrington et al., 2016; Sherrington et al., 2011).

Funktionelle Ansätze sind insofern vielversprechend, da zielgerichtete Interventionen direkt den Alterungsprozess ansprechen und somit in der Lage sind, die maximale Lebenserwartung weiter zu steigern (Ben-Haim et al., 2017). Insbesondere die direkte Ansprache der Mechanismen, die dem Alterungsprozess zugrunde liegen, ist wichtig, anstatt sich nur auf die Behandlung von Krankheiten und deren Symptome zu fokussieren. Damit würde sich nicht nur die mittlere (durchschnittliche Lebenserwartung zum Zeitpunkt der Geburt), sondern auch die maximale Lebenserwartung (höchst möglichstes Lebensalter) deutlich erhöhen (Ben-Haim et al., 2017). Clemson und Kolleg/innen (2012; 2010) beschäftigen sich seit einigen Jahren mit dem Ansatz des alltagsintegrierten Trainings und entwickelten in diesem Zuge das „Lifestyle-integrated functional Exercise“ (LiFE)-Programm. Bei diesem Programm werden spezifische Kraft- und Gleichgewichtsübungen gezielt in den Alltag integriert, sodass das Training nicht gesondert durchgeführt werden muss. Das Konzept zielt darauf ab, ein kontinuierliches und überdauerndes Training zu erleichtern, indem keine zusätzliche Trainingszeit neben alltäglicher Routinetätigkeiten benötigt wird und andererseits ein direkter Bezug zum Alltag, bei der Küchenarbeit (zum Beispiel Kniebeugen beim Entleeren des Geschirrspülers), im Bad (zum Beispiel Einbeinstand beim Zähneputzen) oder auf dem Weg zum Einkaufen (zum Beispiel ein bestimmtes Teilstück der Strecke auf den Zehen oder Fersen absolvieren), hergestellt wird. Letzteres soll wiederum die Nachhaltigkeit des Trainings positiv beeinflussen.

Erste Studien zum LiFE-Programm zeigen, dass sich dieses positiv auf die Kraft- und Gleichgewichtsfähigkeit auswirkt (E. Burton, Lewin, & Clemson, 2014; E. Burton, Lewin, Clemson, & Boldy, 2013; E. Burton, Lewin, Clemson, & Boldy, 2014; Clemson et al., 2012; Clemson et al., 2010), die Sturzrate signifikant reduziert (Clemson et al., 2012; Clemson et al., 2010) und folglich auch die Selbstständigkeit im Alter positiv beeinflusst (Clemson et al., 2012). Die Besonderheit des LiFE Programms liegt vor allem darin, dass es auf einem spezifischen Konzept zur Verhaltensänderung basiert (Abbildung 1), welches ein nachhaltiges Training ermöglicht und somit zu einer überdauernden Verhaltensänderung beitragen soll (Clemson, Munro, & Singh, 2014).

Das LiFE-Programm wurde ursprünglich für die Zielgruppe der über 75-Jährigen entwickelt mit dem Fokus auf die Reduzierung der Sturzrate, das heißt zielgerichtet entwickelt für eingeschränkte, gebrechliche ältere Menschen mit einer Sturzhistorie. Dem aktuellen Kenntnisstand nach fehlt es jedoch an Evidenz, inwiefern ein alltagsintegriertes, funktionell ausgerichtetes Trainingsprogramm bereits bei jungen Älteren (60-70 Jahre) präventiv eingesetzt werden kann, um ein gesundes und aktives Altern zu ermöglichen. Es ist vielmehr wichtig, gerade vor dem Hintergrund der demografischen Alterung (Hartmann-Tews et al., 2012), den Fokus auf die Aufrechterhaltung der Gesundheit und die Ermutigung zu einem bewussten und selbstständigen Umgang mit dieser zu legen. Dies bedeutet, dass es weniger darum gehen sollte, funktionelle Abbauprozesse abzumildern, sondern vielmehr darum, ein gezieltes, funktionelles Training, auch unabhängig vom funktionellen Status älterer Menschen, zu integrieren mit dem Ziel, die physische als auch psychische Gesundheit bestmöglich zu erhalten.



(Quelle: Eigene Darstellung; übersetzt in Anlehnung an Clemson et al., 2014)

Abbildung 1 aLiFE Modell zur Verhaltensänderung

3 Fragestellungen

Vor dem Hintergrund der in den vorherigen Kapiteln aufgezeigten Forschungslücken ist das übergeordnete Ziel der vorliegenden Dissertation die Entwicklung und Evaluation eines neuen alltagsintegrierten Trainingskonzepts für junge Ältere. Dabei liegt der Fokus auf der gezielten Integration spezifischer funktioneller Kraft- und Gleichgewichtsübungen in den Alltag junger Älterer. Die Entwicklung des neuen alltagsintegrierten Trainingskonzepts erfordert einerseits die Identifikation beziehungsweise Entwicklung/Evaluation geeigneter Messinstrumente, welche die Heterogenität in der körperlichen Leistungsfähigkeit der jungen Älteren im Alter von 60-70 Jahren adäquat abbilden können. Andererseits schließt dies die inhaltliche Ausarbeitung des Trainings ein, das heißt die Entwicklung und Evaluation des neu erarbeiten Konzepts und dessen spezifischer Eignung für die Zielgruppe der jungen Älteren (Abbildung 2).

In einem ersten Schritt ging es um die Identifikation geeigneter Messinstrumente für die spezifische Zielgruppe der 60-70-Jährigen. Dies war insofern von Bedeutung, da nur basierend auf einer adäquaten Erfassung der individuellen Leistungsfähigkeit die Entwicklung individualisierter, präventiver Maßnahmen möglich ist. Hierzu wurde eine systematische Literaturanalyse durchgeführt, welche Informationen über die bisher eingesetzten Messinstrumente einerseits und deren Eignung andererseits (Messparameter wie Validität, Reliabilität, Veränderungssensitivität) in dieser Zielgruppe lieferte (Manuskript 1). Im Rahmen dieses Vorgehens wurde folgenden Fragestellungen nachgegangen:

- *Gibt es geeignete Tests für die Zielgruppe der jungen älteren Menschen im Alter von 60-70 Jahren, die die funktionelle Leistungsfähigkeit differenziert genug abbilden, um ein Training individuell zuschneiden zu können?*
- *Wenn ja, welche Tests sind verfügbar und eignen sich für die Implementierung in dieser Zielgruppe?*

Vor diesem Hintergrund erfolgte in einem zweiten Schritt die Überprüfung der Eignung einer anspruchsvolleren Gleichgewichts- und Mobilitätsskala für die spezifische Zielgruppe der jungen Älteren (60-70 Jahre) (Manuskript 2). Im Rahmen dieses Vorgehens wurde folgender Fragestellung nachgegangen:

- *Ist die Community Balance & Mobility (CBM) Skala ein ausreichend anspruchsvolles Messinstrument zur Identifikation leichter Gleichgewichts- und Mobilitätseinschränkungen bei jungen älteren Menschen (60-70 Jahre)?*

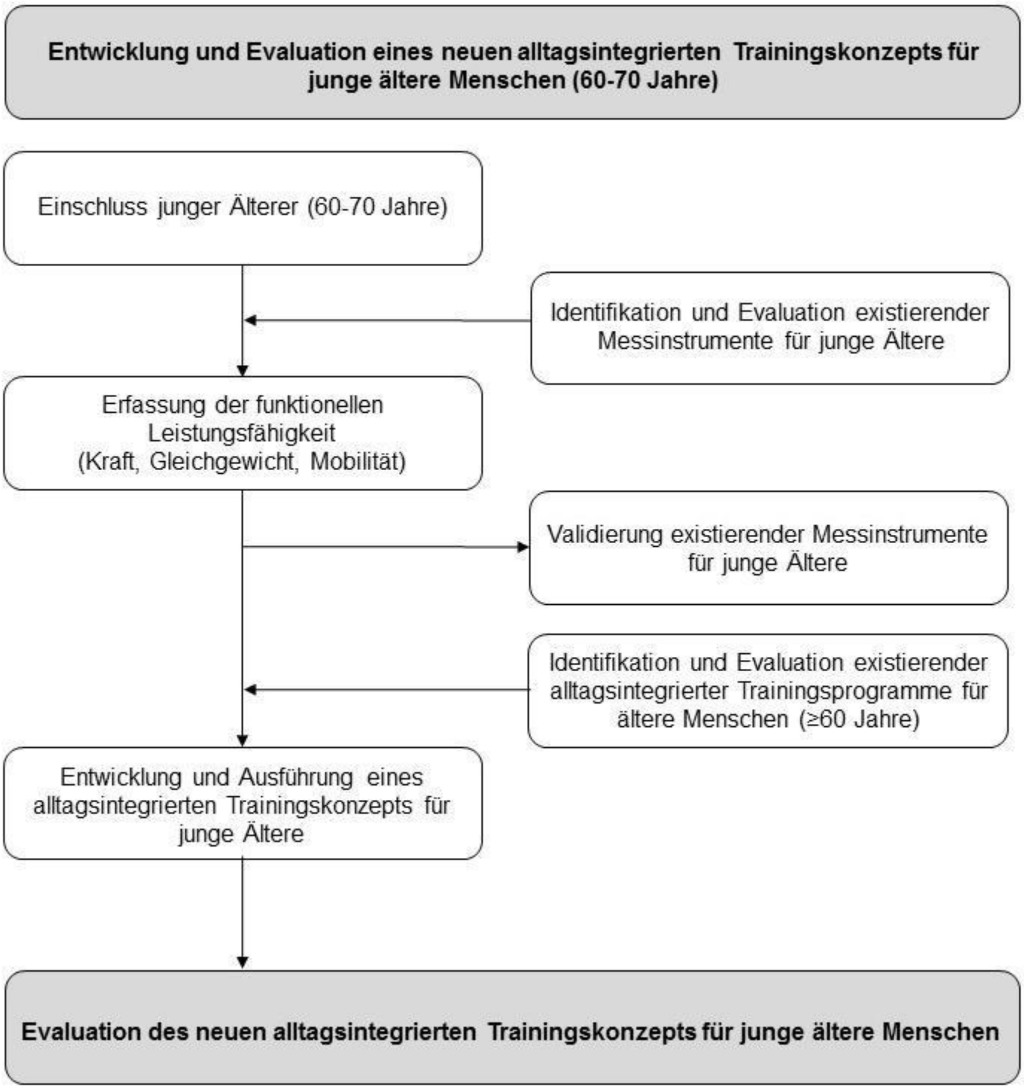
In einem dritten Schritt ging es um die Entwicklung und Evaluation eines neuen alltagsintegrierten Trainingsprogramms, welches funktionelle Übungen gezielt mit alltäglichen Aufgaben verknüpft. Hierfür erfolgte zunächst eine systematische Literaturanalyse zur Identifikation bisher veröffentlichter Studien, welche ein funktionelles, alltagsintegriertes Training angewandt haben (Manuskript 3). Dabei wurde folgender Fragestellungen nachgegangen:

- *Wie ist die derzeitige Evidenz zu Trainingsprogrammen, welche funktionell ausgerichtet und in den Alltag implementiert durchgeführt werden?*
- *Welche Zielgruppen wurden bisher untersucht (u.a. Alter, funktioneller Status)?*
- *Welche Befunde liegen vor, sowohl bezüglich der Durchführbarkeit als auch der Effektivität?*

Darauf aufbauend wird in einem vierten Schritt die Entwicklung und Evaluation eines neuen alltagsintegrierten, auf funktionelle Übungen ausgerichteten, Trainingskonzepts. Zentral hierbei ist die Testung der Durchführbarkeit eines an junge Ältere (60-70 Jahre) angepassten LiFE (aLiFE)-Programms, welche mittels Interviews und Fokusgruppen, sowohl mit Teilnehmenden als auch Trainer/innen, analysiert wird. Dabei sollen folgende Fragen beantwortet werden:

- *Welche motivationalen Strategien unterstützen die Integration von regelmäßigem und langfristigem körperlichen Training in den Alltag?*
- *Welche Aspekte gilt es im Kontext der Gewohnheitsbildung zu berücksichtigen, um körperliches Training regelmäßig und langfristig in den Alltag junger älterer Menschen zu integrieren?*
- *Werden durch die Intervention die Gewohnheiten beeinflusst? Wird der Alltag entsprechend der alltagsintegrierten Übungen adaptiert?*

Nachdem im folgenden Kapitel zusammenfassend die Rahmenbedingungen der vorliegenden Dissertation vorgestellt werden (Kapitel 4), werden die Zusammenfassungen der einzelnen Manuskripte in den Folgekapiteln dargestellt. Dabei liegt der Fokus zum einen auf der Ermittlung geeigneter Messinstrumente für die spezifische Zielgruppe der jungen Älteren (Kapitel 5), zum anderen auf der Entwicklung und Evaluation des Trainingsprogramms in dieser Zielgruppe (Kapitel 6). Die Originalmanuskripte befinden sich im Anhang dieser Dissertation (Kap. 14).



(Quelle: Eigene Darstellung)

Abbildung 2 Methodische Vorgehensweise zur Entwicklung und Evaluation eines neuen alltagsintegrierten Trainingskonzepts.

4 Methodik

Die vorliegende Dissertation ist eingebettet in das von der Europäischen Union geförderte Drittmittelprojekt PreventIT. Als Reaktion auf den demografischen Wandel und den steigenden Bedarf an präventiven Konzepten verfolgt PreventIT das übergeordnete Ziel, ein durch Informations- und Kommunikationstechnik (IKT) gestütztes mobiles Gesundheitssystem (sogenanntes *mHealth* System) zu entwickeln, welches frühzeitig altersbedingte funktionelle Einschränkungen identifizieren und eine Verhaltensänderung hin zu einem aktiv(er)en Lebensstil bewirken soll. Unter Einsatz von Smartphone und -watch soll das entwickelte Trainingsprogramm final zur kommerziellen Nutzung für ältere Menschen zur Verfügung stehen, wobei der Fokus spezifisch auf der Zielgruppe der jungen Älteren im Alter von 60-70 Jahren liegt.

Hierfür wird in Zusammenarbeit mit nationalen und internationalen Kooperationspartner/innen (unter anderem aus Norwegen, Niederlande, England, Italien, Australien) das LiFE-Programm (siehe Kapitel 3.5) weiterentwickelt (sogenanntes angepasstes LiFE-Programm, kurz aLiFE). Dabei soll explizit eine neue Zielgruppe (60-70-Jährige) angesprochen werden, um frühzeitig den funktionellen Einschränkungen im Alter entgegenzuwirken. Entsprechend ist nicht nur eine Weiterentwicklung der Übungen des LiFE-Programms notwendig (unter anderem Erhöhung des Schweregrads, Einführung neuer Übungen, siehe Tabelle 1), auch die Strategien zur Verhaltensänderung müssen adaptiert werden, da bei jungen Älteren ganz andere Lebensbedingungen als auch Motive zum Tragen kommen als es bei älteren Menschen der Fall ist (siehe Kapitel 3.1).

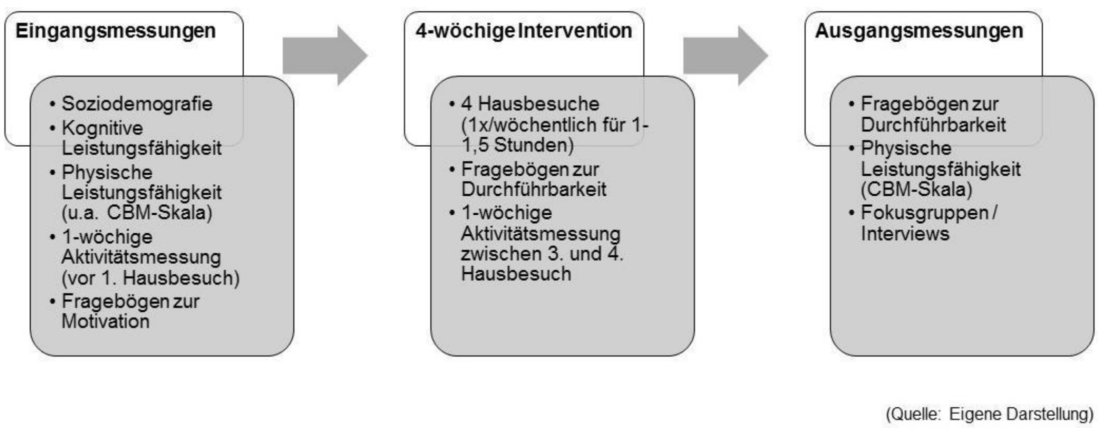


Abbildung 3 Ablauf der 4-wöchigen aLiFE Pilotstudie

Die vorliegende Dissertation ordnet sich in die anfängliche Entwicklungsphase innerhalb des PreventIT-Projekts ein, das heißt, die initiale Entwicklung, Pilotierung und Evaluation des neuen aLiFE-Programms. Das entwickelte aLiFE-Programm wurde im Rahmen einer multizentrischen Pilotstudie über einen vierwöchigen Zeitraum an drei europäischen Standorten (Robert-Bosch Krankenhaus Stuttgart, Technisch-Naturwissenschaftliche Universität Trondheim, Freie Universität Amsterdam) getestet. Die Pilotstudie ermöglichte die Überprüfung der Durchführbarkeit und Akzeptanz des aLiFE-Programms in dieser spezifischen Zielgruppe (Abbildung 3). Darüber hinaus wurden im Rahmen der Entwicklungsphase des aLiFE-Programms verschiedene Messinstrumente zur Ermittlung der funktionellen Leistungsfähigkeit (Kraft, Gleichgewicht, Mobilität) auf dessen Eignung für junge Ältere hin überprüft.

Tabelle 1 Vergleich LiFE und aLiFE - Prinzipien und Übungen

	Prinzip	**Übung**	
		LiFE	**aLiFE**
Gleichgewicht	Die Unterstützungsfläche verkleinern	Tandemstand Tandemgang Einbeinstand	Tandemstand Tandemgang Einbeinstand
	Das Gewicht verlagern und sich bis an die Grenzen der Stabilität bewegen	Gleichgewichtsverlagerung nach vorne, hinten und seitlich	Gleichgewichtsverlagerung nach vorne, hinten und seitlich
	Über Gegenstände steigen	Über Gegenstände steigen	Über Gegenstände steigen
	Gehen, hüpfen und springen in unterschiedlichen Mustern (Geschicklichkeit)		Schritte machen und die Richtung ändern Gehen, hüpfen und springen in unterschiedlichen Mustern
Kraft	Knie beugen	Kniebeuge	Kniebeuge, Ausfallschritt
	Aufstehen	Aufstehen vom Stuhl	Aufstehen vom Stuhl
	Auf die Zehenspitzen	Auf den Zehenspitzen – stehen und gehen	Auf den Zehenspitzen – stehen und gehen
	Auf die Fersen	Auf den Fersen – stehen und gehen	Auf den Fersen – stehen und gehen
	Treppensteigen	Treppensteigen	Treppensteigen
	Beine seitwärts bewegen	Beine seitwärts bewegen	Beine seitwärts bewegen
	Muskeln anspannen	Muskeln anspannen	Muskeln anspannen
Körperliche Aktivität	Mehr bewegen		Längeres gehen Schneller gehen
	Zeit im Sitzen reduzieren		Weniger sitzen Sitzphasen unterbrechen

Quelle: Eigene Darstellung; LiFE-Prinzipien und –Üungen übersetzt in Anlehnung an Clemson et al., 2014

5 Messverfahren zur Identifikation von Risikofaktoren junger älterer Menschen

5.1 Systematische Literaturanalyse randomisiert-kontrollierter Studien zu Testungen der körperlichen Leistungsfähigkeit (Manuskript 1)

Bergquist R*, Weber M*, Schwenk M, Ulseth S, Helbostad JL, Vereijken B, Taraldsen K. Performance-based clinical tests of balance and muscle strength used in young seniors: A systematic literature review (*submitted*).

*geteilte Erstautor/innenschaft

Hintergrund und Zielsetzung: Messinstrumente zur Erfassung der körperlichen Leistungsfähigkeit gelten weltweit als wichtige Indikatoren für die Lebensqualität und das allgemeine Wohlbefinden älterer Menschen. Darüber hinaus ermöglichen diese sowohl die Erfassung als auch Beobachtung des Gesundheitsstatus über einen längeren Zeitraum hinweg und dienen der Vorhersage gesundheitlicher Risikofaktoren wie Multimorbidität, Einschränkungen in Tätigkeiten des alltäglichen Lebens, Krankenhausaufenthalte und frühzeitige Sterblichkeit. Das Ziel von Manuskript 1 ist, Messinstrumente zu identifizieren, welche bisher in gesunden jungen Älteren (60-70 Jahre) angewandt wurden und zu prüfen, inwiefern deren Qualität bezogen auf die Messeigenschaften für die Anwendung in dieser Zielgruppe spricht.

Methodik: Die wissenschaftliche Datenbank MEDLINE wurde zur Identifikation von Messinstrumenten zur Erfassung von Gleichgewicht und/oder Kraft, welche auch ohne laborspezifisches Equipment in der Zielgruppe der 60-70-Jährigen durchgeführt werden können, genutzt. Tests, die in mehr als drei Artikeln angewandt wurden, wurden in eine zweite Literaturrecherche in MEDLINE und Embase eingeschlossen, um relevante methodische Studien, welche die Messeigenschaften dieser Tests erfasst haben, zu identifizieren. Die methodische Qualität wurde mittels der COSMIN-Checkliste (Mokkink et al., 2010) beurteilt.

Wesentliche Ergebnisse: Insgesamt wurden 2354 Treffer nach Ausschluss von Duplikaten identifiziert und letztendlich 195 Artikel eingeschlossen. Neunundfünfzig Gleichgewichts- und 40 Krafttests wurden identifiziert, mit Variationen in Durchführung des Tests und der Bewertung. Einundzwanzig Gleichgewichts- und 11 Krafttests wurden in mehr als drei Artikeln angewandt, wobei proaktive Gleichgewichts- und Muskelausdauertests die am häufigsten angewandten Tests waren. Von den 1452 identifizierten methodischen Studien haben lediglich drei die Kriterien für eine qualitative Beurteilung erfüllt. Dabei hat eine Studie die Validität und Reliabilität der SPPB erfasst, welche gemäß COSMIN-Checkliste als „mittelmäßig" beziehungsweise „gut" bewertet wurden. Zwei Studien haben die Reliabilität des TUG Tests analysiert, mit „schlechter" Qualität gemäß COSMIN-Chekliste, sowohl für die Test-Retest- als auch Inter-Rater-Reliabilität.

Diskussion: Den am häufigsten angewandten Messinstrumenten zur Erfassung von Kraft und Gleichgewicht mangelt es sowohl an standardisierten Anweisungen zur Durchführung als auch an einer Bewertung der Ergebnisse. Die drei methodischen Studien verweisen auf den Bedarf an Studien, welche die Messeigenschaften existierender Tests in jungen Älteren überprüfen und auf die Dringlichkeit der Entwicklung anspruchsvoller Tests, welche sich als valide und reliabel in jungen Älteren erweisen. Dieses ist ausschlaggebend, um die körperliche Leistungsfähigkeit junger Älterer adäquat zu erfassen, um frühe Interventionsmaßnahmen einleiten zu können.

5.2 Messeigenschaften der Community Balance & Mobility (CBM) Skala (Manuskript 2)

Weber M, van Ancum J, Bergquist R, Taraldsen K, Gordt K, Mikolaizak AS, Nerz C, Pijnappels M, Jonkman NH, Maier AB, Helbostad JL, Vereijken B, Becker C, Schwenk M (2018). Concurrent validity and reliability of the Community Balance and Mobility scale in young-older adults (*BMC Geriatrics*, 64: 172-187).

Hintergrund und Zielsetzung: Bestehende Studien zeigen, dass eine Vielzahl an Messverfahren zur Bestimmung von Gleichgewicht und Mobilität im Alter existieren. Allerdings erfordert die steigende Zahl junger älterer Menschen (60-70 Jahre) die Entwicklung geeigneter Messinstrumente zur Erfassung von Gleichgewicht und Mobilität in dieser Zielgruppe, da vorherrschende Tests aufgrund von Deckeneffekten in dieser Zielgruppe keine adäquaten Ergebnisse liefern. Anspruchsvollere Tests hingegen ermöglichen eine präzisere Erfassung des Gleichgewichts und der Mobilität bei jungen Älteren und erleichtern somit eine frühzeitige Einleitung präventiver Maßnahmen zur Verhinderung funktioneller Defizite. In Manuskript 2 wurden daher die Messeigenschaften der Community Balance & Mobility (CBM) Skala, eine anspruchsvolle Skala zur Ermittlung von Gleichgewicht und Mobilität, bei jungen Älteren (60-70 Jahre) analysiert.

Methode: An 51 Personen im Alter von durchschnittlich 66,4 Jahren (± 2,7 Jahre) wurde das Gleichgewicht und die Mobilität mittels der CBM Skala getestet. Die Fullerton Advanced Balance (FAB) Skala, 3-Meter Tandem Walk (3MTW), 8-stufige Gleichgewichtsskala, Timed-Up-and-Go (TUG) und der 7-Meter Gehtest wurden zur Bestimmung der Übereinstimmungsvalidität (Spearmans Rangkorrelationskoeffizient, ρ) eingesetzt. Inter- und Intrarater-Reliabilität wurden mittels „Intraclass Correlation Coefficients“ (ICC) bestimmt, die interne Konsistenz der CBM Skala wurde mithilfe von Cronbachs Alpha (α) und der Item-Skala Korrelationen (Spearmans Rangkorrelationskoeffizient, ρ) ermittelt. Deckeneffekte lagen vor, wenn Personen die höchstmögliche Punktezahl in dem entsprechenden Test erreicht haben.

Wesentliche Ergebnisse: Die CBM Skala korrelierte mit der FAB Skala ($\rho = 0.75$; $p < .001$), 3MTW-Fehler ($\rho = -0.61$; $p < .001$), 3MTW-Zeit ($\rho = -0.35$; $p = .05$), der 8-stufigen Gleichgewichtsskala ($\rho = 0.35$; $p < .05$), TUG ($\rho = -0.42$; $p < .01$) und dem 7-Meter Gehtest ($\rho = 0.46$, $p < .001$). Die Inter- ($ICC_{2,k} = 0.97$) und Intrarater-Reliabilität ($ICC_{3,k} = 1.00$) der CBM Skala waren exzellent, die interne Konsistenz gut bis zufriedenstellend ($\alpha = 0.88$; $\rho = 0.28 – 0.81$). Im Gegensatz zu der FAB und der 8-stufigen Gleichgewichtsskala zeigte die CBM Skala keine Deckeneffekte.

Diskussion: Die Übereinstimmungsvalidität der CBM Skala erwies sich bei jungen Älteren als gut (FAB) beziehungsweise moderat bis gut (andere Vergleichstests). Die Skala empfiehlt sich damit zur Ermittlung von Gleichgewichts- und Mobilitätsdefiziten in dieser spezifischen Zielgruppe. Dies ist insbesondere vor dem Hintergrund der Aufdeckung frühzeitiger altersbedingter Gleichgewichts- und Mobilitätsdefizite relevant, welche möglicherweise durch bereits bestehende Messinstrumente verdeckt werden.

6 Entwicklung und Evaluation eines neuen Trainingskonzepts für ältere Menschen

6.1 Systematische Literaturanalyse bestehender Studien zu alltagsintegriertem funktionellen Training (Manuskript 3)

Weber M, Belala N, Boulton E, Hawley-Hague H, Becker C, Schwenk M (2017). Feasibility and effectiveness of intervention programmes integrating functional exercise into daily life of older adults: a systematic review. *(Gerontology,* DOI: 10.1159/000479965*).*

Hintergrund und Zielsetzung: Aktuelle Studien zeigen, dass nur ein geringer Teil der älteren Bevölkerung (≥65 Jahre) regelmäßig gezieltes Kraft- und Gleichgewichtstraining (8-15% beziehungsweise 6%) ausübt. Die Integration von Bewegung und Training in den Alltag ist ein relativ neuer Ansatz, bei dem Übungen zur Verbesserung von Kraft und Gleichgewicht beispielsweise bei täglichen Hausarbeiten durchgeführt werden sollen. Ziel dieses neuen Trainingsansatzes ist es, eine nachhaltige und überdauernde Trainingsroutine aufzubauen, als Alternative oder Ergänzung zu gezieltem, strukturiertem Training, welches zum Beispiel im Sportverein oder Fitnessstudio durchgeführt wird. Die bestehenden alltagsintegrierten Trainingsprogramme wurden bislang keiner systematischen Effektivitätsanalyse im Rahmen einer Übersichtsarbeit unterzogen. In Manuskript 3 werden daher die bislang veröffentlichten Studien zu alltagsintegrierten funktionellen Trainingsansätzen analysiert. Darauf aufbauend wird ein neues, alltagsintegriertes Trainingskonzept entwickelt.

Methodik: Ausgewählte wissenschaftliche Datenbanken (PubMed, CINAHL, Cochrane Library, Web of Science, PsycINFO, Embase, GeroLit) wurden überprüft und 4415 Treffer nach Ausschluss von Duplikaten identifiziert. Einschlusskriterien waren (1) Studienpopulation (≥60 Jahre), (2) randomisiert-kontrollierte Studien (RCT) und nicht-randomisierten Studien (NRS, beispielsweise kontrollierte Vorher-Nachher Studien), (3) lebensstil-integriertes Trainingskonzept, (4) funktionelles Training mit Fokus auf Kraft, Gleichgewicht oder körperliche Funktionalität und (5) Analyse der Durchführbarkeit und/oder Effektivität des Trainingsprogramms. Das methodische Vorgehen basiert auf den PRISMA-Richtlinien (Moher, Liberati, Tetzlaff, & Altman, 2009). Die RCTs wurden mithilfe der Skala der Physiotherapie Evidenz Datenbank (PEDro) (Hariohm, Prakash, & Saravankumar, 2015) auf ihre Qualität hin bewertet, um die Qualität und Nützlichkeit der Studien sowie ihre Relevanz für die Weiterentwicklung des Trainingskonzepts einschätzen zu können.

Wesentliche Ergebnisse: Die systematische Literaturanalyse in Manuskript 3 zeigt, dass das „Lifestyle-integrated Functional Exercise“ (LiFE) Programm bislang das am besten evaluierte integrierte Trainingsprogramm ist. Dieses Programm erweist sich als effektiver zur Verbesserung von Gleichgewicht, Kraft und funktionelle Leistung verglichen zu strukturiertem Training. Zudem weisen einzelne Studien darauf hin, dass LiFE effektiver bei Sturzprävention ist als herkömmliche strukturierte Programme. Eine Reihe von Interventionsstudien kombiniert integriertes und strukturiertes Training, vorwiegend im institutionellen Bereich wie zum Beispiel Pflegeheimen. In diesen Studien konnten ebenfalls positive Effekte auf das Gleichgewicht und die funktionelle Leistung gezeigt werden, jedoch nicht auf Kraft oder Stürze. In Bezug auf die Nachhaltigkeit alltagsintegrierter Übungen erweisen sich sowohl LiFE als auch kombinierte Bewegungsprogramme als effektivere Ansätze für ein andauerndes, nachhaltiges Training im Vergleich zu strukturiertem Training. Dies beruht vor allem auf einer Verhaltensänderung, welche im Laufe der Zeit durch die gezielte Verknüpfung von Alltagsaktivitäten mit funktionellen Übungen eintritt. So kann zum Beispiel eine effektive Gleichgewichtsübung wie der Einbeinstand regelmäßig beim Zähne putzen durchgeführt werden oder eine regelmäßige Anzahl von Kniebeugen erreicht werden, wenn man diese jedes Mal durchführt, um etwas vom Boden aufzuheben.

Diskussion: Manuskript 3 zeigt, dass die Integration von Bewegung und Training in den Alltag ein vielversprechender Ansatz zur Verbesserung der motorischen Leistungsfähigkeit älterer Menschen ist. Gleichzeitig zeigen die Studien methodische Limitierungen auf, wie zum Beispiel eine zu geringe Stichprobengröße. Umfassend angelegte Studien sowohl zur Durchführbarkeit als auch Effektivität des alltagsintegrierten Trainings in verschiedenen Zielgruppen sind daher notwendig. Betrachtet werden müssen sowohl die Effekte auf spezifische motorische Parameter und Stürze als auch auf psychologische Parameter zur Bestimmung einer langfristigen Verhaltensänderung. Auf Basis dieser systematischen Literaturanalyse wurde ein neues Trainingskonzept entwickelt, welches auf dem LiFE-Programm basiert. Dabei liegt der Fokus vor allem auf der Anpassung an eine jüngere Zielgruppe (60-70 Jahre), welcher auf die Prävention funktioneller Defizite und Aufrechterhaltung beziehungsweise Steigerung der körperlichen Aktivität abzielt.

6.2 Überprüfung der Durchführbarkeit eines angepassten LiFE (aLiFE) Programms bei jungen älteren Menschen (Manuskript 4)

Boulton E, Weber M, Hawley-Hague H, Bergquist R, Van Ancum J, Jonkman N, Taraldsen K, Helbostad J, Maier A, Becker C, Todd C, Schwenk M. Proof of concept of an adapted LiFE (aLiFE) programme specifically developed for young-older adults: perceptions of participants and trainers *(submitted)*.

Hintergrund und Zielsetzung: Zeitliche Verpflichtungen, bedingte Erreichbarkeit oder die fehlende Bereitschaft, einer Sportgruppe beizutreten, sind mitunter Gründe für die geringe Teilnahme älterer Menschen an strukturieren Trainingsprogrammen. Eine vielversprechende Alternative, die in den letzten Jahren an Bedeutung gewonnen hat, ist die Integration von Übungen in den Alltag. Diese Studie untersucht die Durchführbarkeit eines angepassten Lifestyle-integrated Functional Exercise (aLiFE) Programms bei jungen älteren Menschen im Alter von 60-70 Jahren.

Methodik: Die Durchführbarkeit wurde mittels Interviews und Fokusgruppen, sowohl mit den Teilnehmenden als auch Trainer/innen nach Abschluss einer 4-wöchigen Pre-Post-Studie untersucht. Für die Datenanalyse wurde der Framework-Ansatz angewandt (Spencer & Ritchie, 2002). Kodierungen erfolgten mittels NVivo11, welche anschließend in übergreifende Themen zusammengefasst wurden.

Wesentliche Ergebnisse: Einunddreißig Personen im Alter von 66.4 ± 2.7 Jahren (60% Frauen) und fünf Trainer/innen haben an der Studie teilgenommen. Die Teilnehmenden und Trainer/innen beurteilten das Programm positiv. Die individuelle Anpassung, der präventive Ansatz und die Unterstützung durch die Trainer/innen wurden von den Teilnehmenden gut aufgenommen. Die Trainer/innen schätzten den flexiblen Ansatz und die Unterstützung untereinander. Dennoch bemängelten sowohl Teilnehmende als auch Trainer/innen die umfangreiche Papierarbeit und berichteten von der Herausforderung der Integration einzelner Übungen in tägliche Routinen aufgrund eines geschäftigen und abwechslungsreichen Alltags.

Diskussion: Insgesamt zeigte sich eine hohe Akzeptanz des aLiFE-Programms bei 60-70-Jährigen. Die Trainer/innen waren besonders für die Motivation und Unterstützung der Teilnehmenden von Bedeutung. Die Teilnehmenden berichteten von einer Verinnerlichung einzelner Übungen innerhalb des kurzen Interventionszeitraumes, auch ohne kontinuierliche Selbstkontrolle. Die Durchführbarkeit und Effektivität dieses Ansatzes sollte nun in einer randomisiert-kontrollierten Studie getestet werden.

7 Einordnung der Ergebnisse in den Forschungsstand

Die vorliegenden Studienergebnisse belegen die Eignung des aLiFE Programms in der Zielgruppe junger Älterer (60-70 Jahre) (siehe Kapitel 7.2). Wie die systematische Literaturanalyse (Manuskript 3; Kapitel 7.1) zeigt, gibt es für junge Ältere bisher vor allem Programme, welche strukturiertes Training und alltagsintegrierte Übungen kombinieren, wobei sich diese primär auf das strukturierte Training fokussieren (Opdenacker, Boen, Coorevits, & Delecluse, 2008; Opdenacker, Delecluse, & Boen, 2009, 2011). Entgegen dieses Ansatzes und zahlreicher anderer strukturierter Programme, welchen es an Adhärenz und Nachhaltigkeit mangelt (vgl. Kapitel 3.4), ist aLiFE das erste, vollständig in den Alltag integrierte funktionelle Trainingsprogramm. Es lässt sich erfolgreich für die Zielgruppe der jungen Älteren adaptieren, mit dem Ziel der Prävention funktioneller Defizite. Sowohl die Teilnehmenden als auch Trainer/innen berichteten positiv von dem Programm, einhergehend mit einer hohen Akzeptanz. Insbesondere der flexible Ansatz und die Möglichkeit, die Kraft- und Gleichgewichtsübungen individuell anpassen zu können, wurden hervorgehoben und stellten im Gegensatz zu bereits existierenden strukturierten Ansätzen bedeutsame Neuerungen dar. Dies ist besonders vor dem Hintergrund der Heterogenität dieser Altersgruppe positiv zu bewerten (siehe Kapitel 2).

Wichtig für diese Individualisierung sind adäquate Messinstrumente, welche die körperliche Leistungsfähigkeit dieser spezifischen Zielgruppe adäquat abbilden können (vgl. Kapitel 3.3). Dies wird auch durch die systematische Literaturanalyse deutlich (Manuskript 1). So mangelt es vor allem an anspruchsvollen, provokativen Gleichgewichts- und Mobilitätstests für junge Ältere (vgl. Kapitel 3.3; Kapitel 6.1). Entgegen der unzureichenden Aussagekraft bisher angewandter Tests wie dem TUG und die BBS für junge Ältere (Barry et al., 2014; Langley & Mackintosh, 2007; Mancini & Horak, 2010; Pardasaney et al., 2012; Power et al., 2014; Schoene et al., 2013), verweisen die vorliegenden Studienergebnisse auf die CBM als ausreichend anspruchsvolles Messinstrument, welches sowohl das Gleichgewicht als auch die Mobilität in dieser Zielgruppe adäquat abbilden kann (Manuskript 2). Dadurch kann ein Trainingsprogramm wie aLiFE bestmöglich auf die jeweils identifizierten Defizite angepasst werden.

Die komplexen Aufgaben, welche über einfaches Stehen, Gehen und Drehen wie es beispielsweise bei dem TUG-Test der Fall ist (Viccaro et al., 2011), hinausgehen, ermöglichen die Erfassung bereits kleinster, subklinischer Defizite. Dadurch können Hochrisikogruppen besser identifiziert und folglich adressiert werden. So erfahren vor allem die weniger aktiven, jungen Älteren, die viel Zeit im Sitzen verbringen, den größten Nutzen von aLiFE, resultierend in einer Kompression der Morbidität (Fries, 1980) (vgl. Kapitel 3.4).

Das bestätigt sich auch durch die Teilnehmenden, welche bereits in dem 4-wöchigen Interventionszeitraum Verbesserungen ihrer funktionellen Leistungsfähigkeit wahrnehmen und diese auch als wichtige Motivation für eine überdauernde Teilnahme ansehen. Eine kontinuierliche Teilnahme ist besonders vor dem Hintergrund der Nachhaltigkeit eines Programms wichtig, wird jedoch in bisherigen Programmen kritisiert und unzureichend adressiert (Hawley-Hague et al., 2014). Die vorliegenden Studienergebnisse hingegen deuten auf die Wirksamkeit von aLiFE, auch im Kontext einer nachhaltigen Verhaltensänderung hin. Wenngleich der Interventionszeitraum kurz war, scheint das spezifisch auf die jungen Älteren zugeschnittene Modell zur Verhaltensänderung die Internalisierung der Übungen und automatisierte Ausübung während alltäglicher Aktivitäten zu fördern. So berichten vereinzelte Teilnehmende, dass eine kontinuierliche Wiederholung spezifische Übungen, vor allem bei festen Routinen wie Zähneputzen oder bei der Küchenarbeit, zu einer Internalisierung geführt hat (unter anderem Einbeinstand beim Zähneputzen).

Neben den zentralen Motivatoren zur Aufnahme als auch Aufrechterhaltung körperlicher Aktivität (Vitalität, Aktivität, Funktionalität) (Hartmann-Tews, 2010), welche sich auch in den Aussagen der Teilnehmenden wiederspiegeln, trägt vor allem die soziale Komponente zentral zu dem Erfolg von aLiFE bei. Die Zusammenarbeit mit dem/der Trainer/in, einerseits bezogen auf die Planung und Anleitung der Übungen, andererseits der Spaß, der Austausch und die Wertschätzung motivieren zusätzlich. So gelingt es, „fachlich-spielerisch" bedeutsame funktionelle, auf die altersbedingten Defizite zugeschnittene, Übungen in den Alltag zu integrieren und somit einen wesentlichen Beitrag zur Reduktion des Risikos für funktionelle Einschränkungen und frühzeitigem Tod beizutragen (Rillamas-Sun et al., 2017). Weiterhin gelingt es mit den Übungen, die Abwärtsspirale von negativen Konsequenzen (unter anderem Multimorbidität, Stürze, Einschränkungen in den Aktivitäten des alltäglichen Lebens, Krankenhausaufenthalte, Pflegebedürftigkeit, frühere Sterblichkeit) (Cooper et al., 2014; Era et al., 2002; Gillespie et al., 2012; Justice et al., 2016; Perera et al., 2015; Sherrington et al., 2016; Sherrington et al., 2011; Studenski et al., 2011) bezogen auf das Wechselspiel von Kraft-, Gleichgewichts- und Mobilitätsdefiziten zu durchbrechen (vgl. Kapitel 3.4). Somit weist aLiFE nicht nur auf individueller, sondern auch auf gesellschaftlicher Ebene einen bedeutsamen Nutzen auf. Entsprechend wurde der Fokus auch gezielt auf 60-70-Jährige gelegt, da diese Dekade von einem beschleunigten Abbau des Gleichgewichts und der Kraft betroffen ist und die Übungen gezielt die defizitären Systeme wie Visus (Übungen mit geschlossenen Augen durchführen) (Ekdahl et al., 1989; Era et al., 2006; Hytönen et al., 1993; Teixeira et al., 2014), Propriozeption (beispielsweise Einbeinstand) (Ekdahl et al., 1989; Goble et al., 2009; Teixeira et al., 2014), das Vestibulärorgan (beispielsweise Kopfdrehen) (Teixeira et al., 2014) als auch die Kraftausdauer (beispielsweise Ausfallschritte, Kniebeugen beim Zähneputzen, „Hopserlauf") anspricht (Justice et al., 2016).

Wenngleich die Bewertung des aLiFE Programms allgemein positiv ausgefallen ist, gibt es sowohl auf inhaltlicher als auch personenbezogener Ebene Aspekte, die es zukünftig noch zu adressieren gilt. Wie bereits auch in vorherigen Machbarkeits- und auch Effektivitätsstudien zu LiFE in verschiedenen Zielgruppen (E. Burton et al., 2013; E. Burton, Lewin, Clemson, et al., 2014; Keay et al., 2015), haben die Teilnehmenden auch in dieser Studie die, primär mit dem Verhaltensmodell in Verbindung stehende, Papierarbeit als zu umfassend und lästig empfunden. Kritisiert wurde auch die Länge des Manuals. Bezogen auf die Übungen selbst wurden Scham (unter anderem eine mögliche Bloßstellung bei Ausübung der Übungen im Freien), Schmerzen (nicht zwingend mit dem Programm in Verbindung stehend) und Unsicherheit bezüglich der korrekten Ausführung angemerkt. Letzteres könne laut Teilnehmenden durch eine intensivere Anleitung zur korrekten Ausführung verbessert werden und letztlich die Adhärenz weiter erhöhen. Zudem seien sowohl Übungen für die oberen Extremitäten als auch mehr Aufklärung bezüglich des Nutzens einzelner Übungen, welche mehrheitlich als nutzlos und/oder unnatürlich wahrgenommen wurden (beispielsweise der Fersengang) sinnvoll.

8 Schlussfolgerung und Ausblick

Die positiven Befunde der vorliegenden Dissertation zeigen, dass ein gezieltes, auf die jeweiligen individuellen Defizite zugeschnittenes Trainingsprogramm zu einer erhöhten körperlichen Aktivität im Alter(n) beitragen kann und somit nicht nur auf individueller, sondern auch auf gesellschaftlicher Ebene einen erheblichen Nutzen generiert. Insbesondere vor dem Hintergrund der demografischen Alterung stellt das aLiFE-Programm einen vielversprechenden Ansatz da, welcher nachhaltig das Gesundheitssystem revolutionieren könnte. Entsprechend ist das Ziel, die Effektivität des aLiFE-Ansatzes nun in einer 12-monatigen multizentrischen randomisiert-kontrollierten Studie an 180 Teilnehmenden zu testen. Aufgrund der hohen Reliabilität und Validität der CBM wird diese in der Folgestudie auch als zentraler Endpunkt zur Erfassung der Gleichgewichtsfähigkeit und Mobilität eingesetzt. So können einerseits Aussagen über die Effektivität von aLiFE auf diese Parameter getroffen werden, andererseits auch die CBM inhaltlich tiefergehend hinsichtlich ihrer Änderungssensitivität untersucht werden. Zudem wäre dadurch auch in einem nächsten Schritt die Entwicklung einer, gegebenenfalls anwendungsfreundlicheren, Kurzversion der CBM möglich.

Darüber hinaus ermöglicht ein 12-monatiger Zeitraum, präzisere Aussagen über die Nachhaltigkeit des aLiFE-Programms zu treffen. Dies gilt insbesondere vor dem Hintergrund, dass das bisher von keinem anderen, spezifisch für ältere Menschen entwickelten, Trainingsprogramm explizit adressiert wurde. Vor allem der flexible, gleichzeitig praktisch-pragmatische Ansatz des aLiFE Programms fördert eine nachhaltige Verhaltensänderung. Zentral hierbei ist es, eine aktive Verhältnis- und Verhaltensprävention zu fokussieren. Die Aktivitäten sollten hierbei in erster Linie von den Teilnehmenden selbstständig und eigenverantwortlich geplant und integriert werden (sogenanntes *Empowerment*), damit diese ihr Bewusstsein für einen gesunden und aktiven Lebensstil steigern und nachhaltig ändern.

Entgegen zahlreicher existierender Programme, welche primär nur einzelne, punktuelle Aufgaben fokussieren, fördern kontinuierliche Feedbackschleifen, sowohl durch die dokumentarische Arbeit (Selbstkontrolle) als auch durch die Trainer/innen, eine nachhaltige Verhaltensänderung hin zu einem aktiv(er)en Lebensstil (Behrens et al., 2018). Das verbessert nicht nur das allgemeine physische, sondern auch das psychische Wohlbefinden, es reduziert zudem nachhaltig negative Konsequenzen wie Multimorbidität, Pflegebedürftigkeit und frühere Sterblichkeit, resultierend in deutlich reduzierten Gesundheitsausgaben.

Ein weiterer wichtiger Aspekt ist die zunehmende Technologisierung in der heutigen Gesellschaft. So zeigen Studien speziell auch für ältere Menschen, dass technikbasierte Interventionsansätze zur Steigerung der körperlichen Aktivität zunehmen (Jonkman, van Schooten, Maier, & Pijnappels, 2018). Auch vor dem Hintergrund der geringen Teilnahmeraten älterer Menschen an Trainingsprogrammen wird in technikbasierten Programmen eine zukunftsweisende Alternative gesehen, welche sich positiv auf die wahrgenommen Barrieren älterer Menschen auswirken (Valenzuela, Okubo, Woodbury, Lord, & Delbaere, 2018). Diese Entwicklung wird auch im PreventIT Projekt erkannt und folglich in Form eines erweiterten LiFE (eLiFE)-Programms getestet. Die Durchführbarkeit und Effektivität von eLiFE wird hierbei im Rahmen einer 4-wöchigen Pilotstudie und sich daran anschließenden 12-monatigen randomisiert-kontrollierten Studie getestet. Hierfür wird das entwickelte aLiFE-Programm in eine technikbasierte Version transformiert und mittels Smartphone und –watch den Teilnehmenden vermittelt, wobei Trainer/innen unterstützend zur Seite stehen.

Ein langfristiges, vor allem praktisch relevantes Ziel könnte die generelle Implementierung des aLiFE-Programms in der älteren Bevölkerung sein. Insbesondere der steigende Bedarf an präventiven Ansätzen und flexiblen Modellen wird durch das aLiFE-Programm adressiert. So könnten beispielsweise in Sportvereinen oder Kommunen gezielt Personen als aLiFE Trainer/innen ausgebildet werden. Das würde dazu beitragen, die Verbreitung des vielversprechenden, präventiven und auf die demografische Alterung reagierenden Ansatzes zu gewährleisten. Gleichzeitig wäre in diesem Kontext die Überlegung, das Programm in einem Gruppenkonzept zu testen, beispielsweise in der Form, dass die Übungen wöchentlich in einem Gruppenformat mittels Trainer/innen-Team vermittelt und die Teilnehmenden dann dazu ermutigt werden, diese selbstständig in ihren Alltag zu integrieren. Das könnte, im Vergleich zum zeit- und kostenintensiven aLiFE-Programms, möglicherweise eine günstigere Alternative darstellen, da die individuellen Hausbesuche wegfallen und zusätzlich die soziale Komponente durch gemeinsames Einüben und Austausch gestärkt wird.

Gleichzeitig wäre die Vermarktung der eLiFE Applikation für Smartphones und –watches ein zukunftsweisender, auf die zunehmende Technologisierung reagierender, nächster Schritt. Das setzt jedoch voraus, dass sich das eLiFE Programm als geeignetes, auf hohe Akzeptanz stoßendes und effektives Programm erweist. Zudem bleibt die Frage der Nachhaltigkeit bei dieser Art der Aktivitätsförderung offen, da der persönliche Kontakt nach wie vor ein zentraler Motivator ist.

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10 Lebenslauf

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10/2013 – 09/2015	M.A. Studium an der Deutschen Sporthochschule Köln, Sport- und Bewegungsgerontologie
09/2010 – 05/2013	B.A. Studium an der Universität Mannheim, Soziologie mit Beifach BWL
06/2010	Allgemeine Hochschulreife, Viktoria-Luise Gymnasium in Hameln

Berufliche Erfahrungen

Seit 10/2017	Wissenschaftliche Hilfsfachkraft am Netzwerk AlternsfoRschung (NAR), Universität Heidelberg
04/2017 – 03/2018	Wissenschaftliche Hilfsfachkraft an der Evangelischen Hochschule Ludwigsburg (Projekt „Distance Caregiving“)
10/2015 – 12/2015	Wissenschaftliche Mitarbeiterin am Institut für Soziologie und Genderforschung, Abteilung Gender- & Diversity-Studies, Deutsche Sporthochschule Köln
10/2015 – 01/2016	Honorarkraft am BGF-Institut, Köln
10/2015 – 01/2016	Freiberufliche Fitnesstrainerin „Fit ab 65“ am Trainingsinstitut Prof. Dr. Baum, Köln

01/2014 – 09/2015	Wissenschaftliche Hilfsfachkraft am Institut für Soziologie und Genderforschung, Deutsche Sporthochschule Köln
02/2015 – 04/2015	Praktikum am BGF-Institut Köln, Köln
10/2014 – 03/2015	Lehrbeauftragte für das Fachtutorium Statistik & Methoden für Bachelorstudiengänge, Deutsche Sporthochschule Köln
08/2011 – 11/2012	Studentische Hilfskraft am Mannheimer Institut für Public Health, Sozial- und Präventivmedizin, Mannheim
04/2011 – 07/2011	Praktikum am Mannheimer Institut für Public Health, Sozial- und Präventivmedizin, Mannheim

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Sprachkenntnisse	Englisch – sehr gut Französisch – gut
Computerkenntnisse	MS Office & Open Office – sehr gut SPSS – sehr gut MAXQDA – sehr gut NVivo – sehr gut STATA – gut
Seminare	Lifestyle-integrated Functional Exercise-Trainerin Kraft- und Balancetraining bei Demenz Team- und Konfliktfähigkeit Work-Life-Balance Writing and publishing in English-Language journals for scholars in the humanities and social sciences Research Data Management Designing Research Posters

11 Weitere Publikationen und Kongressbeiträge

Publikationen

Gordt K, Mikolaizak AS, Nerz C, Barz C, Gerhardy T, **Weber M**, Becker C, Schwenk M (2018) German version of the Community Balance and Mobility Scale – Translation and evaluation of measurement properties. Z Gerontol Geriat, DOI: 10.1007/s00391-018-1374-z.

Schwenk, M, Bergquist, R, Boulton, E, Van Ancum, JM, Nerz, C, **Weber, M**, Barz, C, Jonkman, NH, Taraldsen, K, Helbostad, JL, Vereijken, B, Pijnappels, M, Maier, AB, Wei, Z, Becker, C,Todd, C, Clemson, L, Hawley-Hague, H (2018). Development and Proof-of-Concept of the Adapted Lifestyle-integrated Functional Exercise (aLiFE) Programme for Preventing Functional Decline in Young Seniors (Gerontologist; submitted).

Kongressbeiträge

Weber, M, Bergquist, R, Bouton, E, Van Ancum, J, Gordt, K, Nerz, C, Jonkman, NH, Taraldsen, K, Helbostad, JL, Vereijken, B, Hawley-Hague, H, Pijnappels, M, Maier AB, Mikolaizak, AS, Becker, C, Todd, C, Clemson, L, Schwenk, M (2018). Lifestyle-integrated Functional Exercise (LiFE) for Preventing Functional Decline in Young Older Adults: Conceptualisation, development, and initial testing of an intervention programme. 23nd annual Congress of the European College of Sport Science, 04.-07. Juli 2018, Dublin, Irland (Vortrag; nach Call for Papers).

Kramer B, Franke A, Otto U, Bischofberger I, Van Holten K, **Weber M** (2017). Distance Care (DiCa): Challenges and Potentials Beyond National Distances and International Boundaries. 1. Tagung des DGGG Arbeitskreises “Alter und Technik”, 17.-18.11.2017, Freiburg (Poster; nach Call for Papers).

Weber M, Van Ancum J, Bergquist R, Taraldsen K, Gordt K, Maier AB, Helbostad J, Becker C, Schwenk M (2017). Die Community Balance & Mobility Scale: Ein geeigneter Test zur Einschätzung von Gleichgewichts- und Mobilitätsdefiziten bei jungen Älteren? Jahrestagung der deutschen Gesellschaft für Geriatrie, 28.-30. September 2017, Frankfurt (Symposium; nach Call for Papers).

Weber M, Van Ancum J, Bergquist R, Taraldsen K, Maier AB, Helbostad JL, Gordt, K, Becker C, Schwenk M (2017). Measurement Properties of the Community Balance and Mobility Scale in Young-Older Adults. 21st IAGG World Congress of Gerontology and Geriatrics, 23.-27. Juli 2017, San Francisco, Kalifornien (Poster; nach Call for Papers).

Kramer B, Franke A, Otto U, Bischofberger I, Van Holten K, **Weber M**, Kunz H (2017). Distance Care (DiCa): Challenges and Potentials Beyond National Distances and International Boundaries. 21st IAGG World Congress of Gerontology and Geriatrics, 23.-27. Juli 2017, San Francisco, Kalifornien (Poster; nach Call for Papers).

Gordt K, **Weber M**, Van Ancum J, Bergquist R., Taraldsen K, Maier AB, Helbostad JL, Becker C, Schwenk M (2017). Measurement Properties of the Community Balance and Mobility Scale in Young-Older Adults. ISPGR World Congress, 25.-29. Juni 2017, Fort Lauderdale, Florida (Poster; nach Call for Papers).

Weber M, Schwenk M (2016). Alltagsintegriertes, funktionelles Training zur Verbesserung der motorischen Leistungsfähigkeit und Steigerung der körperlichen Aktivität im Alter: eine systematische Literaturrecherche. Gerontologie und Geriatrie Kongress, 7. bis 10. September, Stuttgart (Vortrag; nach Call for Papers).

Weber M, Oberle C, Barz C, Becker C, Schwenk M (2016). Entwicklung eines lebensstil-integrierten, körperlichen Bewegungsprogramms für junge Ältere: das EU-Projekt PreventIT. Bewegung, Raum und Gesundheit: dvs Tagung „Wechselwirkungen im Spannungsfeld geänderter Lebensbedingungen und Mobilitäten“, 22. bis 23. September, Karlsruhe (Vortrag; nach Call for Papers).

Diehl K, Bock C, **Schlüter M**, Greinert R, Breitbart EW, Schneider S (2012). Einschätzung des eigenen Hauttyps und Risiken der natürlichen und künstlichen Sonne: Bessere Kenntnis und höheres Risikobewusstsein bei Frauen. 7. Jahrestagung der DGEpi, 26. bis 29. September, Regensburg (Vortrag; nach Call for Papers).

Bock C, Diehl K, **Schlüter M**, Greinert R, Breitbart EW, Schneider S (2012). Solariennutzung in Deutschland – Aktuelle Ergebnisse einer bundesweiten epidemiologischen Studie zu Nutzungshäufigkeit, Motiven und determinierenden Faktoren. 57. Jahrestagung der GMDS, 16. bis 21 September, Braunschweig (Vortrag; nach Call for Papers).

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13 Erklärung gemäß § 8 Abs. (1) c) und d) der Promotionsordnung der Fakultät

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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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Declaration in accordance to § 8 (1) c) of the doctoral degree regulation of Heidelberg University, Faculty of Behavioural and Cultural Studies

Ich erkläre, dass ich die vorgelegte Dissertation selbstständig angefertigt, nur die angegebenen Hilfsmittel benutzt und die Zitate gekennzeichnet habe.
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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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14 Manuskripte zur Inauguraldissertation

Manuskript 1

Bergquist R*, Weber M*, Schwenk M, Ulseth S, Helbostad JL, Vereijken B, Taraldsen K. Performance-based clinical tests of balance and muscle strength used in young seniors: A systematic literature review (*re-submitted*).

*geteilte Erstautor/innenschaft

Performance-based clinical tests of balance and muscle strength used in young seniors: A systematic literature review

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Abstract

Background. Many balance and strength tests exist which have been designed for older seniors aged ≥70 years. To guide strategies for preventing functional decline, valid and reliable tests are needed to detect early signs of functional decline in young seniors. Currently, little is known about which tests are being used in young seniors, and their methodological quality. This two-step review aims to 1) identify commonly used tests of balance and strength, and 2) evaluate their measurement properties in young seniors.

Methods. First, a systematic literature search was conducted in MEDLINE to identify primary studies that employed performance-based tests of balance and muscle strength, and which aspects of balance and strength these tests assess in young seniors aged 60-70. Subsequently, for tests used in ≥3 studies, a second search was performed to identify method studies evaluating their measurement properties. The quality of included method studies was evaluated using the Consensus-based Standards for selection of health Measurement Instruments (COSMIN) checklist.

Results. Of 2354 articles identified, 195 met the inclusion criteria. For the first objective, fifty-nine balance and 40 muscle strength tests were identified, with variations in administration mode and outcome reporting. Twenty-one balance tests and 11 muscle strength tests were used in ≥3 studies, with proactive balance tests and muscle power tests used most often. For the second objective, the search revealed 1452 method studies, of which three were included for quality assessment. In one study, construct validity and test-retest reliability of the Short Physical Performance Battery were rated ‘excellent’ and ‘good’, respectively with the COSMIN checklist. Two studies, both rated “poor” with COSMIN, assessed reliability of the TUG.

Conclusion. Commonly used balance and muscle strength tests in young seniors vary greatly with regards to administration mode and outcome reporting. Few studies have evaluated measurement properties of these tests when used in young seniors. There is a need for standardisation of existing tests to improve the informative value and the comparability.

Key words: Systematic review, Performance-based tests, Measurement properties, Older adults, Balance, Muscle Strength

Background

Numerous studies have demonstrated that impairments in balance and decreased muscle strength in lower extremity muscles are important risk factors for early age-related decline in physical function [1-5], falls [3-6], future disabilities [7], hospitalization [5], and death [6-8]. Early declines in balance and muscle strength are already apparent in the third decade of life [9-12], with an accelerated decline occurring from the decade of young seniors aged 60 to 70 years of age [9, 13-15]. Especially age-related visual impairments, most obvious from 50 years and older [9, 16, 17], along with age-related impairments in the vestibular and the proprioceptive system [16], contribute to the acceleration of balance decline. For muscle strength, especially age-related changes in lean muscle mass greatly increase the risk for physical inactivity, mobility deficits, functional limitations and falls [2, 15, 18].

Accordingly, early detection of loss of balance and muscle strength is important to prevent age-related functional decline in young seniors [19-23]. Balance and muscle strength tests can be used to assess and monitor individual's health over time, and predict multi-morbidity, dependence in basic ADLs and early mortality [18, 24-27].

Such tests also are of substantial value in predicting future health status and functional performance in older adults [27].

Numerous performance-based clinical tests assessing balance and/or muscle strength exist. Tests of grip strength, walking speed, sit-to-stand, and standing balance are shown to be markers of both current and future health [1, 18, 24-26]. As a result, there is an increased interest in these tests and their potential use as simple screening tools in the general population to identify people who may benefit from targeted interventions aimed at preventing functional decline [1, 18, 28, 29].

However, in order to test balance and muscle strength adequately, it is important that the tests are sufficiently challenging. For young seniors, generally functioning at a higher level, it is questionable whether existing balance and muscle strength tests are sensitive enough to detect early subtle balance declines [1, 28]. Balance is a complex composite of multiple body systems including the ability to align different body segments and to generate multi-joint movements to effectively control the body position and movement [30]. Since balance is highly task-specific, several aspects needs to be assessed which can be categorized into static steady-state balance (i.e., maintaining a steady position in sitting or standing), dynamic steady-state balance (i.e., walking), proactive balance (i.e., anticipating a predicted disturbance such as crossing or walking around an obstacle), and reactive balance (i.e., compensating a disturbance), for example [30]. However, the majority of balance tests have been designed for older adults aged 70 years and above [31]. Recent systematic reviews of the literature on balance tests have shown that widely used assessment tools such as the Berg Balance Scale (BBS) or Short Physical Performance Battery (SPPB) show ceiling effects in community-dwelling, healthy older adults aged 60 years and over [28, 32]. Ceiling effects of these instruments in higher functioning older adults will hamper the detection of early balance deficits, and thus intervention-related changes over time may not be detected [33, 34]. Although some balance tests such as the Fullerton Advanced Balance (FAB) scale [35], are developed for use in higher functioning older adults, these tests typically do not include tasks that challenge balance for the specific population of healthy, higher functioning older adults [36, 37].

For muscle strength, commonly used tests such as the five time sit-to-stand are not challenging enough in order to detect risk factors in higher functioning older adults [38]. Especially with regard to confirm the effects of an intervention, such tests have ceiling effects are most older adults can perform the test effortlessly and therefore do not show changes in performance level [38].

At present, no systematic literature reviews have examined which balance and muscle strength tests are used for the population of young seniors. The aim of this systematic review was to 1) identify and performance-based clinical tests used to measure balance and/or muscle strength in young seniors aged 60-70 years, and 2) to evaluate the measurement properties of the most commonly used performance-based clinical balance and muscle strength tests.

Methods

Study design

The study is a two-step systematic literature review with two separate literature searches. The first step included the search and systematic review of performance-based clinical tests used for measuring balance or muscle strength in young seniors. The second step included a search and a systematic review of methodological studies evaluating the measurement properties of the most often used performance-based clinical tests identified in step one.

Search strategy

The first search was performed in MEDLINE to identify relevant studies published until June 1st 2016. A combination of free-text and MeSH-terms was used that represents the following concepts: 'postural balance', 'muscle strength', 'movement', motor activity', 'physical exertion', 'physical endurance', 'exercise tolerance', and 'physical fitness'. Additional search terms aimed to exclude animal studies, participants outside our target age group, and non-English studies (see Additional file 1). In the second search, we combined a search on the most commonly identified tests with a search on measurement properties, including validity, reliability, sensitivity, accuracy, responsiveness, sensitivity and specificity (see Additional file 1).

Inclusion/exclusion criteria

In the first step, articles were included if they (1) described a performance-based clinical test that measured balance and/or muscle strength, (2) included participants with an age or mean age between 60-70 years, and (3) were written in English. Articles were excluded if (1) in principal the test could not be completed without fixed laboratory equipment, (2) all groups were included on the basis of having a clinical condition (i.e., no healthy and/or control groups), and (3) manuscripts were reviews, books, posters, or conference proceedings. In the second step, articles were included if they (1) described a performance-based clinical test that was used in at least 3 studies identified in the first search, (2) evaluated one or more measurement properties in one or more of the tests described, and (3) included participants with an age or mean age between 60-70 years.

For the selection of articles in the first part of the study, two authors performed independent reviews of article abstracts. Discrepancies were discussed until agreement was achieved, and if not, a third reviewer made the final decision. The tests detected were labelled “in-lab” when they required advanced, fixed lab equipment, or “out-of-lab”, if in principal they could be performed in a home setting. The review of full-texts was completed by three of the authors where one reviewed all articles and two reviewed one-half each. Discrepancies were discussed with one of the other reviewers and a decision was made based on consensus. For the second part of the study, two authors each screened one-half of the abstracts and full-texts of the methodological studies.

Data extraction

Information from each full-text article was extracted into an excel sheet, containing information about the performance-based clinical tests (name of the test, measurement unit, scoring, and sample characteristics).

Results were categorized into sections representing balance or muscle strength measures. Since balance tests are task-specific, balance tests were categorized according to the framework of Shumway-Cook & Woollacoot [30]: (1) static steady-state balance (i.e., maintaining a steady position in sitting or standing), including measures of postural sway obtained during quite standing (e.g. CoM sway); (2) dynamic steady-state balance (i.e., walking); (3) proactive balance (i.e., anticipating predicted disturbances such as crossing or walking around an obstacle); (4) reactive balance (i.e., compensating disturbances); and (5) and results of balance test batteries. Muscle strength tests were categorized according to a previous published qualitative review [10], resulting in the following categories: (1) 1 Repetition Maximum (1RM); (2) Maximum Isometric Strength (MIS); and (3) muscle power.

Assessment of measurement properties

The measurement quality of the method studies included in the second step was evaluated using the COSMIN checklist [39]. COSMIN describes how to rate the quality of the following nine categories of measurement properties: internal consistency, reliability, measurement error, content validity, structural validity, hypotheses testing, cross-cultural validity, criterion validity, and responsiveness, with several items within each category [39]. Each category is rated as “poor”, “fair”, “good” or “excellent”, with a “worse-score-count”-approach, meaning that each category will get the lowest rating achieved for any of the items within that category [39]. Two amendments were made to the COSMIN guidelines. The first refers to the handling of missing cases. Because missing cases largely is an issue with questionnaires and not tests of physical performance, it was not considered relevant for the quality assessment, and thus articles were not given negative ratings for not describing it. The second refers to sample sizes. Articles with sample sizes between 21 and 30 were rated as “fair” instead of “poor”, as the sample size affects the precision of estimates rather than the quality of the methodological study itself [40].

Results

Study selection

Out of 2354 articles identified, 195 articles were included in the full-text review (Figure 1). In total, 59 balance tests and 40 muscle strength tests were identified (see Additional file 2). Out of these tests, 22 balance tests and 11 muscle strength tests were used in ≥3 articles. These tests were included in the second search on measurement properties, and revealed only three method studies from reviewing 874 abstracts and 131 full-text articles (Figure 2).

Balance Performance tests

Static steady-state balance tests

A total of 27 tests assessing static steady-state balance were identified. Single-activity measures (21 tests) were grouped into four main activity domains: (1) Side-by-side, (2) Semi tandem, (3) Tandem, and (4) One-leg-stand. Variations were found in performance within each category regarding (1) time (range 10-120s), (2) vision (eyes open; eyes closed), (3) surface (firm; foam), and (4) number of trials (range 1-6 trials). The method of scoring included (1) total time (s), (2) category of time intervals (categorized according to the total time), (3) percentage of participants able to hold the position, and (4) body sway measures (e.g., displacement of the Center of Pressure, CoP; sway velocity).

Three Romberg tests were identified, with variations in (1) time (range 10-60s), (2) standing positions (Side-by-Side; Side-by-Side and Tandem; Side-by-Side, Semi-tandem, and Tandem), (3) vision (eyes open; eyes closed), and (4) incorporated muscle strength element (i.e., abduction of the upper limbs). The method of scoring included (1) total time (s), (2), scoring (categorized according to the total time), and (3) percentage (ability to hold the position). Three other tests identified were the Equi test [29], the Sensory Organization Test (SOT) [30], and the modified Clinical Test of Sensory Interaction in Balance (mCTSIB) [8], assessing measures of body sway (e.g., CoP displacement).

Dynamic steady-state balance tests

A total of 11 tests assessing dynamic steady-state balance were identified: (1) the tandem walk, with variations in the distance walked (9.14m; 10m), (2) the Step test, with variations in the demand of the activity (using the worse leg), (3) The Four Square Step Test (FSST), (4) a step width and length measuring walking test, (5) the Maximum Step Length (MSL) test, (6) the 360° turn [5], (7) the 6 m backwards test,

(8) the 10m walk under single- and dual-task condition, (9) the floor transfer task, (10) the Star Excursion Balance Test (SEBT), and (11) a walking test measuring dynamic balance and agility. The method of scoring included (1) total time (s), (2) distance (step width and length), (3) number of steps, (4) number of missteps, (5) percentage (inability to complete the test), and (6) scoring (categorized according to the total time for completion of test).

Proactive balance tests

Eight tests for assessing proactive balance control were identified. The Timed Up and Go (TUG) test was used in 52 studies, with variations in (1) set pace (self-paced, fast paced), (2) distance walked (range 2.44-3.05m), (3) turn (walk to a line on the floor and return; walk to a cone, turn around the cone and return), (4) chair (with/without armrests; with/without backrest; height range 40-46 cm), (5) number of trials (range 1-4), (6) incorporated cognitive (counting backwards) and motor task (carrying a cup of water), and (7) outcome measure (s, m/s). One study investigated the chair rise and walk test, and 17 studies the 8-feet Up-and-Go test, both tests evaluated by time (s). Another 21 studies investigated the Functional Reach Test (FRT), with variations in (1) number of trials (range 1-5), (2) arms (extending the right or left arm forward; raising both arms in front), (3) hands (making a fist; with fingers extended), and (4) distance (tip of the middle finger; position of the third metacarpal). The method of scoring included (1) maximum distance reached (cm; inches), and (2) percentage (maximum distance reached; normalized to height). Three other tests were the Lateral Reach Test (LAT), evaluated by the maximum distance reached (cm), and the 7m obstacle walk respectively the Zigzag walking test, both evaluated by the total time (s) [109].

Reactive balance tests

Seven tests for assessing reactive balance control were identified: (1) the Reactive Balance Test, measuring oscillations in medio-lateral and anterior-posterior directions, (2) the Push and Release Test, measuring the amount of steps needed to regain balance, (3) the adaptive gait test, measuring gait speed (m/s) and the number of step errors, (4) the Step Execution Test, measuring reaction time (ms), (6) the Backwards Stepping Test, measuring ground reaction forces (N/kg), and (7) the Crossover Stepping Test, measuring ground reaction forces (N/kg).

Balance performance test batteries

Six balance performance tests, consisting of different balance tasks, were identified: (1) the Berg Balance Scale (BBS) which was used in 23 studies, (2) the Short Physical Performance Battery (SPPB), which was investigated in 21 studies, (3) the Tinetti Performance Oriented Mobility Assessment (POMA), which was investigated in five studies, (4) the Fullerton Advanced Balance (FAB) scale, (5) the Physical Performance Test (PPT) with variations in the number of included items (range 7-9), and (6) the Continuous Scale-Physical Functional Performance-10 item (CS-PFP-10) test. All balance test batteries used a scoring scheme (e.g. 0 ‘unable to perform’ up to 4 ‘able to perform the task safely’) for the assessment of the performance.

Muscle Strength Performance

One Repetition Maximum tests

We identified six tests measuring the 1 Repetition Maximum (1 RM) of upper- and lower-body extremities. Fifty-four studies investigated handgrip strength, with variations in (1) the measurement instrument (electronic; hydraulic; bulb hand dynamometer), (2) testing position (sitting; standing), (3) demand (both hands; dominant hand; preferred hand; adjusted size for men and women), and (4) number of trials (1- 3).

The method of scoring included (1) force (kg; pounds; kg/bodyweight; pounds/square; Newton; kilopascal), (2) percentage (force scores, i.e., kg classified as weakness), and (5) outcome (mean of trials; best trial). Other studies used 1 RM of shoulder flexors [86], hip muscles [163], knee extensors [86], legs [164], or toes [165], either assessed by force (kg) or torques.

Maximum Isometric Strength tests

There were five tests measuring Maximum Isometric Strength (MIS). Four studies used MIS tests of knee extensors, with variations in (1) outcome (mean of trials; best trial), and (2) outcome dimension (kg; N/k; percentage, i.e., muscle strength/body-weight). Four studies evaluated leg muscle strength, assessed by force (kg). Ankle dorsi-flexor MIS tests were used in two studies, either evaluated by force (kg) or percentage (muscle strength/bodyweight). One study included MIS tests of hip extensors and flexors, and knee flexors, evaluated by percentage (i.e., muscle strength in relation to total bodyweight).

Muscle power tests

We identified 29 muscle power tests. For upper-body extremities, three tests were identified. The 30 s Arm Curl Test was used in nine studies, with variations in the weight used (2.0 kg; 2,27 kg for women and 3.63 kg for men). The test recorded the number of repetitions for 30 s. Abdominal muscle power was investigated in two studies and the number of repetitions for 30s was recorded. Single forearm contractions, evaluated by Maximum Voluntary Contraction (MVC, in kg), was investigated in one study.

For lower-body extremities, six versions of the Sit-to-Stand (STS) test were used in 83 studies, with variations in (1) method of measurement (time for one repetition;

time for five repetitions; time for ten repetitions; number of repetitions in 15 s; 30 s; 60 s), (2) chair (height: standard; adjusted; range 30-60 cm; with backrest; without backrest; without armrests), (3) position (back at the back of the chair; sitting in the middle of the chair; sitting in the front half of the chair; sitting on the edge of the chair), (4) time of measurement (starting/finishing in a sitting or standing position), (5) pace (self-paced; fast paced), (6) number of trials (range 1-3), and (7) outcome (mean of trials; best trial). The method of scoring included (1) total time (s), (2) repetitions, (3) scoring, (4) force (N/s in kg; W in kg), and (5) speed (stands per minute).

There were seven different types of stair climbing tests investigated in 11 studies with variations in (1) number of steps (standard flight of stairs; range 8-15 steps), and (2) method of measurement (time; stair climbing power; W).

Six studies investigated stair ascent, with two of them also investigating stair descent. Tests varied in (1) number of steps (range 1-23) and (2) method of measurement (time; score).

Seven other tests for measuring muscle power of lower-body extremities were identified: (1) Lift and Reach, assessed by repetitions over one minute, (2) Floor rise to standing, assessed by time (s), (3) Five Step Test, assessed by time (s), (4) One-Time Kneel-to-Stand, assessed by time (s), (5) Functional Leg Extensor Muscle Strength, assessed by the maximum weight in relation to bodyweight, (6) Standing Long Jump, assessed by distance (cm), and (7) Single Knee Extension Contractions, assessed by maximum work rate.

Assessment of measurement properties

The quality assessment of the three method studies we included [41-43] are shown in an additional file (see Additional file 3). These studies describe a few (reliability and validity), but not all (internal consistency, measurement error, content validity, hypotheses testing, cross-cultural validity, criterion validity, and responsiveness according to the COSMIN checklist [39]) measurement properties of two instruments (SPPB and TUG). Two studies assessing inter-rater and test-retest reliability of the TUG were found to be of poor quality, with the lowest achievable rating based on the COSMIN checklist [42, 43]. According to the COSMIN checklist, the quality of the assessment of validity and test-retest reliability of SPPB was 'excellent' and 'good', respectively [41].

Discussion

This systematic review identified 99 performance-based clinical tests used to measure balance and/or muscle strength in young seniors, of which 59 measured balance and 40 measured muscle strength. The TUG (51 articles) and BBS (23 articles) were the most used balance test in our sample. Different variations of the sit-to-stand test (e.g. five times sit-to-stand, 30-sec sit-to-stand) were most often used to assess muscle strength (87 articles), with the five times sit-to-stand as the most commonly used test (39 articles). Only three method studies were identified for the most used performance-based clinical tests, where the TUG and SPPB was evaluated in samples of young seniors. However, there is a lack of knowledge on measurement properties for these two tests since the few revealed studies in young seniors only evaluated some few methodological aspects (reliability and validity) with varying methodological quality.

Proactive balance was the aspect of balance that was tested most frequently, with TUG as the most frequently used test (51 articles; 24,039 participants). This finding aligns with a review that found TUG to be the most used test to predict falls in healthy community-dwelling older adults aged ≥60 years [32]. TUG is fast to perform and easy to administer, and cut-offs between 12 and 13s have shown moderate to high sensitivity and specificity in predicting falls in older adults [44, 45]. However, the TUG is a general test of mobility that provides little or no information on underlying balance deficits [30]. Performance of TUG is a relatively complex task in terms of motor performance, including a ‘sit-to-stand’-movement, walking, turning and a ‘turn-to-sit’-movement, but for young seniors, the score of total duration may not be sensitive enough to reveal early signs of functional decline [20]. The instrumented version of TUG could potentially be a more useful test of balance and mobility in higher functioning groups as more details of the quality and quantity of the performance than just the total duration can be obtained objectively [46].

For balance performance test batteries, BBS was the most commonly used test (23 articles; 1,174 participants), closely followed by the SPPB (21 articles; 11,325 participants). BBS is widely used and has been coined the “gold standard” of balance assessment tools [47]. BBS is a significant predictor for ADL disability onset in older adults aged 80 and over [48], but in samples with a mean age in the mid-seventies, it suffers from ceiling effects [49-51], even in older adults with falls history [31]. A systematic review recommended SPPB as the performance-based tool for measuring physical function in older adults due to superior qualities related to validity, reliability, and responsiveness compared to other tests [52]. This review generally reported little ceiling effects for the SPPB in the “general (mixed) population” of community-dwelling older adults. However, when applied in higher-functioning community-dwelling older adults, the SPPB also showed ceiling effects [33, 53]. Despite being extensively used in older people in general and receiving appraisals for its measurement properties, the BBS and SPPB do not appear as good enough for assessing physical performance in young seniors due to ceiling effects.

The most frequently used muscle strength test across all categories were those including some variation of the ‘sit-to-stand’-movement (87 studies), with the ‘Five times sit-to-stand’ (5xSTS) (39 articles; 39,988 participants) and the ‘30 second chair stand’ (30STS) (35 articles; 4,961 participants) being the most popular among them.

The 5xSTS is commonly used as a test of physical performance in clinical assessments [54], and is also part of the SPPB test battery. We found a large variety in how this test was administered, thus making comparisons between versions a challenge. In the original and most applied protocol, the subject is “timed from the initial sitting position to the final standing position at the end of the fifth stand” [55]. In an earlier meta-analysis, the mean score on 5xSTS from 4,184 participants between 60-69 years was 11.4 s [56]. This is relatively fast compared to identified cut-offs of 13.6s, for indication of increased disability and morbidity [57], and 15 s for predicting recurrent fallers [58]. However, as also this test lacks validation in young seniors, we have no basis for recommending this performance-based clinical test as a good measure for this specific population.

The second most used tool with a STS-variation was the 30STS, originally developed to overcome floor effects of the 5xSTS [59]. We did not identify any method study that assessed the measurement properties of 30STS, but in community-dwelling adults with a mean age of 70.5 ± 5.5 years, the test-retest reliability (ICC .89) and concurrent validity was moderate, with associations with weight-adjusted 1 RM leg-press of r=.71 (women) and .78 (men) [59]. Therefore, the 30STS could be suitable to measure physical performance in young seniors, but further studies are warranted to confirm this assertion.

Test-retest reliability was assessed for the SPPB and TUG [41, 42], and inter-rater reliability for TUG [43]. The quality of both method studies assessing the TUG was ‘poor’, while the one assessing the SPPB was ‘excellent’. SPPB was the only performance-based clinical test validated in young seniors, with a strong level of evidence for both content and construct validity [41]. However, we found no evidence for internal consistency, measurement error, criterion validity or responsiveness for either of these tests, thus this review cannot support a recommendation for these tests for assessing physical performance in young seniors.

A limitation of this systematic review is that we only performed the search for performance-based clinical tests in MEDLINE. Some potentially useful tests might therefore not have been identified. However, this review was based on a broadly designed literature search which aimed at getting a broad overview of existing performance-based clinical tests used for measuring balance and/or muscle strength in young seniors. Due to the large number of identified and included articles, it is unlikely to have missed frequently used tests. Despite gait speed being a very common measure of physical performance in older adults, we did not include any gait speed measurements. Gait speed is not a specific measure of balance or muscle strength, but rather considered to be a general measure of health and function, which was not our focus.

Conclusion

This systematic review identified a large number of performance-based clinical tests that have been used to measure balance and/or muscle strength in young seniors. The most commonly used balance tests suffer from ceiling effects in this sample of young seniors. Additionally, there is a lack of consensus on how to administer balance and muscle strength tests, and how to report their outcomes. Only three method studies have been identified, so more studies are required to assess measurement properties of existing tests in young seniors. There is a need for guidelines on how to administer and conduct identified tests to improve the informative value and the comparability of outcomes. One the other hand, new and more challenging tests than identified in this review are most likely required to adequately assess young senior's physical performance, and to be able to identify declines in function at an early stage and to timely initiate preventive strategies.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors reported no conflicts of interest.

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Author's contributions

RB and MW performed the review of abstracts. RB, MW, SU, and KT performed the review of full-texts and data extraction. KT assisted in decision making. RB and MW drafted the manuscript. KT, MS, JLH, and BV helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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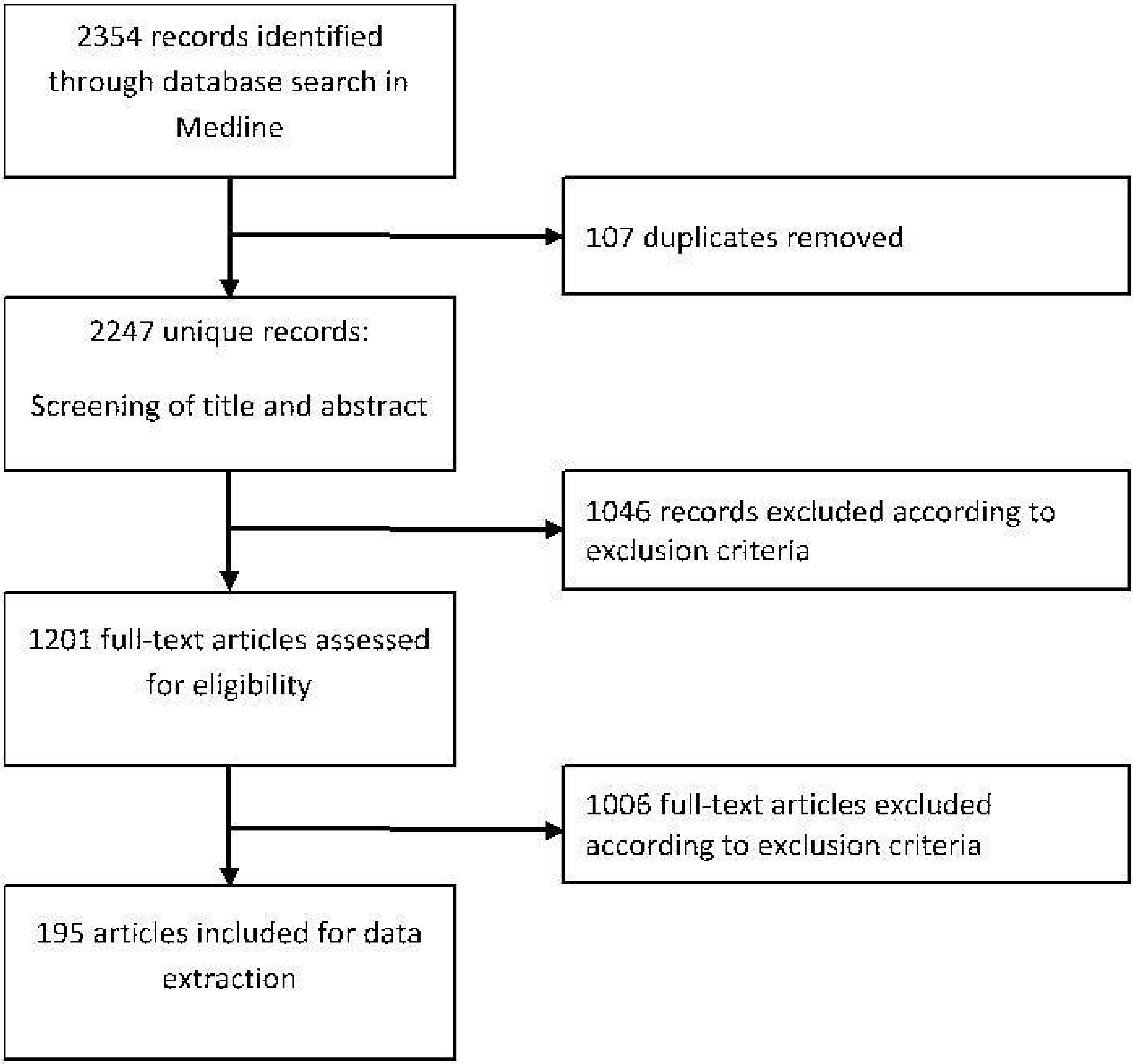
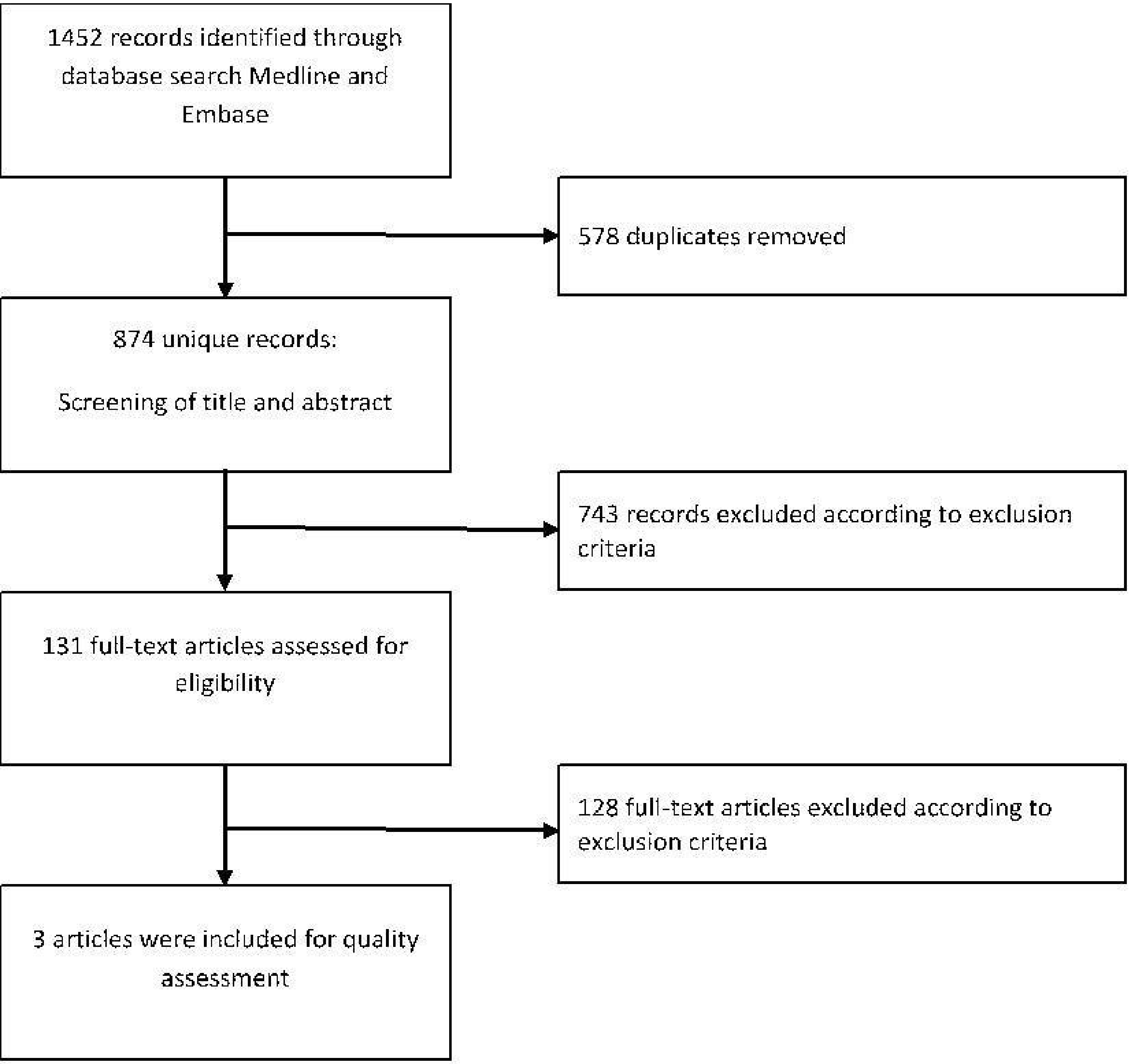
Figures

Figure 1. Study selection of performance based tests through the different phases (first search).

Figure 2. Study selection of method studies through the different phases (second search).


2354 records identified through database search in Medline
107 duplicates removed
2247 unique records:
Screening of title and abstract
1046 records excluded according to exclusion criteria
1201 full-text articles assessed for eligibility
1006 full-text articles excluded according to exclusion criteria
195 articles included for data extraction


1452 records identified through database search Medline and Embase
578 duplicates removed
874 unique records:
Screening of title and abstract
743 records excluded according to exclusion criteria
131 full-text articles assessed for eligibility
128 full-text articles excluded according to exclusion criteria
3 articles were included for quality assessment

Additional file 1

Database search

Search for physical performance tools in MEDLINE (from 1946) to 1 June 2016 (last update).

1. ((young or younger or early) adj2 (retired or retirement or elderly or senior*1 or elder*1)).ti,ab.

2. (older adult*1 or older healthy adult*1 or older active adult*1 or older healthy individual*1 or older active individual*1 or older active men or older active women or older healthy men or older healthy women).ti,ab.

3. ((year*1 or age or aged) and ("50-70" or "50-65" or "51-69" or "55-70" or "55-69" or "60-70" or "60-65" or "61-69")).ab.

4. 1 or 2 or 3

5. muscle strength/ or movement/ or motor activity/ or physical exertion/ or physical endurance/ or exercise tolerance/ or physical fitness/ or postural balance/

6. (measured or measurement* or measuring or assess* or test*1 or scale*1).ti,ab. or Geriatric assessment/ or Anthropometry/ or outcome*.mp.

7. (fitness or physical function or physical performance or balance or strength).ti,ab.

8. limit 7 to medline

9. 7 not 8

10. (gait or leg*1 or walking or walk or knee or knees or postural sway or stand or standing or lower extremit* or lower limb*1).mp. or (go or step or steps or stepping).ti,ab.

11. (4 and (5 or 9) and 6 and 10) not animals/

Search for methodological studies of identified tools in MEDLINE (from 1946) and EMBASE (from 1974) to 19 December 2017 (last update).

1. (tandem walk* or tandem stand* or (side-by-side and (stand or feet or standing)) or feet together or semi-tandem or one leg* stand* or step test or timed up go or "8 foot up" or eight foot or functional reach or (grip strength and (measur* or test* or assess*)) or arm curl or sit to stand or chair stand or chair rise or stair climbing or stair ascent or isometric strength or handheld dynamomet* or performance oriented mobility scale or tinetti or fullerton advanced balance scale or berg balance or short physical performance battery).m_titl.
2. Observer variation/ or "Predictive value of tests"/ or Psychometrics/ or psychometr*.ti. or Reference Values/ or exp "Reproducibility of Results"/ or "Sensitivity and Specificity"/ or Validation studies.pt. or Evaluation Studies.pt. or accura*.ti. or clinimetr*.ti. or consisten*.ti. or develop*.ti. or discrimina*.ti. or feasib*.ti. or predictiv*.ti. or propert*.ti. or psychometr*.ti. or reliab*.ti. or repeatab*.ti. or reproducib*.ti. or responsive*.ti. or sensitiv*.ti. or specificity*.ti. or subscale*.ti. or suitab*.ti. or test-retest.ti,ab. or useful*.ti. or utility.ti. or valid*.ti. or varia*.ti.
3. 1 and 2

Table 1 Balance tests

	Test characteristics		Scale		Study population		
Balance test	**Detailed Description**	**Unit**	**Level**	**Items**	**N[a]**	**Age**	**Sex[b]**
Static steady-state balance							
Side-by-side, eyes open, 10 s (7 studies)	Holding the position [1-6] Three trials [7]	Time (s) [3, 4, 6] Score [1, 5] Sway velocity CoG (degrees/s) [7] % of participants able to hold the position) [2]	N; O; R	1	13584	40-87 (62.6-70.4)	7593 F, 5871 M
Side-by-side, eyes closed, 10 s (1 study)	Three trials [7]	Sway velocity CoG (degrees/s)	R	1	37	60-81 (67.7±5.3)	28 F, 9 M
Side-by-side, eyes open, 30 s (6 studies)	Holding the position, eyes open [8-10] Two trials (with audio-biofeedback; without audio-biofeedback) [11] Two trials (comfortable stance with eyes open; narrow stance with eyes open) [12, 13] Three trials (eyes open; visual feedback about the performance from the computer screen; following visual cues on the computer screen to move the body to hit targets identified on the screen) [14] Twelve 30-s trials, randomly completed: three with no postural threat, nine with a possible perturbation (a push forward or pull backward to the upper trunk by the examiner; three of nine with a perturbation after 30s, six of nine with a perturbation at 1s, 5s, 10s, 15s, 20s or 25s [15]	Time (s) [8, 10] CoP displacement (mm [12, 13]; cm [9]) % of time that the trunk tilt within specified angle limits; RMS and MPF of trunk tilt [11] Postural control, movement time, path length [14] Trunk roll/trunk pitch angle and velocity [15]	R	1-12	13909	52-90 (62.7-71.6)	6768 F, 7124 M

Side-by-Side, on foam, eyes open, 30 s (1 study)	Holding the position [9]	CoP displacement (cm)	R	1	122	69.7-71.6	90 F, 32 M
Side-by-side, eyes closed, 30 s (4 studies)	Holding the position [9, 14] Two trials (comfortable and narrow stance) [12, 13]	CoP displacement (mm [12, 13]; cm [9]) Postural control, movement time, and path length [14]	R	1-2	329	57-75 (65.3-71.6)	243 F, 120 M
Side-by-side, 60 s (1 study)	Two trials [16]	CoP displacement (cm)	R	1	54	60+ (66.0±5.0)	30 F, 24 M
Semi-tandem, 10 s (5 studies)	Holding the position [2-6]	Time (s) [3, 4, 6] Score [5] % of participants able to hold the position [2]	N; O; R	1	9091	40-87 (62.6-70.0)	5070 F, 3955 M
Semi-tandem, 30 s (3 studies)	Holding the position [8, 17] Two trials (with audio-biofeedback; without audio-feedback) [11]	Time (s) [8, 17] % of time that the trunk tilt within specified angle limits; RMS and MPF of trunk tilt [11]	R	1-2	13392	52-90 (62.7-65.0)	6430 F, 6956 M
Tandem, 10 s (7 studies)	Holding the position [2-4, 6, 9, 18, 19]	Time (s) [3, 6] CoP displacement (mm [4]; cm [9, 18]) % of participants able to hold the position [2, 19]	N; R	1	9265	40-87 (62.6-71.6)	5082 F, 4080 M
Tandem, 30 s (2 studies)	Holding the position [8, 17]	Time (s)	R	1	13386	52-90 (65.0±4.8)	6430 F, 6956 M
Tandem, 60 s (1 study)	Three trials [20]	Time (s)	R	1	12	69.0±3.0	12 F, 0 M
OLS (5 studies)	N/A [21-25]	Time (s) [21-25] Score [24]	N; O; R	1	2266	52-84 (64.0-69.1)	1197 F, 1069 M

		n (%) balance lost <5s [23]					
OLS, no time limit (3 studies)	On the dominant leg [26] On the right leg [27] Three trials [28]	Time (s)	R	1	718	50-79 (53.9-73.1)	409 F, 309 M
OLS, eyes closed, no time limit (2 studies)	Holding the position as long as possible on the dominant leg with eyes closed [29] Three trials with eyes closed [30]	Time (s)	R	1	272	50-79 (62.8-67.1)	75 F, 20 M
OLS, 15 s (1 study)	Three trials on each leg with eyes open and eyes closed [31]	CoP displacement (cm)	R	2	19	60-68	9 F, 10 M
OLS, 25 s (1 study)	Two trials on each leg [32]	n (%) able to hold 20 s	N	2	26	IG: 60.5±4.1 CG: 59.7±3.0	18 F, 8 M
OLS, 30 s (4 studies)	Holding the position [33, 34] Holding the position on each leg [35] Three trials on each leg, eyes open [36]	Time (s)	R	1-2	3202	55-84 (62.0-69.0)	1506 F, 1695 M
OLS, eyes closed, 30 s (2 studies)	Three trials on each leg [36, 37]	Time (s)	R	1-2	1812	60-84 (63.2-69.0)	927 F, 885 M
OLS, 60 s (13 studies)	Holding the position on the dominant leg [38-40] Holding the position, eyes open [41, 42] One trial on each leg [43] Two trials on the preferred leg [7, 44] Two trials on each leg [12, 13, 45, 46] Three trials (two trials on the preferred leg; one trial on the opposite leg) [20]	Time (s)	R	1-2	8326	34-90+ (61.8-77.0)	5313 F, 3004 M
OLS, 60 s, eyes closed (5 studies)	Holding the position [41, 42, 47, 48] Two trials on each leg [49]	Time (s)	R	1-2	502	60-84 (66.3-69.3)	211 F, 291 M
OLS, 120 s (1 study)	One trial on each leg [50]	Time (s)	R	2	501	65-74 (69.3-69.7)	279 F, 222 M
Romberg Test (4 studies)	N/A [33] Feet together and tandem stand, both stances with eyes open and eyes closed, 10 s [51]	Time (s) [33, 51, 52] Score [4]	O; R	1-4	450	50-80 (50.8-68.2)	215 F, 181 M

	Parallel, semi-tandem and tandem stand, 10 s [4] Standing with both feet together and eyes closed, 60 s [52]						
Sharpened Romberg (2 studies)	Bipedal position with eyes open and eyes closed [53, 54]	Time (s)	R	2	76	62.5-72.8	26 F, 50 M
Romberg with Jendrassik maneuver (1 study)	Standing with both feet together, eyes closed and performing abduction of the upper limbs for 30 s [26]	n (%) able to hold the position >20 s	R	1	266	65-74 (69.5±3.0)	142 F, 124 M
Equi Test (1 study)	Twelve 20-s trials in a side-by-side position; 6 conditions (each condition twice): (1) normal vision, fixed support, (2) eyes closed, fixed support, (3) vision sway-referenced, fixed support, (4) normal vision, support sway-referenced, (5) eyes closed, support surface sway-referenced, (6) vision and support surface both sway-referenced [55]	N/A	R	6	55	61-83 (69.3±5.5)	36 F, 19 M
SOT (1 study)	Six 20-s trials, standing on a force platform, with the platform and/or visual surround sway referenced, according to subject's anteroposterior sway (1-3 motionless platform, 4-6 sway-referenced platform) [56]	Body sway angles	R	6	23	60-78 (66.2-71.3)	0 F, 23 M
mCTSIB (1 study)	Four 30-s trials: quite standing on a firm surface with eyes open and eyes closed, quite standing on a compliant (foam) surface with eyes open and eyes closed [18]	CoP displacement (cm)	R	4	37	69.0±8.0	N/A
Dynamic steady-state balance							
Tandem walk (3 studies)	On a beam, two trials [57] 10-foot line, as quickly as possible without making mistakes (i.e. stepping completely off the line or failing to follow a heel-to-toe pattern), three trials [20] Pre-marked 9.14m tape line on the floor [58]	Time (s) [20, 58] Number of missteps [20] n (%) who failed [57]	O; R	1	73	65-85 (67.4-77.0)	50 F, 23 M
Step test (2 studies)	Stepping one foot on, then off, a 7.5-cm block as quickly as possible in 15 s [59]; with the worse leg [60]	Number of steps on/off the block	R	1	67	53-83 (65.7-66.9)	38 F, 29 M

Four Square step test (6 studies)	Stepping as fast as possible in forward, sideways, and backward directions over 4 canes resting flat on the floor in a cross formation with the tips of the canes facing together, moving first in a clockwise direction and then counterclockwise position, without touching the canes, both feet make contact with the floor in each square before moving to the next [7, 35, 61-64]	Time (s)	R	1	470	55-81 (62.0-71.5)	363 F, 95 M
Step width & length, eyes open and eyes closed (1 study)	Footprints recorded on a 0.9x6.1 m (3x20 ft) paper walkway, triangular (base=5 cm) shapes were cut from adhesive moleskin and attached to the soles of the shoes at the midline of the toes. A square moleskin shape (5x5 cm) was attached to the midline of the heel. A stamp pad inker was used to apply black ink to the triangular and squared shaped moleskin [54]	Distance (mm)	R	1	56	66.7-72.8	41 F, 15 M
MSL test (2 studies)	Standing with the feet together and then stepping out as far as possible with the preferred leg adjacent to a yardstick taped on the floor, before returning to the starting position, two trials [7] Stepping maximally with one leg while keeping the other leg planted and then return to the initial position in one step; for each leg and direction (front, side, back); five trials [20]	Distance (inches)	R	1	59	60-81 (67.7-77.0)	50 F, 9 M
360° turn (1 study)	Making a 360° turn, allowed to use assistive devices [5]	Score	O	1	282	60-74	228 F, 54 M
6m backwards walk (3 studies)	6m backwards walk, placing one foot directly behind the heel of the other with the shoes touching [65-67]	Time (s)	R	1	77	65-84 (68.9-69.7)	44 F, 40 M
10-m walk under single- and dual-task condition (1 study)	10 m instrumented walkway, single and dual task (walking while counting backwards aloud) conditions in 1) normal gait pattern, 2) narrow gait, 3) overlapping gait, and 4) tandem gait [51]	Stride time, stride length, stride width, stride velocity	R	8	54	65-80	N/A
Floor Transfer Task (1 study)	Standing upright on a mat, transferring to a sitting position on the floor mat, then returning to standing in any preferred way [68]	Time (s)	R	1	39	61.2±7.5	27 F, 12 M
SEBT (2 studies)	Balancing on the stance leg and reaching with the opposite leg as far as possible, five reaches in the anterior, medial, and posterior directions, calculating the star composite reach distance,	Distance (cm)	R	6	212	65.4-68.9	107 F, 99 M

	i.e. sum of the normalized reach distances for the right and left leg for all reach directions [69] Standing at the center of a grid placed on the floor, with eight lines extending at 45° increments from the center of the grid, placing one leg in the center of the grid, with the opposite leg reaching as far as possible along the eight defined directions in order to touch the furthest point on the floor as lightly as possible so as to avoid using the reach leg for support, and then return to the center of the grid without losing balance, the distance from the center of the grid to the reached point is measured [70]						
Dynamic balance/agility (2 studies)	Rapidly standing from a chair, walking around cones, and returning to the chair [71, 72]	Time (s)	R	1	120	60-84 (66.1-69.8)	43 F, 79 M
Proactive balance							
TUG (51 studies)	Two trials [75, 76]; natural and fast speed [77] 3 m version; two trials [78] Getting up from a chair with armrests, walk 3m, return and sit down again [70, 71]; walk 3 m to a mark placed on the floor [79] Getting up from a chair, walk 3 m, turn, walk back, and sit down [8, 40, 80-83]; as quickly as possible, without running; two trials [84]; three trials [85]; habitual gait [37, 51, 86, 87]; chair without armrests [68] Rising from a chair (40 cm high), walking 3 m, turning around, and sitting down again as fast as possible; two trials [88, 89] Rising from a chair, walking to and from a point located 3 m ahead at preferred speed, and then sitting down again; two trials [44] On a command, participants get up from an armless, backless chair (43 cm high), walk forward 3 m, turn around, walk back to the chair and sit down again [32] On cue, participants rise from the chair, walk 3 meters to a line on the floor and return to their	Time (s) [8, 9, 12, 17, 24, 26, 29-32, 38, 40, 44, 51, 61, 62, 64, 68-71, 73, 75-100] Time (m/s) [37, 74]	R	1-3	24039	50-99 (61.4-77.0)	14952 F, 8731 M

initial seated position[90, 91]; normal armchair (44 cm high [12]); marker of 20 cm diameter [92]
Sitting in a free-standing padded armchair, then stand up without use of arms, walk at a comfortable and safe pace to a line on the floor 3 m away, turn and walk back to the chair and sit down again [93]
Sitting in a normal chair (45 cm high), with the back against the chair, standing up, walking 3 m as quickly and safely as possible past a line on the floor, turn around, walk back to the chair, and sit down once again with the back against the chair; two trials [26]
Rising from a chair (45 cm high) without using the arms to assist, walk 3 m to a cone, turn around the cone and return to the seat [94]
Standing up from a standard chair of 45 cm height, walking 3 m, turning around a cone, returning to the chair, and sitting down again in the shortest time possible without running; two trials [38]
Getting up from a chair, walking 10 ft, turning, walking back, and sitting down; three trials [40, 95]
Sitting with the back against the chair (approximately 46 cm high), on a command participants rise from a standard arm chair, wearing their own shoes and/or using an ambulatory aid, walk a distance of 10 ft, and return to the seat with their back resting against the back of the chair [96]
Sitting in a chair, then stand up without using the hands, walk to the end of a 10-ft pathway, turn around, walk back and sit down as quickly and safely as possible [17]
Getting up from a sitting position in an armless chair, walk 2.5 meters, return and sit down again in the same chair. A flag indicated the distance of 2.5 m from the chair; mean of three trials [97]
Sitting in a chair and on a command, standing and moving as quickly as possible around a

	cone placed 2.5 m away from the chair and return to the chair and sitting down [69, 98] Sitting on a chair (43 cm high), with back support, travel a distance of 2.43 m, turn around a cone positioned at the end of the route, return, and sit down again at the chair; two trials [99] Rising from a chair on a command, walk 8 ft, and return to sit in a chair [31] 3-trials: 1) Get up from a chair, walk 3 m straight on, turn around a cone, walk back to the chair, and sit down; 2) with an additional cognitive task (counting backwards in step 3, starting with 97), and 3) with an additional motor control task (transporting a cup of water without spilling any water during the TUG) [100] Standing up and sitting down in a chair, walking and turning while simultaneously completing a cognitive task of counting backwards from 100 in 3's [62, 64] N/A [9, 24, 29, 30, 61, 73, 74]						
mTUG (1 study)	Standing up from a seated position, walk a distance of eight feet at usual pace, return to the chair, and sit back down [101]	Time (s)	R	1	101	60-80 (65.3-67.4)	69 F, 32 M
Chair rise and walk (1 study)	Starting from a seated position, then stand up and walk as quickly as possible in a predetermined straight line to a pylon 9.14 m, go around the pylon, and return to the original seated position [58]	Time (s)	R	1	39	65-85	20 F, 19 M
8-ft Up and Go (17 studies)	Part of the SFT [25, 36, 42, 102-107] Getting out of a chair, walk 8 ft, turn around a cone, return to the chair and sit down as quickly as possible [108-112]; two trials [113] Sitting in a chair, hands on thighs and feet flat on the floor, on a command, stand up, walk as quickly as possible around a cone placed 8 ft ahead of the chair, and return to a fully seated position on the chair [114]; two trials [115]	Time (s)	R	1	3372	51-89 (62.1-70.1)	2341 F, 908 M
FRT (21 studies)	Two trials [78] Three trials [116]	Distance (cm) [10, 12, 14, 26, 44, 47, 48, 51,	R	1	11654	50-99 (61.5-71.3)	7861 F, 3768 M

	Part of the SFT [75]	66, 67, 70, 75, 78, 88, 89, 118-120]	
	Reaching forward as far as possible without moving the feet [10, 117]	Distance (inches) [63]	
	Maximum distance a person can reach forward beyond arm's length while standing in a fixed position, three trials [56]	% (normalized using height) [56, 117]	
	Measuring participant's balance with a tape measure horizontally on the wall and the participant reaching forward as far as possible from the waist without losing balance [70]		
	Standing with the feet shoulder-with apart, making a fist, and raising the arm to be parallel with the floor. The assessor took an initial reading on the yardstick, using the knuckle of the third metacarpal as the landmark, then reaching forward along the yardstick without moving the feet [63]		
	Standing and then raising both arms in front to shoulder level while the heels touch the ground [47, 48, 118]; two trials [88]		
	Reaching forward beyond arm's length while maintaining a fixed base of support in the standing position; right and left arm recorded [51]; five trials [14]		
	Participants place their feet behind a marked line and whilst maintaining a fixed base of support reach forward along a preplaced measure tape [66]		
	Extending the right or left arm forward, while standing with legs apart, two trials [44]		
	Raising the arm closest to the wall to shoulder height; the position of the third metacarpal is recorded. Subjects are instructed to keep the feet flat on the floor and lean forward as far as possible without losing balance, touching the wall, or taking a step; two trials [12]		
	Raising one arm at 90 degree with fingers extended. A yardstick was mounted on the wall at shoulder height. The distance that a participant could reach while extending forward from the initial upright posture to the maximal anterior leaning posture without moving or lifting the feet is visually measured in cm, according to where the		

	middle finger tip is positioned on the mounted yardstick; two trials [89] Standing close against a wall with a measurement tape fixed on the wall and keep the shoulder in 90° flexion parallel to the tape; reach forward maximally with arm outstretched equal to shoulder's height without moving the feet or touching the wall; mean of three trials [119] Standing with the feet a comfortable distance apart and behind a line perpendicular and adjacent to a wall, the arm closest to the wall is then raised to shoulder height, and the position of the tip of the middle finger is measured; feet flat on the floor and leaning forward as far as possible without losing balance, touching the wall, or taking a step. The position of the tip of the middle finger is then recorded at the point of furthest reach, and the difference between the two points is recorded as the maximal distance; three trials [26] N/A [67]						
LRT (1 study)	Standing with the back to (but not in contact with) a wall, feet placed in a standardized position with 0.1 m between the most medial aspects of the heels, with each foot angle at 30°, then reaching directly sideward as far as possible without overbalancing, taking a step or touching a wall; two trials [12]	Distance (cm)	R	1	28	57-73 (65.9-66.0)	3 F, 25 M
7m obstacle walk (1 study)	7 m walk with stepping over a 30 cm obstacle at the 4 m point, normal pace; two trials [98]	Time (s)	R	1	134	69.6-70.3	85 F, 49 M
Zigzag walking (1 study)	Walk along a 10-m walkway with four cones placed 2 m apart on the floor between the start and finish points as quickly as possible. The cones were set to alternate from side to side with a distance of 0.5 m from a line drawn through the start and finish points. Participants walk around the outside of each cone and walk through the finish point; two trials [121]	Time (s)	R	1	81	50-74 (59.0-61.0)	40 F, 41 M
Reactive balance							

Reactive balance test (1 study)	Stand erect in bipedal step stance with hands placed on hips and gaze fixated on a cross on the nearby wall on a two-dimensional balance platform. Medio-lateral perturbation impulses are unexpectedly be applied in order to investigate reactive postural control (10 s intervals); three trials [51]	Summed oscillations of the platform in medio-lateral and anterior-posterior directions	R	2	54	65-80	N/A
Push and release test (1 study)	Standing in a comfortable stance with eyes open and pushing backward against a palm of the examiners' hand. After the examiner suddenly releases his or her hands, participants are required to regain balance [51]	Amount of steps to regain balance	O	1	54	65-80	N/A
Adaptive gait test (1 study)	Walking barefoot at self-selected comfortable pace within a narrow, 6.1-m-long path with a cognitive task (reciting the days of the week in reverse order); four trials [122]	gait speed (m/s), step errors (n)	R	1	20	61-81	69.1±8.6
Step Execution Test (2 studies)	Standing barefoot and upright on a force platform viewing an 'X' displayed on a screen, 3 m in front, step as quick as possible (step length 50-60 cm), following a tap cue on their heel, nine trials (forward, backward, sideward) [123] Stand with the foot of the preferred leg on a foot-pad, and react to an auditory stimulus by stepping rapidly onto a second foot-pad 18 inches away; two trials [7]	Reaction time (ms)	R	1	72	60-88 (67.7-69.6)	9 F, 28 M
Backwards stepping test (1 study)	When signaled, lean as far backwards as possible, and then take a backward step with the unloaded leg; three trials (eyes open, eyes closed) [124]	Ground reaction force (N/kg)	R	1	36	65-75 (66.2-68.3)	31 F, 5 M
Crossover stepping test (1 study)	When signaled, lean as far laterally as possible, and then take a crossover step with the unloaded leg; three trials (eyes open, eyes closed) [124]	Ground reaction force (N/kg)	R	1	36	65-75 (66.2-68.3)	31 F, 5 M
Balance test battery							
BBS (23 studies)	14 balance tasks (5 static, 9 dynamic) with varied difficulty (e.g. sit-to-stand, standing with eyes open and eyes closed, tandem stand, one-leg stand, transfers, reaching for an object, a 360° turn; each scored from 0 to 4 [11, 17, 29,	Score (0-56)	O	14	1174	56-88 (61.4-74.0)	678 F, 491 M

	36, 38, 40, 55, 68, 71, 74, 77, 79, 82, 83, 91, 96, 123, 125-130]						
SPPB (21 studies)	Three hierarchical standing balance tests (side-by-side, semi-tandem, tandem position for 10 s each), 4-m walk at usual speed (m/s), and five repeated chair stands as quickly as possible (s), each scored from 0 to 4 [10, 38, 69, 87, 94, 119, 131-145]	Score (0-12) [10, 38, 69, 87, 94, 119, 131-141, 144, 145] Score summarized in quartiles (lower body function: poor, fair, good excellent) [143] % score (7-9; 10-12 points) [142]	O	3	11325	60-89 (65.4-72.3)	9125 F, 2200 M
Tinetti Test / Performance Oriented Mobility Assessment (5 studies)	Tinetti's balance and gait evaluation [53] 13-item balance and 9-item gait assessment, each scored from 0 (unable) to 1 (able to perform) [146] Static sitting balance (rising from the sitting position without using), standing balance (the first five seconds after the subject's sternum was gently pushed by the examiner, and when stance was stabilized, staggering or excessive sway of the subject was examined with the subject standing and his eyes closed); 360° turn, observing steadiness and continuity of steps [147-149]	Score (0-28) [53] Score (0-22) [146] POMA balance score [147-149]	O	3-28	7236	55.0-97.6 (62.5-66.8)	4801 F, 2435 M
PPT (1 study)	Two versions, i.e. a 9-item scale, including writing a sentence, simulated eating, 360° turn, putting on and removing a jacket, lifting a book and putting it on a shelf, picking up a penny from the floor, a 50-foot walk test, and climbing stairs (scored as two items); and a 7-item scale, not including stairs; each scored from 0-4 [60]	7-item score (0-28), 9-item score (0-36)	O	7-9	35	60-83 (68.0±5.5)	24 F, 11 M
mPPT (1 study)	Nine items, including Romberg test, chair sit-to-stand, lifting a book from waist height to a shelf at shoulder level, putting on and taking off a coat, picking up a penny from the floor, 360° turn, 15 m walk, ascending one flight of stairs, climbing 4 flights of stairs; each scored from 0-4 [84]	Score (0-36)	O	9	56	60+ (67.4-68.8)	30 F, 26 M
FAB scale	Ten static and dynamic balance tasks (stand, reach, turn in a circle, step up and over, tandem walk, one-leg stand, stand on foam with eyes	Score (0-40)	O	10	94	52-89 (65.3-69.5)	64 F, 30 M

(2 studies)	closed, two-footed jump, walk with head turns, maintain a reactive posture), each scored from 0-4 [106, 128]						
CS-PFP-10 (1 study)	10 household tasks, including carrying a pot of water from one counter to another; carrying groceries onto and off a 4-step platform; transferring laundry; donning and removing a jacket; sweeping kitty litter into a dustpan; climbing stairs; sitting down and getting up from the floor; picking up 4 scarves from the floor; 6 m walk; maximal reach [139]	Score (0-100)	O	10	26	60+ (68.6-72.3)	22 F, 4 M

[a]The total number included was the total number of participants in all studies per balance test; [b]M: Male; F: Female; (sex was not reported in all papers, and the number will differ from total included in [a]); OLS: One-leg standing balance; SEBT: Star Excursion Balance Test; TUG: Timed Up and Go; FRT: Functional Reach Test; LRT: Lateral Reach Test; SOT: Sensory Organization Test; BBS: Berg Balance Scale; SPPB: Short Physical Performance Battery; PPT: Physical Performance Test; mPPT: modified Physical Performance Test; FAB: Fullerton Advanced Balance; CS-PFP-10: Continuous Scale-Physical Functional Performance-10 item test; N: Nominal; O: Ordinal; R: Ratio; RMS: Root Mean Square; MPF: Mean Power Frequency; CoP: Center of Pressure; CoG: Center of Gravity; MSL: Maximum Step Length; ft: feet; max: maximum; s: seconds; rep: repetitions; %: percentage; n: number of participants; N/A: not applicable.

Table 2 Muscle strength tests

	Test characteristics		Scale		Study population		
Strength test	**Description / Variation**	**Unit**	**Level**	**Items**	**N[a]**	**Age**	**Sex[b]**
One repetition maximum							
Handgrip strength (54 studies)	Both hands, best trial [150] Bi-handgrip strength, two trials [75] Standing and then grasping a grip device; best of three trials [27] Sitting position, shoulders adducted, neutrally rotated, elbow flexed at 90°, forearm neutral - dominant hand; best of three trials [151] - both hands, three trials for each hand, best score [87] Electronic / hydraulic dynamometer - best trial (number not specified) [8, 34] - two trials [136] - three trials [58]; mean of three trials [133] - best of three trials [37, 42, 122, 126] - standing; mean of three trials [152] - Sitting, shoulders adducted, neutrally rotated, elbow flexed at 90°, forearm neutral; mean of two trials [153] - dominant hand, arm by side; best of three trials [109, 154] - dominant hand, sitting in an upright position, arm of the measured hand unsupported and parallel to the body; one trial [51] - dominant hand, sitting, dominant shoulder in rest position, elbow flexed 90° without support, forearm and wrist at neutral position; best of three trials [138] - dominant hand, sitting comfortably, dominant arm by side, elbow flexed 90°, hand held in mid-supination/pronation position; best of three trials [119] - both hands, one trial in each hand; best score [46]	Force (kg) [2, 8, 27, 34, 37, 42, 50, 51, 73, 75, 78, 93, 108, 119, 122, 126, 134, 136, 138, 140, 144, 150, 151, 153-160, 162-169] [43, 118, 140, 141, 152] [28, 58, 86, 87, 157] Force (pounds) [17] Force (kg)/body-weight (kg) [109] % of people with force scores (kg, classified as weakness) [133] kg/cm^2 [52] Force (pound per square) [161] Force (kPa) [24] Force (Newton) [46]	R	1-2	76148	34-89 (60.4-70.5)	46707 F, 28678 M

- both hands; three trials in each hand, best score for each hand [155]; best trial of the dominant hand [156]
- best score of both hands [140]; best score of each hand [157]; sum of best score of each hand [78]; mean score of each hand [158]
- both hands, wrist in neutral position, elbow flexed at 90°; three trials for each hand; mean of each hand [159]
- both hands, two trials for each hand, mean for each hand and larger mean from one of the hands [144]
- N/A [24]

Bulb hand dynamometer
- both hands, holding at shoulder level, two trials in each hand; mean of both hands added [160]
- dominant hand, medium (women) or large (men) dynamometer, sitting; best of three trials [52]
- both hands, three trials in each hand; mean for each hand [161]
- both hands, two trials in each hand; mean for each hand [162]

Calibrated dynamometer
- both hands, elbow flexed to 90° [108]
- preferred hand, arm raised overhead then slowly lowered towards floor [17]; three trials [28]

Handheld dynamometer
- both hands, standing, best of two trials with each hand [2, 43, 50, 93]
- both hands, two trials on the dominant and three trials on each hand [164]
- two trials; mean score [134]; best score [86, 165]
- dominant hand [118]; mean of two trials [166]; mean of three trials [167]
- sitting, elbow flexed two 90°, best of two trials [141]; best of three trials [168, 169]
- N/A [73, 163]

Shoulder flexor strength (1 study)	Right arm, 90° shoulder flexion, elbow in full extension; mean of three trials [36]	Force (kg)	R	1	85	65-84 (69.0±0.4)	37 F, 48 M
Hip muscle strength (1 study)	Supine on a plinth, both legs 10° abducted, a strap (5 cm wide) around the plinth and over the pelvis; for the examiner-resisted test, participants pushed as hard as possible against the HHD as the examiner provided resistance, stabilizing and positioning the HHD; for the belt-resisted test, HHD is placed between the side of the test leg and a second strap (5cm width), participants spread their legs apart simultaneously as hard as possible [170]	Torques	R	2	20	68.4±5.2	20 F, 0 M
Knee extensor strength (1 study)	Computer-based manual muscle testing, knee at 30° flexion; mean of three trials [36]	Force (kg)	R	1	85	65-84 (69.0±0.4)	37 F, 48 M
Leg strength (1 study)	Sitting in a standard chair (45 cm high), connected to a WBB (57° angle from the ground) via custom seatbelt straps; pressing the feet on the WBB as hard and as fast as possible; three trials [171]	Force (kg)	R	1	30	65+ (69.0±4.2)	18 F, 12 M
Toe grasping strength (1 study)	Barefoot, one-leg stand, both hands on the wall in front, holding the dynamometer grasping bar with the toes [172]	Force (kg)	R	1	57	52-78 (66.3±6.8)	57 F, 0 M
Maximal Isometric Strength (MIS)							
Hip extensor & flexor strength (1 study)	HHD, mean score [117]	& (strength/body weight)	R	1	39	60-78 (68.5-69.7)	15 F, 24 M
Knee extensor strength (4 studies)	HHD, sitting upright, raising lower legs up 90°, parallel to the ground, holding this position as strongly as possible against the maximum persistent (5 s) force applied by the examiner through the HHD placed on the front of the ankle proximal to the medial malleolus; two trials for each leg, best score [173] HHD; mean score [9, 117]	Force (kg) [47, 173] % (strength/body weight) [117] N/kg [9]	R	1-2	621	60-78 (67.3-71.6)	463 F, 158 M

	Leaning back in a chair, extending both legs at the knee while pulling against a dynamometer; best of two trials [47]						
Knee flexor strength (1 study)	HHD, mean score [117]	% (strength/body weight)	R	1	39	60-78 (68.5-69.7)	15 F, 24 M
Leg strength (4 studies)	Dynamometer, both legs simultaneously [174]; mean of two trials [162] Dynamometer, both legs simultaneously, standing with back straight against a wall and knees 115° flexed; a bar connected by a chain to the dynamometer was held in front of the thighs and has to be lifted upwards with maximum force using only the legs, and keeping the neck and back straight; mean of two trials [160, 175]	Force (kg)	R	1	1878	50-79 (61.4-63.3)	907 F, 964 M
Ankle dorsiflexor strength (2 studies)	HHD; mean score [9, 117]	% (strength/body weight) [117] N/kg [9]	R	1	161	60-78 (68.5-69.7)	105 F, 56 M
Muscle power							
Upper body muscle power							
30 second arm curl (9 studies)	Part of the SFT [35, 102, 104, 111, 176] Performing as many biceps curls as possible in 30 s, using a 2.27-kg dumbbell (full range of motion; study in women) [110] Flexing and extending the elbow of the dominant hand, lifting a weight (8 lb [3629g] dumbbell for men; 5lb dumbbell [2268g] for women) through the complete range of motion as many times as possible in 30 s [114] Sitting on a chair, using the dominant hand to bring a weight (2.0 kg) up and down (flex and extend the biceps) as many times as possible in 30 s [118] Hand curling a hand weight (5 pounds for women and 8 pounds for men) for 30 s [95]	Repetitions	R	1	3472	51-89 (62.0-69.9)	2408 F, 1039 M
Abdominal Strength (2 studies)	Lying down on an abdominal pad, with knees flexed at 90°, hands set on the pad frame. Rise	Repetitions	R	1	252	59-60+ (63.0-66.9)	230 F, 122 M

	with the chest up to approximately 30° from the floor as many times as possible in 30 s [108] Lying on sit-up equipment and performing sit-ups with the feet attached to the equipment's foot holders as many times as possible in 30 s [153]						
Single forearm contractions (1 study)	Dynamic single contractions in both arms, HHD at 10%, 20%, and 40% of the subject's maximum voluntary contraction [177]	MVC (kg)	R		32	59-85 (66.0±2)	13 F, 19 M
Lower body muscle power							
Five times Sit-to-Stand (39 studies)	Part of the SPPB [23, 24] Rising from a chair and sitting back down five times [8, 109]; without arm support [157, 178, 179]; time measured at the final sitting down, best of three trials [92] Five repetitive chair stands as quickly as possible with arms folded across the chest [1, 46, 51, 140, 164, 167]); mean of two trials [7, 180]; mean of three trials [68, 126] Sitting in a standard chair, arms folded across the chest, standing up and sitting down five times as fast as possible [165] Getting up and sitting from a chair (43 cm high, flat seat), arms crossed over the chest, rising until full extension at trunk and lower limb joints, and returning with the back fully supported at the back of the chair; best of two trials [99] Standard chair (43.2 cm high), transferring to a standing position and returning to a sitting position, not allowed to use arms [181] Standard padded chair (43.2 cm high) without armrests, both arms crossed against the chest, starting from a seated position and standing up (legs straight) and sitting down (full weight on the chair) [182] Getting up from and sitting down on the chair (43.6 cm high) without arm rests [100]	Time (s) [1-3, 5, 6, 8, 19, 23, 39, 46, 51, 60, 66-68, 77, 84, 90, 92, 99, 100, 109, 126, 140, 157, 164, 165, 167, 173, 178, 179, 181-186] Score (0-4) [24]	R	1	39988	40-90+ (58.7-71.0)	21395 F, 18511 M

	Standing and sitting five times from an armless chair (46 cm high), not permitted to use arms [90]
	Straight-back chair, placed against a wall, with a hard seat and standard height, sitting with the feet on the floor and arms folded across the chests on the chair, time measured at the final standing position [2]
	Standing up and sitting down as quickly as possible five times in a row from an armless straight-back chair, arms across the chest, time measured at the final standing position [5]; time measured at the final sitting position [3]
	Sitting in a hard-backed chair (43 cm high), arms folded across the chest, rising as fast as possible to a full standing position, then returning to a full-sitting position five times [66, 67]
	Rising fully from a standard armless, backless chair five times as fast as possible, arms folded closely to the trunk, no moving of the feet during the test, time measured at the final sitting position [32]
	Standing up from a straight-backed chair (43 cm high) five times at a self-selected pace, arms folded across the chest [39]
	Sitting on a chair with the back touching the backrest, seat height adjusted to participant's lower leg length, knees flexed at 90°, time measured at the final sitting position [183]
	Standing up and sitting down five times as quickly as possible from a straight-backed chair [184]; time measured at the final standing position [19]
	Standard chair with arm rests, both arms crossed against the chest, starting from a seated position (upper back against seat), standing up to full extension and sitting down again (upper back against seat), best of two trials [84]
	N/A [6, 60, 77, 173, 185]

One time sit-to-stand (6 studies)	Sitting in a straight-back chair, barefooted, on cue, standing up and sitting down as quickly as possible, upper extremity use not permitted [17] Sitting on a chair (43 cm high), on cue, rising to full stance; best of three trials [187] Adjusted seat height (5 cm increments from 45 to 60 cm) to achieve a 90/90 (hip/knee angle), sitting on the front half of an instrumented chair, using the arms as normally during the task, while standing as quickly as possible, three trials [91] Chair rise from different seat heights (43 cm, 38 cm, 30 cm) [188] Standing up as quickly as possible from a standard chair (43 cm high), arms crossed across the chest and feet shoulder-width apart placed flat on the floor [4] N/A [189]	Time (s) [4, 17, 187-189] Force (N/s [kg]; W [kg]) [91]	R	1	378	60-74 (61.6-69.9)	215 F, 63 M
Ten times sit-to-stand (4 studies)	Rising from a sitting to a standing position with straight back and legs and sitting down again as fast as possible [37] Straight-backed chair (45cm high), arms crossed against the chest, rising as quickly as possible without the use of the hands [168, 169] N/A [61]	Time (s) [61, 168, 169] Speed (stands per minute: [10/s]*60) [37]	R	1	1997	50-81 (62.6-66.9)	1054 F, 943 M
15 second Sit-to-stand (1 study)	Straight-backed, nonpadded, flat-seated, armless chair, Standing without using hands or arms, arms folded across the chest; mean of two trials [134]	Repetitions	R	1	5777	65-79 (69.8-70.1)	5777 F
30 second sit-to-stand (35 studies)	Part of the SFT [35, 42, 102-104, 106, 107, 176]; two trials [105] Part of the Fullerton Functional Fitness Test [111] Standing in front of a stable chair, hands across the chest, then practicing sitting down and standing up for 30 s [27] Sitting in a chair (43 cm high) with arms crossed at the wrists and holding against the chest, then	Repetitions	R	1	4961	51-91 (62.0-71.6)	3345 F, 1589 M

	standing up as many times as possible [112, 113, 190])	
	Sitting on a standard armless chair (45 cm high), looking straight forward with arms folded across the chest, then standing up and sitting down as many times as possible [108]	
	Rising up and sitting down with arms folded in front of the chest as quickly as possible on a firm, armless chair placed against a wall [58, 191]	
	Standing up and sitting down from a bench without armrests and back support as many times as possible, feet flat on the floor, initial foot placement and chair height individually adjusted [192]	
	Stand up from a seated position as many times as possible [193]	
	Stand fully upright and then return to the seated position as many times as possible [47, 48, 62, 114, 115]	
	Different chair heights (43 cm; then adjusted to 80, 90, 100, 110 and 120% of the participants' lower leg length), last attempt at the end of 30 s is counted as a full stand if the participant is more than halfway up from sitting [186]	
	Standard padded chair (43.2 cm high) without armrests, starting from the seated position and standing up (legs straight) and sitting down (full weight on the chair); mean of two trials [182]	
	Sitting on a chair, back straight, feet shoulder-width apart and flat on the floor, arms crossed at the wrists and held against the chest, then rising to a full stand and returning to a fully seated position as many times as possible [118]	
	Chair (44 cm high) without arms, sitting in the middle of the chair, feet shoulder width apart and placed on the floor at an angle slightly behind the knees, arms crossed at the wrists and held against the chest, then rising to a full stand and returning back to the initial seated position, as many full stands as possible; mean of two trials [12, 13]	

	Sitting in the middle of the chair, arms across the chest, then rising to a full stand and returning to a fully seated position as many times as possible [95] Standard chair with arm rests, both arms crossed against the chest, starting from a seated position (upper back against seat), standing up to full extension and sitting down again (upper back against seat); best of two trials [84] Sitting in a standard-height chair with arms crossed over the chest, then stand fully and sit down again as many times as possible [70] N/A [9, 22, 69, 152]						
1 minute sit-to-stand (2 studies)	Stand up from and sit down from a standard height chair without the use of the arms [194] Sitting on the edge of a standard-height chair, arms crossed over the chest, and repeatedly standing up from and returning to a seated position without assistance [4]	Repetitions	R	1	123	55-70 (62.2-70.7)	76 F, 47 M
One time kneel-to-stand (1 study)	Part of MOD scale [188]	Score (0-5)	R	1	259	60+ (67.6±7.0)	143 F, 116 M
Floor rise to standing (2 studies)	Lying in a supine position, with feet together and hands palm down and at the side, then rising to a standing position [66, 67]	Time (s)	R	1	49	65-84 (69.1-69.3)	26 F,23 M
Five Step Test (1 study)	N/A [173]	Time (s)	R	1	621	50+ (66.8-69.4)	428 F, 193 M
Stair climbing (1 study)	Walking up and down a standard flight of stairs, three times at self-selected pace, using the handrail for support only if needed [39]	Time (s)	R	1	1133	55-79 (63.8-64.1)	632 F, 501 M
Stair climbing (8 steps) (1 study)	Climbing eight steps (17 cm high, 31cm long) without using the handrail, requiring a step by step pattern; best of two trials [99]	Time (s)	R	1	26	65.6-67.8	N/A

Stair climbing (10 steps) (3 studies)	Climbing a flight of stairs (10 steps) as quickly as possible without using the handrails or any other aid (14 cm high [62]; 7.8 cm high [64] Ascending and descending a flight of stairs (10 steps, 0.27 m high and 0.18 m deep) as quickly and safely as possible, while having the option of using a single handrail for support [195]	SCP (W) [62, 64] Time (s) [195]	R	1	212	50-75 (62.7-71.5)	152 F, 67 M
Stair climbing (11 steps) (3 studies)	Ascending a standard fight of stairs (11 stairs, 16 cm high), avoiding the use of the handrail [66, 67]; as rapidly as possible [65]	Time (s) [65-67] SCP (W) [66, 67]	R	1	77	65-84 (68.9-69.3)	37 F,40 M
Stair climbing (12 steps) (1 study)	Ascending and descending 12 stairs, permitted to use the handrail, but not allowed to use it to push or pull oneself [181]	Time (s)	R	1	44	45-80 (58.7-61.4)	29 F, 15 M
Stair climbing (14 steps) (1 study)	Walk as fast as possible up 14 stairs without the use of railings [191]	Time (s)	R	1	30	68.5±5.1	15 F, 15 M
Stair climbing (15 steps) (1 study)	Ascending and descending a flight of 15 stairs (18 cm high, 27 cm tread) at normal pace, preferably without using the handrail [98]	Time (s)	R	1	134	69.6-70.3	85 F, 49 M
Stair ascent (23 steps) (1 study)	Walking up one flight of stairs consisting of 23 steps (16.5 cm high, 19.2 cm wide) as quickly as possible; after 14 steps, the participants make a left-hand wrap-around turn and then completed the remaining nine steps; not allowed to use the handrails; best of the two trials [196]	Time (s)	R	1	62	60-83 (66.6-71.0)	N/A
Stair ascent (10 steps) (4 studies)	Ascending a 10-stair prop (17 cm high, 30 cm deep) at fast pace [109] Walking up 10 steps in an expeditious and safe manner, placing one hand close to the handrail for balance if necessary, but not on the handrail [179] Ascending a 10-stair flight (16.5 cm stair high) as fast as possible, use of handrail allowed [51]	Time (s)	R	1	158	62-80 (66.0-70.0)	69 F, 35 M

	Climbing 10 steps as fast as comfortably possible with one hand near, but not on, the handrail [137]						
Stair ascent (4 steps) (1 study)	Walking up 4 stairs (15 cm high), arriving on a full stance on the fourth step without any support or help, three trials, best score [187]	Time (s)	R	1	33	60-74 (64.4-65.7)	21 F, 12 M
Stair ascent (one time) (1 study)	Part of MOD scale [188]	Score (0-5)	R	1	259	60+ (67.6±7.0)	143 F, 116 M
Stair descent (10 steps) (1 study)	Walking down 10 steps in an expeditious and safe manner, placing one hand close to the handrail for balance if necessary, but not on the handrail [179]	Time (s)	R	1	19	66.0±1.0	14 F, 5 M
Stair descent (one time) (1 study)	Part of MOD scale [188]	Score (0-5)	R	1	259	60+ (67.6±7.0)	143 F, 116 M
Functional leg extensor strength (1 study)	Taking a short step forward, first with the right leg, squat down until the knee of the tracking leg lightly touches the mat, and then rise up immediately and step back to the starting position, then repeating with the left leg [39]	Maximal weight relative to the subject's body weight	R	1	1133	55-79 (63.8-64.1)	632 F, 501 M
Lift and reach (one minute) (2 studies)	Sitting at a standard height desk, then repeatedly lifting a weight onto and off a shelf placed on the desk located at shoulder level immediately in front (10 pound for women, 20 pound for men) [194] Sitting in a standard chair at a standard height desk (75 cm), then lifting a weight repeatedly onto and off a shelf positioned at approximate shoulder height, 37 cm above the desktop (5 kg dumbbell for women, 8 kg dumbbell for men) [4]	Repetitions	R	1	123	55-70 (62.6-70.7)	76 F, 47M
Standing long jump (1 study)	Jumping horizontally, using a 2-ft. takeoff and landing, three trials, measured at the heel of the foot [28]	Distance (cm)	R	1	73	50-79	43 F, 30 M

Single knee extension contractions (1 study)	Single knee extension contractions with a hand-grip device at 20%, 40%, and 60% of the subject's max voluntary contraction [177]	Maximum work rate (WR_{max})	R	3	32	59-85 (66.0±2.0)	12 F, 19 M

[a]The total number included was the total number of participants in all studies per strength test; [b]M: Male; F: Female; (sex was not reported in all papers, and the number will differ from total included in [a]); s: second ds; rep: repetitions; cm: centimeter; R: Ratio; N: number of participants; HHD: Hand Held Dynamometer; WBB: Wii Balance Board; SFT: Senior Fitness Test; MVC: Maximum Voluntary Contraction; MOD scale: Modification scale; SCP: Stair Climbing Power.

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Additional file 3

Table 1. The quality of studies assessing validity and /or reliability of included balance and strength tools and the rating of the reported results

			Validity		**Reliability**			
Assessment Tool			Construct		Inter-rater		Test-retest	
	ref	n	Quality of study	Reported result	Quality of study	Reported result	Quality of study	Reported result
TUG	[1]	12					P	PCC .90-.97
	[2]	10			P	$ICC_{3,1}$ .97		
SPPB	[3]	150	E	N/A			G	ICC .87

Notes: Balance Tools: Timed Up-and-Go (TUG), Short Physical Performance Battery (SPPB). Quality of study (COSMIN): excellent (E), good (G), fair (F), poor (P); Pearson Correlation Coefficient (PCC), Intraclass Correlation Coefficient (ICC), number (n), reference (ref), Not Applicable (N/A),

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Manuskript 2

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RESEARCH ARTICLE Open Access

Concurrent validity and reliability of the Community Balance and Mobility scale in young-older adults

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Abstract

Background: With the growing number of young-older adults (baby-boomers), there is an increasing demand for assessment tools specific for this population, which are able to detect subtle balance and mobility deficits. Various balance and mobility tests already exist, but suffer from ceiling effects in higher functioning older adults. A reliable and valid challenging balance and mobility test is critical to determine a young-older adult's balance and mobility performance and to timely initiate preventive interventions. The aim was to evaluate the concurrent validity, inter- and intrarater reliability, internal consistency, and ceiling effects of a challenging balance and mobility scale, the Community Balance and Mobility Scale (CBM), in young-older adults aged 60 to 70 years.

Methods: Fifty-one participants aged 66.4 ± 2.7 years (range, 60–70 years) were assessed with the CBM. The Fullerton Advanced Balance scale (FAB), 3-Meter Tandem Walk (3MTW), 8-level balance scale, Timed-Up-and-Go (TUG), and 7-m habitual gait speed were used to estimate concurrent validity, examined by Spearman correlation coefficient (ρ). Inter- and intrarater reliability were calculated as Intra-class-correlations (ICC), and internal consistency by Cronbach alpha and item-total correlations (ρ). Ceiling effects were determined by obtaining the percentage of participants reaching the highest possible score.

Results: The CBM significantly correlated with the FAB ($\rho = 0.75$; $p < .001$), 3MTW errors ($\rho = -0.61$; $p < .001$), 3MTW time ($\rho = -0.35$; $p = .05$), the 8-level balance scale ($\rho = 0.35$; $p < .05$), the TUG ($\rho = -0.42$; $p < .01$), and 7-m habitual gait speed ($\rho = 0.46$, $p < .001$). Inter- ($ICC_{2,k} = 0.97$), intrarater reliability ($ICC_{3,k} = 1.00$) were excellent, and internal consistency ($\alpha = 0.88$; $\rho = 0.28$–0.81) was good to satisfactory. The CBM did not show ceiling effects in contrast to other scales.

Conclusions: Concurrent validity of the CBM was good when compared to the FAB and moderate to good when compared to other measures of balance and mobility. Based on this study, the CBM can be recommended to measure balance and mobility performance in the specific population of young-older adults.

Trial registration: Trial number: ISRCTN37750605. (Registered on 21/04/2016).

Keywords: Aging, Balance, Mobility, Physical performance, Assessment, Measurement properties, Older adults

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Background

Balance ability generally starts to decline in the third decade of life [1], with an accelerated decline occurring in the sixth decade [2, 3]. Older adults (≥65 years) are more prone to experience a loss of function preventing them to maintain posture and respond to unexpected perturbations caused by slips or trips [4]. Young-older adults of retirement age (60–69 years [5]) generally function at a higher level compared to (old-) older adults. However, their more active lifestyle potentially exposes them to more high-risk balance-challenging situations. Subsequently, the risk for stumbles and near-falls is significantly higher [6]. With a dramatic increase in the proportion of young-older adults (baby boomer generation), a paradigm shift is requested towards early stage innovative population-level efforts to prevent loss of balance [7].

Regular physical activity (PA) is important to maintain independence and prevent functional decline. Current guidelines for older adults aged ≥65 years recommend at least 150 min of moderate intensity or 75 min of vigorous intensity aerobic training per week [8]. Persons with poor mobility should undertake training three or more days per week to improve balance and prevent falls [8]. However, less than 50% of older adults meet the current PA recommended [9] and only 6% complete regular balance training [10].

In order to promote early balance and mobility interventions, adequate assessment strategies are needed to identify subtle balance and mobility deficits in relatively active, high-functioning young-older adults. To date, most balance and mobility assessment tools have been developed to quantify deficits in frail older adults aged ≥70 years [11–16]. Current systematic reviews focusing on functional balance assessment have shown that several assessment tools developed for older adults are not appropriate for detecting early balance and/or gait deficits in community-dwelling older adults with a more active lifestyle [17, 18]. For example, the Berg Balance Scale (BBS), a widely-used, valid and reliable test of functional balance in frail older adults aged ≥70 years [12, 18]. This test reached ceiling effects when used in community-dwelling older adults aged ≥60 years [15, 17, 18]. With most of the items focusing on basic functional mobility (e.g. transfers, standing unsupported, sit-to-stand), the BBS does not include challenging dynamic balance tasks such as tandem walking, hopping, or climbing stairs. Likewise, the Short Physical Performance Battery (SPPB) was initially developed for community-dwelling older adults aged ≥70 years [19]. This test has also shown ceiling effects in higher-functioning community-dwelling older adults aged ≥60 years [15, 20]. Ceiling effects of these instruments do not only hamper the detection of early balance deficits, but also prevent the detection of intervention-related changes over time in higher functioning older adults [20, 21].

Current systematic reviews focusing on mobility in older adults conclude that tests such as the Timed Up and Go (TUG) test, the Dynamic Gait Index (DGI), or the Performance Oriented Mobility Assessment also suffer from ceiling effects when applied in independently living, higher functioning older adults [13, 17]. They are not challenging enough to adequately assess the performance of older adults who do not display marked mobility deficits, because they lack more demanding mobility components such as turning the head while walking [11, 13, 14, 17, 22].

In summary, several studies have shown that balance and mobility measures developed for older, frailer adults show ceiling effects when applied in high-functioning older adults [13, 15, 17, 18, 20, 23]. The lack of high-challenging balance tasks in the aforementioned scales can result in early signs of balance and mobility decline to remain unidentified. This makes the currently available balance and mobility tests less suitable when the aim is to determine intervention eligibility aimed at preventing decline in balance and mobility at an early stage [13, 24, 25].

In this context, the applicability of the Community Balance and Mobility Scale (CBM) has recently generated significant interest in clinical practice for assessing balance and mobility deficits in community-dwelling older adults, either healthy (mean age 70.3 years [26]) or with knee osteoarthritis (mean age 62.5 years [27]). Unlike commonly used balance and mobility tests such as the BBS [12], SPPB [19] or the Tinetti test [14], the CBM includes several challenging tasks to assess specific aspects of balance and mobility which are necessary to function independently within the community. For example, walking while gaze shifting and turning the head, picking up an object from the floor (crouching) while walking, and complex walking maneuvers, such as forward to backward walking, sideways walking, or suddenly stopping, are included in the CBM [28, 29]. The CBM was initially developed to measure subtle balance deficits in patients with mild traumatic brain injury aged 26.2 years [30] to 31.0 years and is found to be valid and reliable in this population [28, 30].

Recently, the CBM has been validated in a sample of independently living, community-dwelling older adults aged ≥65 years (mean age 73 ± 7), showing excellent correlations with the BBS ($\rho = 0.87$), good correlations with the Timed Up and Go test ($\rho = -0.69$) and self-selected gait speed ($\rho = -0.65$) [26]. Reliability of the rating scheme was also analyzed based on videotaped assessments resulting in high inter- ($ICC_{2,k} = 0.95$; 95% CI = 0.88–0.98) and intrarater reliability ($ICC_{3,k} = 0.96$; 95% CI = 0.93–0.98) [26]. Moreover, the CBM showed no ceiling effects as compared to BBS (23%) and SPPB (33%) [26].

While these findings suggest that the CBM has added value in the assessment of community-dwelling older adults, the measurement properties in the specific population of young-older adults aged 60–70 years are yet to be evaluated. Young-older adults are an extremely heterogeneous population, where some older adults have substantial balance and mobility deficits while others have only minor deterioration in balance performances [31]. The CBM may represent a specific assessment tool for detecting both minor and major balance and mobility deficits in this population, and in turn may allow early interventions to be tailored to prevent functional decline.

In this study, we aimed to examine the concurrent validity and reliability of the CBM in community-dwelling healthy young-older adults (60 to 70 years). The evaluation was performed as preparatory part of the European Commission funded project PreventIT (Horizon 2020 grant no 689238), which aims to develop a lifestyle-integrated training intervention to prevent functional decline in young-older adults.

The first aim of the present study was to examine the concurrent validity of the CBM by comparing its scores to other established balance and mobility measures thought to have related theoretical constructs. We expected a positive association with the Fullerton Advanced Balance Scale [32] as this scale has also been developed to measure balance problems of varying severity in functionally independent older adults. We expected a negative association with the Timed Up-and-Go test [33] based on previous validation studies in older adults [26, 27]. Furthermore, we hypothesized moderate to good associations with balance tests measuring static steady-state balance control (8-level balance scale, comprising the five level balance scale from the SPPB and additional challenging tasks at a higher level, such as "tandem stand eyes closed" [34]) and dynamic steady-state balance control (3 Meter Tandem Walking [34], and gait speed [26–28, 30, 35]). The second aim was to investigate the ceiling effects of the CBM as compared to other challenging balance and mobility assessments which, based on previous findings, were expected to be lower for the CBM [26, 27, 30]. The third aim was to investigate the intra- and interrater reliability of the rating scheme of the CBM, which was expected to be high based on previous studies in other populations [26, 28]. Finally, we aimed to analyze the internal consistency reliability.

Methods

Design

We used a cross-sectional study design for evaluating the concurrent validity and potential ceiling effects of the CBM. The inter- and intra-reliability was also obtained based on video-recordings of the assessments (described below). The data collection was embedded into the PreventIT project (phase 1). PreventIT is a three-year project aiming at developing a lifestyle-integrated training intervention for young-older adults aged 60 to 70 years. Phase 1 of the PreventIT project included pilot studies at the sites involved in the project (Stuttgart, Heidelberg, Amsterdam, and Trondheim). The pilot studies aimed to test the measurement properties of balance and mobility instruments in young-older adults. Another purpose of the PreventIT pilot studies was to test the feasibility of the lifestyle-integrated training intervention using questionnaires and focus groups. This feasibility testing occurred after the cross-sectional study for validating the CBM and did not influence this study.

Participants

For the purpose of evaluating the measurement properties of the CBM in the specific population of young-older adults, we included 51 community-dwelling young-older adults. Inclusion criteria for this study were: community-dwelling older adults aged between 60 and 70 years, able to walk independently, and no cognitive impairment (Montreal Cognitive Assessment [36] ≥ 26 points). Participants were excluded if they reported severe cardiovascular, pulmonary, neurological, or mental disease. Participants were recruited for the pilot studies with the main purpose of examining a lifestyle-integrated training intervention in Germany (Robert-Bosch Hospital, Stuttgart; Heidelberg University), Norway (Norwegian University of Science and Technology), and the Netherlands (Vrije Universiteit Amsterdam). Ethical approval from the local institution review boards as well as written informed consent from participants were obtained in all four study centers prior to participation.

Measures

Demographics and clinical variables were collected, including age, sex, body mass index, comorbidities, falls history in the previous year, and five performance-based assessment tests of balance and mobility as described in the following.

Balance and mobility assessments

The Fullerton Advanced Balance (FAB) scale is designed to identify balance deficits [32, 37] and has been validated in functionally independent older adults aged 75 ± 6 years with increased fall risk [32]. It includes 10 items scored from zero to four (higher values indicate better performance) with a maximum score of 40 points [32]. The tasks on the FAB are "Stand with feet together and eyes closed", "Reach forward to retrieve a pencil held at shoulder height with outstretched arm", "Turn 360 degrees in right and left directions", "Step up onto and over a 6-inch bench", "Tandem walk", "Stand on one leg", "Stand on foam with eyes closed", "Two-footed jump", "Walk with head turns", and "Reactive postural control".

The 8-level balance scale is an extended version of the SPPB [19] that incorporates several higher-level balance performance tasks [34]. The items are "Side-by-side Standing, narrow base Romberg" (eyes open; eyes closed), "Semi Tandem" (eyes open), "Tandem Stand" (eyes open; eyes closed), and "One Leg Stand" (eyes open; eyes closed; eyes closed with cognitive distractor). Participants have to complete successfully a balance task for 30 s before progressing to the next task. The highest level of balance test performed successfully was rated (maximum score: 8).

The three meter tandem walk (3MTW) test is a modified version of the FAB [32], measuring dynamic balance. The test requires participants to complete a three meter walk heel-toeing as quickly as possible, with as few errors as possible [34]. Number of errors during walking were defined as touching examiner or object in the environment, making a step with no heel-toe contact, or touching the ground in some other spot on the way to positioning the foot where it should be [34]. The time for completion (seconds) and the number of errors were recorded in a subsample ($n = 31$).

The Timed-Up-and-Go (TUG) test is a valid test evaluating basic functional mobility of older adults [33]. The test requires participants to stand up from a standard arm chair (45 cm height), walk three meters, turn around, walk back, and sit down again while being timed with a manual stopwatch [33, 38]. The time for completion (seconds) was recorded.

Gait speed measurement was derived from the InChianti gait assessment [35]. Participants are instructed to walk seven meters at their usual pace while being timed using a manual stopwatch. Gait speed was calculated by dividing the length of the walkway by the time used from start to finish (meters per seconds).

The CBM scale evaluates high-level balance and mobility on 13 items, with six items performed with both the right and left side of the body, resulting in a total of 19 tasks, scored from zero ("unable to perform") to five ("performs independently") and is suggested to represent underlying functional skills required in the community [28]. The tasks are "Unilateral Stance", "Tandem Walking", "180 Degree Tandem Pivot", "Lateral Foot Scooting", "Hopping Forward", "Crouch and Walk", "Lateral Dodging", "Walking and Looking", "Running with Controlled Stop", "Forward to Backward Walking", "Walk, Look & Carry", "Descending Stairs", and "Step-Ups x1 Step" [28]. Higher scores are indicative of better balance and mobility. One item (descending stairs) offers an extra point if participants are able to carry a basket while descending stairs [29]. Individual tasks of the CBM were scored, giving a maximum summary score of 96 points.

Testing procedure

Data collection took place in movement laboratories at four test sites: (1) Germany (Robert-Bosch Hospital, Stuttgart), (2) Germany (Heidelberg University), (3) Norway (Norwegian University of Science and Technology), and (4) the Netherlands (Vrije Universiteit Amsterdam). All tests were conducted in a single assessment lasting about 1.5–2 h. All participants wore their own low-heeled shoes and were allowed sufficient rest periods at any given time. Trained research staff conducted the assessments.

The CBM testing sessions were videotaped with a digital camera (Sony HDR-CX240E) in full HD, which also recorded the sound, an important feature for the subsequent rating (e.g. to hear the start signal of several tests). Camera height was fixed at 1 m and specific camera positions and angles for each task were predetermined in order to standardize the video recording. The videotaped assessments were scored by two experienced examiners to evaluate interrater reliability. Both raters had on average five years' experience in assessing balance and mobility using different scales. They received a standardized manual on how to perform the CBM and carried out over 10 assessments. One rater was an exercise scientist (MW), the other a physical therapist (KG). Both raters scored each item independently, being allowed to watch the videos twice, and each of them was blinded to the rating of the other assessor. To determine intrarater reliability, videotaped performance on the CBM was assessed by the same rater a second time three weeks after the first rating.

Statistical analyses

Concurrent validity

Concurrent validity between the CBM and the other balance and mobility tests was assessed using the Spearman's rank correlation coefficient (ρ) since the results of the 8-level balance scale ($p < .001$), errors during 3MTW ($p < .001$), and gait speed test ($p < .05$) were not normally distributed according to the Kolmogorov-Smirnov test. Correlation coefficients of $\rho < 0.25$ were considered as small; 0.25–0.50 as moderate; 0.50–0.75 as good; and > 0.75 as excellent [39].

The determination of the sample size for Spearman's rank correlation coefficient was based on 2-tailed $\alpha \leq 0.05$, statistical power greater than 80%, and a correlation threshold value for the correlation coefficient of 0.50 according to previous validation studies [26, 28, 30]. Based on these assumptions, the minimum sample size required was $n = 29$ [40].

Additionally, exploratory analyses were performed using t-tests in order to examine differences in the CBM performance with regard to the history of falls (fallers vs. non-fallers). T-test was used since the results of the CBM were normally distributed.

Inter- and Intrarater reliability and internal consistency

Intraclass Correlation Coefficients (ICC) were utilized for total score interrater ($ICC_{2,k}$) and intrarater ($ICC_{3,k}$) reliability [41]. Desirable standards for reliability coefficients are reported to range from 0.90–0.95 [42]. Inter- and intrarater reliability for each item were evaluated with a generalized kappa statistics [43]. Internal consistency was assessed by Cronbach's alpha coefficient and item-total correlations, utilizing Spearman's rank correlation coefficient (ρ). Internal consistency with an $\alpha > 0.9$ was considered as excellent, > 0.8–0.9 as good, > 0.7–0.8 as acceptable, > 0.6–0.7 as questionable, > 0.5–0.6 as poor, and ≤ 0.5 as unacceptable [44].

Item-total correlations, assessed for each individual item and the total CBM score, with a value > 0.2 were considered as satisfactory [45].

Ceiling effects

Descriptive statistics included mean, standard deviation, minimum and maximum values of the applied tests. Ceiling effects were analyzed by calculating the percentage of individuals obtaining the highest possible score for the included scales, but only for those assessments which have a clearly predefined minimum or maximum score (CBM, FAB, and 8-level balance scale).

Statistical analysis was performed using IBM SPSS Statistics Version 24.0 (IBM Inc., New York, USA).

Results

A total of 51 participants aged 66.4 ± 2.7 years (range, 60–70 years; 74.5% female) were tested. Participant characteristics are summarized in Table 1. The number of participants included in the different analyses varied (N = 31–51). For the TUG and gait speed test, the first five participants were not assessed. For the participants in Heidelberg (n = 16), 3MTW performance was rated only by errors, but not by time. Because time was unavailable, these participants were excluded from statistical analysis on the 3MTW test, resulting in a subsample of 31 participants for which information on time and errors was available.

Table 1 Characteristics of the participants (n = 51)

	Mean (SD) or % (n)
Country	
Germany (Stuttgart, Heidelberg)	60.8% (31)
Norway (Trondheim)	19.6% (10)
The Netherlands (Amsterdam)	19.6% (10)
Age, years	66.4 (2.7)
Women	74.5 (38)
Body-Mass-Index, kg/m^2	28.2 (6.0)
Comorbidities, number	1.2 (1.2)
Fallers	19.6% (9)
Number of falls (last 12 months)	0.3 (0.6)

N = 51; *SD* Standard Deviation

Concurrent validity of the CBM

Figure 1 displays the association between CBM and FAB (ρ = 0.75; 95% CI = 0.59; 0.85, p < .001).

Good correlations were found between CBM and 3MTW errors (ρ = − 0.61; 95% CI = − 0.83; − 0.33, p < .001). Moderate correlations were found between CBM and gait speed (ρ = 0.46; 95% CI = 0.22; 0.66, p < .001), TUG (ρ = 0.42; 95% CI = − 0.10; − 0.67, p = .006), 8-level balance scale (ρ = 0.35, 95% CI = 0.04; 0.61, p = .013), and 3MTW time (ρ = − 0.35; 95% CI = − 0.65; 0.00, p = .05) (Table 2). For the discriminative ability of the CBM, no statistically significant differences were identified between fallers (mean score 58.3 ± 14.6) and non-fallers (mean score 66.3 ± 11.8; p = .09).

Inter- and intrarater reliability and internal consistency of the CBM

Inter- and intrarater reliability coefficients were excellent with $ICC_{2,k}$ evaluating interrater reliability at 0.97 (95% CI = 0.94–0.98) and $ICC_{3,k}$ evaluating intrarater reliability at 1.00 (95% CI = 0.99–1.00).

Kappa values for individual item reliability are summarized in Table 3. All kappa values were statistically significant (p < 0.001). For intrarater reliability, kappa values for 10 of the 19 items were above 0.80 (very good agreement), the other nine were between 0.61 and 0.80 (good agreement). For interrater reliability, two items were above 0.80, ten between 0.61 and 0.80, five between 0.41 and 0.60 (moderate agreement). Two items showed low kappa value of 0.31 and 0.34 respectively [46].

Internal consistency was evaluated, with a Cronbach's alpha of 0.88, indicating good internal consistency.

Item-total correlations ranged from 0.81 ("Hopping forward left") to 0.28 ("Lateral dodging"). The five items which most strongly correlated with the CBM total score were "Hopping forward left/right", "Unilateral stance left", "Forward to backward walking", and "Lateral foot scooting left" (Table 4).

Ceiling effects of the CBM and other assessment tools

The participants' scores are presented in Table 5. The distribution of the CBM scores in the overall sample was negatively skewed, with a median score of 67 points, being higher than the midpoint of the scale (48 points). On the CBM and 8-level balance scale, 0% reached the full score. On the FAB, 2% reached full score.

Discussion

This study is the first to analyze the measurement properties of the CBM in a sample of young-older adults aged 60 to 70 years. As hypothesized, a good correlation with the FAB was found, indicating strong construct validity of the CBM in the target population of young-older adults. Furthermore, moderate to good correlations with

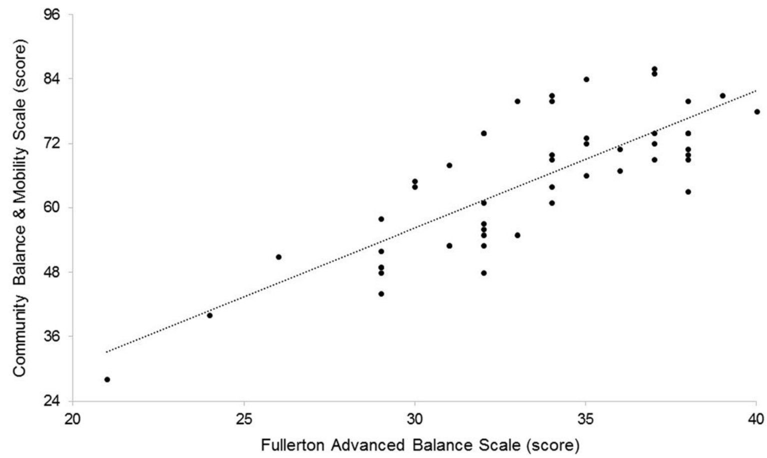

Fig. 1 Relationship between CBM total scores and FAB total scores ($n = 49$)

other measures suggest that the CBM measures mobility performance (TUG), dynamic steady-state balance control (3 MTW, and gait speed) and static steady-state balance control (8-level balance scale). This is in line with previous studies estimating the measurement properties of the CBM in older adults [26] or those with mild traumatic brain injury [28, 30]. Importantly, the CBM does not show ceiling effects in contrast to other advanced balance scales such as the FAB.

A good correlation was found between the CBM and FAB, showing that both measure a similar construct. Both scales assess performance of more challenging balance tasks, including static, dynamic, proactive, and reactive balance control [28, 30, 32]. The ceiling effect in the FAB may have prevented a higher correlation with the CBM. However, it may also indicate that the tasks within the FAB are not challenging enough to discern difficulties in balance performance in high-functioning older adults [26, 28]. Moreover, the FAB was developed and evaluated to analyze balance impairments in community-dwelling older adults, rather than detecting subtle balance deficits in high-functioning older adults [32]. The correlation with the TUG was moderate ($\rho = -0.42$), which was lower than expected and lower than reported in a previous study which validated the CBM in older adults [26]. The lower correlation in our sample of young-older adults might be explained by the fact that the TUG is not a highly

Table 2 Correlations between CBM and balance, gait, and walking outcomes

Balance and/or mobility tests	Spearman correlation with CBM score		
	ρ (p)	95% CI	*p*-value
FAB scale (score)	0.75	0.59; 0.85	<.001
8-level balance scale (score)	0.35	0.03; 0.61	.013
3MTW test (seconds)[a]	−0.35	−0.65; 0.00	.05
3MTW test (errors) [a]	−.61	−0.33; − 0.83	<.001
TUG test (seconds)[b]	−0.42	−0.10; − 0.67	.006
Gait speed (cm/seconds)[b]	0.46	0.22; 0.66	<.001

CBM Community Balance & Mobility Scale, *FAB* Fullerton Advanced Balance Scale, *3MTW* 3 Meter Tandem Walk, *TUG* Timed Up-and-Go; ρ Spearman correlation coefficient, *CI* Confidence Interval
[a]Data reported on 31 participants; [b]Data reported on 46 participants

Table 3 Inter- and intrarater reliability on item level

	Kappa values (SE)[a]	
Test item (0–5 points)	Intrarater reliability	Interrater reliability
Unilateral stance left	0.94 (0.04)	0.67 (0.08)
Unilateral stance right	0.91 (0.05)	0.78 (0.08)
Tandem walking	0.85 (0.07)	0.74 (0.08)
180° Tandem pivot	0.84 (0.07)	0.55 (0.10)
Lateral foot scooting left	0.91 (0.05)	0.73 (0.08)
Lateral foot scooting right	0.82 (0.07)	0.68 (0.08)
Hopping forward left	0.81 (0.07)	0.59 (0.08)
Hopping forward right	0.78 (0.07)	0.48 (0.09)
Crouch and walk	0.80 (0.08)	0.54 (0.10)
Lateral dodging	0.90 (0.07)	0.67 (0.11)
Walking and looking left	0.75 (0.11)	0.66 (0.12)
Walking and looking right	0.70 (0.12)	0.31 (0.12)
Running with controlled stop	0.75 (0.10)	0.88 (0.08)
Forward to backward walking	0.70 (0.10)	0.34 (0.09)
Walk, look and carry left	0.62 (0.13)	0.49 (0.12)
Walk, look and carry right	0.75 (0.12)	0.68 (0.13)
Descending stairs	0.79 (0.20)	0.85 (0.15)
Step-ups × 1 step left	0.92 (0.05)	0.65 (0.10)
Step-ups × 1 step right	0.91 (0.60)	0.77 (0.10)

SE Standard Error
[a]All kappa values are statistically significant with *p*-values = 0.000

Table 4 Item analyses of the CBM (n = 51)

Test item	Item analyses (ρ) Item-total correlation[a] (RO)
Unilateral stance left	0.71 (2)
Unilateral stance right	0.66 (6)
Tandem walking	0.31 (17)
180° Tandem pivot	0.38 (15)
Lateral foot scooting left	0.67 (5)
Lateral foot scooting right	0.53 (11)
Hopping forward left	0.81 (1)
Hopping forward right	0.69 (4)
Crouch and walk	0.36 (16)
Lateral dodging	0.28 (19)
Walking and looking left	0.56 (10)
Walking and looking right	0.51 (12)
Running with controlled stop	0.43 (13)
Forward to backward walking	0.70 (3)
Walk, look and carry left	0.65 (7)
Walk, look and carry right	0.60 (9)
Descending stairs	0.31 (18)
Step-ups × 1 step left	0.61 (8)
Step-ups × 1 step right	0.40 (14)

[a]calculated on the correlation between the item score and the total score; RO, Rank order with 1 = highest value and 17 = lowest value

challenging assessment tool, but rather measures basic functional performance which is typically applied in older adults or patient populations aged ≥70 years [13, 33, 38]. In the present sample, the average time to perform the TUG was 9.1 ± 1.8 s. A study which validated the CBM in older adults reported an average TUG time of 10.4 ± 2.2 s and found a higher correlation between both measures ($\rho = -0.69$) [26]. The poor discriminative ability of the TUG may have prevented the correlation between the TUG and the CBM from being higher. Recent studies confirm this assumption, showing that the TUG is able to discriminate performances in less healthy, lower-functioning populations (e.g. fallers), but not at discriminating performances in healthy, high-functioning groups [13].

The CBM showed good correlation with 3MTW errors ($\rho = -0.61$). The 3MTW errors classify a subject based on errors made during a challenging dynamic balance task, which is similar to the classification scheme of the CBM which may explain the good correlation. For 3MTW time, the correlation was lower ($\rho = -0.35$) as compared to 3MTW errors. This suggests that the quality of task execution (3MTW errors) is more strongly linked to CBM performance as compared to the time of task execution (3MTW time).

Habitual gait speed, a less challenging measure of dynamic balance, showed a moderate correlation with the CBM ($\rho = 0.46$). This suggests that a simple assessment of gait speed, commonly applied in older adults aged ≥70 years [47], may not be sufficient to detect subtle balance deficits in a sample of young-older adults. However, these measurements were intentionally included for comparing the CBM to commonly applied clinical assessment tools and because it has been used in previous validation studies with the CBM in samples of older adults and knee osteoarthritis patients [27, 28].

As expected, a moderate correlation was found between the CBM and the 8-level balance scale ($\rho = 0.32$). The 8-level balance scale is a measure of static steady-state balance control whereas the CBM primarily evaluates dynamic aspects of balance during complex mobility tasks. In line with the present findings, previous studies have reported moderate associations between static and dynamic steady-state balance control, suggesting that both aspects of balance control are partly interrelated, but represent distinct aspects of balance control (e.g. Functional Reach Test vs. gait speed, $r = 0.08–0.39$ [48] or one-leg stand vs. jumping over a hurdle, $r = 0.05–0.23$) [49].

An excellent inter- and intrarater reliability of the CBM total score was found, exceeding the recommended standards of 0.90 to 0.95 for clinical assessments [42]. For the first time, the reliability of the scoring of the single items

Table 5 Score characteristics of the CBM and other balance and mobility scales

	Mean (SD)	Median	IQR	Minimum	Maximum	Ceiling (100%)	Ceiling (90%)[c]
CBM (0–96 points)	64.7 (12.7)	67.0	55.0–74.0	28.0	86.0	0%	0%
FAB (0–40 points)	33.3 (4.0)	34.0	31.0–37.0	21.0	40.0	2.0%	30.6%
8-level balance (0–7 points)	5.1 (1.1)	5.0	4.0–6.0	2.0	7.0	0%	9.8%
3MTW (time; cont.)[a]	8.4 (2.5)	7.6	6.8–9.4	4.5	16.7	NA	NA
3MTW (errors; cont.) [a]	.97 (0.32)	0.0	0.0–2.0	0.0	7.0	N/A	N/A
TUG (cont.)[b]	9.1 (1.8)	9.1	7.9–10.6	5.4	13.1	NA	NA
Gait speed (cont.)[b]	128.1 (21.8)	125.0	114.0–142.0	84.3	182.8	NA	NA

N = 51; [a]Data reported on 31 participants; [b]Data reported on 46 participants;[c]90% of maximum attainable score; SD, Standard Deviation; IQR, Interquartile Range; CBM, Community Balance & Mobility Scale (score); FAB, Fullerton Advanced Balance Scale (score); 3MTW, 3 Meter Tandem Walk; TUG, Timed Up-and-Go test (seconds); Gait speed (cm/seconds); cont., continuous scale of the CBM were also evaluated, showing good to very good intrarater reliability [46] for all 19 items. This finding suggests that if the same rater evaluates a participant's performance on the CBM scale on two separate occasions, high reliability can be expected. For interrater reliability, only five out of the 19 test items had a moderate and two a fair agreement (i.e., "Forward to backward walking" and "Walking and looking right") [46]. Possible explanations for these two items might be that raters rated individual's performance differently, such as maintaining straight path versus veering during walking (e.g., "Forward to backward walking") as well as difficulties to determine for how long the participant's eyes focused on a point (e.g., "Walking and looking").

The Cronbach's alpha as a measure for internal consistency was 0.88. Although it does not exceed the value of 0.90 suggesting redundancies among items [50], further studies should analyze if there are redundant items to design a shortened version of the CBM. As indicated by the results (Table 4), each individual item correlated > 0.20 with the total score, indicating satisfactory internal consistency [45]. On the same note, our findings indicate that future studies with adequate sample sizes should perform a more detailed analysis to purify the CBM. As indicated by Table 4, item-scale correlations for seven items were < 0.50 ("Tandem walking", "180° Tandem pivot", "Crouch and walk", "Lateral dodging", "Running with controlled stop", "Descending stairs", and "Step ups × 1 step right") which may suggest that their additional value is limited as the cut-off points for internal consistency vary [51–53]. Future studies could determine the underlying factors that represent the CBM construct and eliminate items which cannot be assigned to a factor for purification of the assessment tool. Such factor analyses require a sample size of at least 10 participants per item in the scale [54], which would be 190 participants for the CBM. The development of a shortened CBM has been requested previously [26] and could be of significant benefit as the original version takes 20–30 min to complete.

A limitation of this study is that the sample consists of participants from three countries. While beneficial, cross-national research has limitations. It might be that variation in the performance across the countries could have occurred, despite standardized operating procedures.

Additionally, females were overrepresented in our sample (75%) as compared to the general population aged ≥60 years (56% [55]). However, the sample was too small to perform a stratified analysis for gender. Additionally, the posthoc exploratory analyses for the ability of the CBM to discriminate young-older fallers (mean score 58.3 ± 14.6) from non-fallers (mean score 66.3 ± 11.8) did not reveal statistically significant differences ($p = .09$). A larger sample is needed to evaluate the validity for discriminating fallers from non-fallers.

This cross-sectional study did not allow the determination of responsiveness. Further studies are needed to evaluate the responsiveness of the CBM in the target population.

Conclusions

This study provides evidence that the CBM is a suitable tool for the assessment of challenging balance and mobility performances in healthy, young-older adults. The CBM tasks represent meaningful everyday performances which are specifically required to ambulate safely within an everyday environment. With trained assessors, the scale is easily administered, requires little equipment, and most importantly, is valid and reliable in the studied target population. Based on the present results, the CBM has been selected as an end point within the EU project PreventIT and is currently used within a randomized controlled trial evaluating a lifestyle-integrated training intervention for preventing functional decline in healthy, young-older adults (registered online; https://clinicaltrials.gov/ct2/show/NCT03065088). The CBM may help to better understand the mechanisms of early balance and mobility decline in young-older adults and inform the development of treatments and intervention programmes aimed at improving early deterioration in balance and mobility, which is in line with the recently updated guidelines for early implementation of neuromotor exercise training in public health approaches [7].

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Availability of data and materials

The datasets used and analyzed during the current study are available from the PreventIT consortium upon reasonable request.

Authors' contributions

MW, JvA, RB, KT, KG, and CN contributed in the data collection. MW and KG carried out the video-rating. MW performed the statistical analysis and drafted the manuscript. MS developed the study concept and design, coordinated the study, and assisted in the statistical analysis, and in drafting the manuscript. KT, SM, CN, MP, NHJ, ABM, JLH, BV, and CB conceived the study, participated in its design and coordination, and helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Ethics approval and consent to participate

The study procedures were approved by the local institution review boards, i.e. in Stuttgart: Medical Ethical Committee at the University Medical Center Tübingen, approval date 07/04/2016, 033/2016BO2; Amsterdam: Medical

Ethical Committee, VU University Medical Center, approval date 13/04/2016, NL56456.029.16; Trondheim: REC central, approval date 29/04/2016, central midt 2016/48; and Heidelberg: Medical Ethical Committee of the Faculty of Behavioural and Cultural Studies of Heidelberg University, approval date 20/06/2016.
Written informed consent from participants were obtained in all four study centers prior to participation.

Competing interests
The authors declare that they have no competing interests.

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Manuskript 3

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Feasibility and Effectiveness of Intervention Programmes Integrating Functional Exercise into Daily Life of Older Adults: A Systematic Review

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Keywords
Aging · Balance · Daily life · Exercise training · Lifestyle · Physical performance · Feasibility · Functional exercise · Individual activity plan · Habit formation

Abstract
Background: Traditionally, exercise programmes for improving functional performance and reducing falls are organised as structured sessions. An alternative approach of integrating functional exercises into everyday tasks has emerged in recent years. ***Objectives:*** Summarising the current evidence for the feasibility and effectiveness of interventions integrating functional exercise into daily life. ***Methods:*** A systematic literature search was conducted including articles based on the following criteria: (1) individuals ≥60 years; (2) intervention studies of randomised controlled trials (RCTs) and non-randomised studies (NRS); (3) using a lifestyle-integrated approach; (4) using functional exercises to improve strength, balance, or physical functioning; and (5) reporting outcomes on feasibility and/or effectiveness. Methodological quality of RCTs was evaluated using the PEDro scale. ***Results:*** Of 4,415 articles identified from 6 databases, 14 (6 RCTs) met the inclusion criteria. RCT quality was moderate to good. Intervention concepts included (1) the Lifestyle-integrated Functional Exercise (LiFE) programme integrating exercises into everyday activities and (2) combined programmes using integrated and structured training. Three RCTs evaluated LiFE in community dwellers and reported significantly improved balance, strength, and functional performance compared with controls receiving either no intervention, or low-intensity exercise, or structured exercise. Two of these RCTs reported a significant reduction in fall rate compared with controls receiving either no intervention or low-intensity exercise. Three RCTs compared combined programmes with usual care in institutionalised settings and reported improvements for some (balance, functional performance), but not all (strength, falls) outcomes. NRS showed behavioural change related to LiFE and feasibility in more impaired populations. One NRS comparing a combined home-based programme to a gym-based programme reported greater sustainability of effects in the combined programme. ***Conclusions:*** This review provides evidence for the effectiveness of integrated training for improving motor performances in older adults. Single studies suggest advantages of integrated compared with structured training. Combined programmes are positively evaluated in institutionalised settings, while little evidence exists in other populations. In summary, the approach of integrating functional exercise into daily life represents a promising alterna-

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tive or complement to structured exercise programmes. However, more RCTs are needed to evaluate this concept in different target populations and the potential for inducing behavioural change.

Introduction

Exercise programmes specifically developed for improving functional performance play an important role in maintaining functional independence and reducing falls in older adults [1–3]. Several programmes have been positively evaluated in different target populations [4–6]. While the exercise content differs among these programmes, all of them are delivered in a structured format either in groups [7–10] or individually at home [4, 11–13]. Common characteristics are standardised repetitive exercises, performed several times a week. While structured programmes are an essential element of intervention strategies [14], authors have repeatedly discussed the lack of long-term adherence to them [15, 16]. Survey data suggest that the proportion of persons aged 65 years or older participating in specific strength and balance training programmes is less than 13% [17].

For many older adults, engagement in structured exercise or sport is not appealing [18, 19]. This is often related to a lack of transportation, limited access to facilities [20], time commitments [21–23], unwillingness to join a group [22], or aversion to exercise, as some do not regard themselves as "sporty" [18]. Recent studies highlight older adults' preference for lifestyle activities, such as cleaning or gardening, rather than performing specific exercises [24]. Structured programmes typically do not include a behavioural change concept for fostering long-term adherence and habitualisation of exercise. The development of alternative approaches for those who are not interested in structured exercise and which implement behavioural change concepts has been repeatedly requested [7, 21, 25].

Integrating exercises into daily life has been discussed as one promising alternative to structured programmes [25, 26]. Integrated programmes aim to turn daily routines into opportunities for exercising rather than performing separate exercises. Some studies have focused solely on increasing daily walking time, for instance by walking to the store rather than taking the bus [27, 28]. This approach has been expanded to integrate various functional exercises designed for improving balance and strength [29]. Functional exercises are performed with the purpose of enhancing basic everyday motor performances, e.g. stair climbing, obstacle crossing, or rising from a chair, and are based on the principle of specificity of training [29]. Studies suggest that functional exercise training is effective because the training content is linked to the specific outcome (i.e., being closely aligned with daily tasks) [29, 30]. Examples of integrated training tasks are squatting when reaching to a low shelf or drawer, or intentionally stepping over objects in the daily environment for practising a specific motor skill, which is relevant for safe ambulation.

One advantage of integrated training is that it can be performed without reserving extra time for training. It has been proposed that integrated training may become habitual after a period of regular practice [25, 26, 31].

Integrated training seems to be a promising concept. The aim of this systematic review is to summarise the available evidence for the feasibility and effectiveness of lifestyle-integrated functional exercise training in older adults.

Methods

A systematic literature search was performed in May 2016 according to the PRISMA statement [32]. Searches were conducted in PubMed, Web of Science, Cochrane Library, PsycInfo, CINAHL, and GeroLit without any language or publication date restrictions. Initial search terms were compiled and iteratively refined by content experts in the fields of geriatrics, gerontology, exercise, and library science. The PubMed search strategy (online suppl. Table S1; for all online suppl. material, see www.karger.com/doi/10.1159/479965) was modified for the other databases.

Inclusion criteria were: (1) individuals aged ≥60 years; (2) intervention studies including randomised controlled trials (RCTs) and non-randomised studies (NRS) (e.g., controlled before-after studies); (3) use of a lifestyle-integrated approach; (4) use of functional exercises focusing on strength, balance, or physical functioning; and (5) reporting outcomes about feasibility and/or effectiveness (i.e., balance, strength, physical functioning, mobility, falls, and psychosocial aspects). Reference lists of relevant articles were subsequently hand-searched to identify additional appropriate articles.

Study selection was performed by 2 independent reviewers (M.W., T.G.). In case of disagreements, the articles were discussed with the other authors. Titles and abstracts of retrieved references were screened for inclusion, and full texts of potential articles were analysed further to determine inclusion. Data extraction included information about study design and aims, setting, sample characteristics, outcome parameters, adherence, adverse events, and results. Authors were contacted for additional information that was not available from the articles. We aimed to include all intervention studies that evaluated aspects of feasibility and/or effectiveness of integrated training, regardless of study design. We report study results separately for RCTs and NRS. Methodological qual-

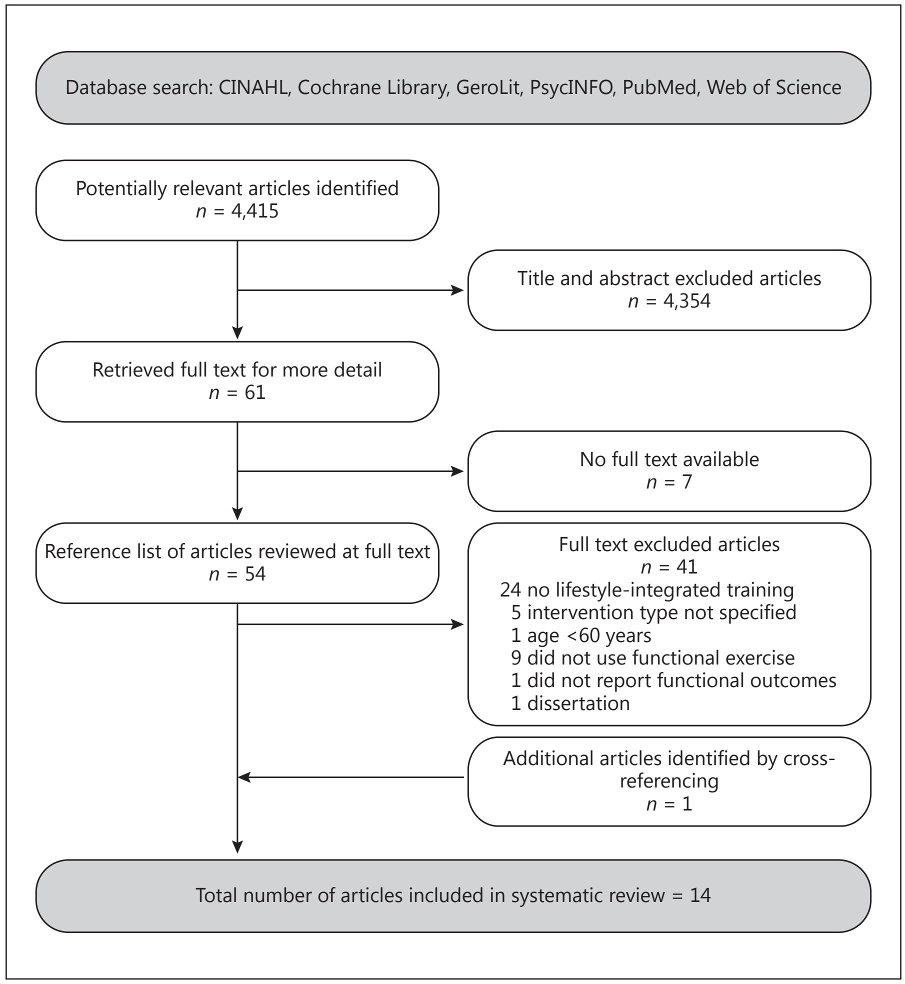

Fig. 1. Flowchart showing the literature search and the extraction of studies meeting the inclusion criteria.

ity of RCTs was rated using the PEDro scale ranging from 0 to 11 points [33]. Risk of bias was assessed using the Cochrane Collaboration's Risk of Bias Tool [34].

Results

Study Selection

Out of 4,415 articles screened, 14 met the inclusion criteria (Fig. 1). Among these, 7 [25, 26, 35–39] reported RCTs. One RCT was published in 2 articles on short- [35] and long-term effects [36]. In total, 6 RCTs were included. Seven articles [40–46] reported NRS. Among these, 3 articles [40–42] reported before-after studies focusing on feasibility [40–42], acceptance [41, 42], motor performances [40–42], and behavioural change [41]. Four articles [43–46] reported 1 controlled trial including effects on fitness and cardiorespiratory risk factors [46], and short- [43] and long-term effects on physical activity (PA) [44, 45].

Methodological Quality

Quality rating of RCTs is shown in Table 1. The average PEDro Score was 7.8 points (range 7–9). Methodological weaknesses were lack of concealed allocation [37–39], lack of participant blinding (all RCTs), and dropout rates >15% [26, 37, 38].

Risk of bias rating was performed for all articles included (online suppl. Table S2). No article had risk of bias related to incomplete outcomes and selective reporting, 6 NRS articles had risk of selection bias [40–46], and 5 articles (2 RCTs [37, 39], 3 NRS [40–42]) had a risk of performance bias.

Studies Using an RCT Design

An overview of RCTs is provided in Table 2. In summary, RCTs compared the interventions with passive controls [25], controls receiving ordinary care [37–39], or structured exercise [26, 35, 36]. Included were community dwellers with a history of falls [25, 26] or receiving

Table 1. Results of quality scoring of RCTs using the PEDro Scale

	Burton et al. [35, 36]	Clemson et al. [25]	Clemson et al. [26]	Grönstedt et al. [37]	Kerse et al. [38]	Peri et al. [39]
Eligibility criteria specified	×	×	×	×	×	×
Random allocation	×	×	×	×	×	×
Concealed allocation	×	×	×	–	–	–
Groups similar at baseline	×	×	×	×	×	×
Participant blinding	–	–	–	–	–	–
Therapist blinding	–	–	–	–	–	–
Assessor blinding	–	×	×	×	×	×
<15% dropouts	×	×	–	–	–	×
Intention-to-treat analysis	×	×	×	×	×	×
Between-group statistical comparison	×	×	×	×	×	×
Point measures and variability data	×	×	×	×	×	×
Sum score	8	9	8	7	7	8

PEDro, Physiotherapy Evidence Database, studies are classified as excellent (9–11 points), good (6–8 points), fair (4–5), and poor (<4); ×, criterion is evidenced in the article; –: criterion is not evidenced, not applicable, not coded, or could not be determined in the article.

restorative home care [35, 36], and institutionalised older adults [37–39]. Sample sizes ranged from 34 to 473 participants, mean age from 80.2 to 85.0 years, and percentage of women from 50 to 85%.

Interventions

The intervention period ranged from 8 weeks [35, 36, 40] to 12 months [38]. The programmes were delivered by physio- and occupational therapists [25, 26, 35, 36], home-help service staff [37], or usual caregivers [38, 39]. All RCTs consistently recommended that integrated exercises should be performed daily, as often as possible throughout the day.

The most frequently evaluated intervention was the Lifestyle-integrated Functional Exercise (LiFE) programme [25, 26, 35, 36]. LiFE focuses on embedding functional exercises into daily life, thereby enhancing the overall level of PA. The programme is taught by professional trainers during 5–7 home visits and 2 follow-up phone calls over a 6-month period [47].

A participants' manual illustrates the LiFE "principles" for improving balance, lower-limb strength, and increasing PA [48]. Balance principles include postures and walking with gradual reduction in the base of support (e.g., upgrading tandem stand to one-leg stand over time), and dynamic movements that perturb the centre of gravity (e.g., leaning in different directions, stepping over obstacles) [26]. Strength principles include functional activities focusing on improving lower extremity muscles around the hip and knee (e.g., squatting, chair rise, sideward walking) and ankle (e.g., toe stand, toe and heel walking) with gradual increase of intensity through performing more challenging activities [26]. Important elements of LiFE are strategies for behavioural change, based on habit re-framing theory [49]. LiFE activities are linked to daily tasks by using situational and environmental cues (e.g., tooth brushing) as prompts to action. The idea of LiFE is to perform the activities intentionally and consciously until they become a habit.

Two RCTs evaluated the LiFE programme in older fallers [25, 26]. One of these RCTs [25] used a control group not receiving any intervention. The other [26] compared LiFE with a structured exercise programme which included balance and strength exercises (with ankle cuff weights) performed 3 times a week at home. As with LiFE, the structured training was taught by professional trainers during 5–7 sessions and 2 follow-up phone calls over a 6-month period [47]. Participants in a third group (controls) performed low intensity and flexibility exercises taught during 2 sessions, 1 booster session, and 6 follow-up phone calls.

One RCT [35, 36] evaluated a modified version of LiFE in a restorative home care setting. The teaching period was shorter (8 weeks). Care managers (health professionals, nurses) taught the programme during regular visits every 10–14 days (3 times on average). LiFE was compared with structured training including balance and

Table 2. Description of the 10 trials with regard to study purpose, subjects, settings, and interventions

First author [Ref.]	Study design	Study purpose	Subjects and setting	Intervention	Behaviour change approach	T, F, D	Delivery of the intervention	Follow-up	Adherence
Randomised controlled trials									
Burton [35, 36]	Pragmatic RCT	Compare the effectiveness of LiFE vs. structured exercise on greater functional gains	n = 80 Mean age: IG: 80.2 years, CG: 79.6 years Female: IG: 75%, CG: 90% Dropout: IG: 2.5%, CG: 7.5%	IG: LiFE CG: structured balance and strength exercises	Habit formation framework aiming to make LiFE activities habitual	IG: T: individualized F: daily D: 8 weeks CG: T: 15–20 min F: 3× weekly D: 8 weeks	IG: PTs, OTs, nurses, 5 home visits CG: restorative home care team	8 weeks and 6 months	IG: 4.05 times/week (4.91 times/week during the 8 weeks, 3.62 times/week at follow-up) CG: 3.66 times/week (4.42 times/week during the 8 weeks, 3.28 times/week at follow-up)
Clemson [25]	Pilot RCT	Determine the adherence and effectiveness of LiFE on fall prevention	n = 34 Mean age: IG: 81.0 years, CG: 82.0 years Female: IG: 50%, CG: 44%, Dropout: 11.1%	IG: LiFE CG: none	Habit formation framework aiming to make LiFE activities habitual	T: individualized F: daily D: 3 months	PTs, OTs, 5 home visits, 2 booster phone calls, 2 follow-up phone calls	3 months and 6 months	N/A
Clemson [26]	Randomized parallel trial	Determine the effectiveness of LiFE on fall prevention	n = 317 Mean age: 83.4 years Female: 54.9% Dropout: IG: 26.2%, IG: 7.5%, IG2: 8.6%, CG: 13.3%	IG1: LiFE IG2: structured balance and strength exercises CG: gentle and flexibility exercises	Habit formation framework aiming to make LiFE activities habitual	IG1: T: individualized F: daily D: 6 months IG2: T: N/A F: II: 3× weekly D: II: 6 months CG: T: N/A F: N/A D: 6 months	IG1 and IG2: PTs, OTs, 5 home visits, 2 booster phone calls, 2 follow-up phone calls CG: PTs, OTs, 2 home visits, 2 booster phone calls, 6 follow-up phone calls	6 months and 12 months	IG1: 33% (over 6 months), poor adherence (<25%): 7% IG2: 29% (over 6 months), poor adherence (<25%): 19% CG: 34% (over 6 months), poor adherence (<25%): 11%
Grönstedt [37]	Randomized clinical trial	Determine the effectiveness of an individually tailored intervention program on function	n = 332 Mean age: 85.0 years Female: 73.5% Dropout: IG: 15.9%, CG: 17.8%	IG: individually tailored physical and daily activities in different combination CG: ordinary care and treatment	Individual goal setting strategies related to physical and daily activities	T: individualized F: daily D: 3 months	OTs, PTs, staff members at the unit, daily visits	3 months	N/A
Kerse [38]	Cluster RCT	Determine the effectiveness of an individualized functional activity program on quality of life	n = 473 Mean age: 84.3 years Dropout: IG: 32%, CG: 29%	IG: individualized program of physical activities based on repetitions of activities of daily living CG: usual care	Behavioural strategies focusing on goal setting for improving physical function	T: individualized F: daily D: 12 months	Healthcare assistants, number of visits depend on resident's needs	3 months, 6 months and 12 months	N/A
Peri [39]	Cluster RCT	Determine the effectiveness of an individualized functional activity programme on function, mobility and quality of life	n = 149 Mean age: 84.7 years Female: IG: 85%, CG: 83% Dropout: IG: 13.7%, CG: 19.7%	IG: individualized program of physical activities based on repetitions of activities of daily living CG: usual care	Behavioural strategies, focusing on goal setting for improving physical function	T: individualized F: daily D: 6 months	Healthcare assistants, number of visits depend on resident's needs	3 months and 6 months	N/A

Table 2 (continued)

First author [Ref.]	Study design	Study purpose	Subjects and setting	Intervention	Behaviour change approach	T, F, D	Delivery of the intervention	Follow-up	Adherence
Non-randomised studies									
Opdenacker [43–45] Van Roie [46]	Controlled trial	Determine the effectiveness of a lifestyle intervention vs. structured exercise on physical activity and on self-esteem	n = 186 Mean age: IG1: 63.3 years, IG2: 67.0 years, CG: 67.9 years Female: IG1 and IG2: 50%, CG: 54.5% Dropout: IG1: 23.3%, IG2: 18.3%, CG: 30.3%	IG1: Home-based lifestyle intervention, including endurance, strength, flexibility and balance IG2: structured exercise program, including endurance, strength, flexibility and balance CG: assessments	Behavioural strategies, derived from self-determination theory, transtheoretical model and social-cognitive theory, targeting self-supportive behaviour (enhancing autonomy, reducing support)	IG: T: individualized F: daily D: 11 months IG2: T: 60–90 min F: 3× weekly D: 11 months	IG1: exercise psychologist, 1 home visit, 5 monthly collective sessions, 16 booster phone calls IG2: instructors at a fitness centre	6 months, 11 months and 23 months	IG1: 85.5% (11 post-test), 87.0% (follow-up) IG2: 82.8% (post-test), 83.7% (23 follow-up) C: N/A
Burton [40]	Before-after study	Test the feasibility of LiFE in terms of suitability in restorative home care	n = 9 Mean age: 80.8 years Female: 75% Dropout: 11.1%	IG: LiFE, including 7 balance and 6 strength principles CG: none	Habit formation framework aiming to make LiFE activities habitual	T: individualized F: daily D: 8 weeks	PTs, OTs, nurses, 5 home visits	8 weeks	N/A
Fleig [41]	Before-after study	Test the feasibility of a group-based EASY-LiFE intervention in terms of habit formation	n = 13 Mean age: 66.2 years Female: 100% Dropout: 23.1%	IG: group-based LiFE CG: none	Phase-specified behavioural change techniques making everyday actions habitual	T: individualized F: daily D: 4 months	Exercise physiologists, personal trainer, health psychologists, 7 group sessions	6 months	N/A
Keay [42]	Before-after study	Determine the feasibility of LiFE in older adults with visual impairment	n = 16 Mean age: 70.0 years Female: 92.9% Dropout: 6.2%	IG: LiFE CG: none	Habit formation framework aiming to make LiFE activities habitual	T: individualized F: daily D: 3 months	Trained orientation and mobility instructors, 7 home visits	5 months	N/A

RCT, randomized controlled trial; LiFE, lifestyle-integrated functional exercise; LAT, LiFE assessment tool; PT, physiotherapists; OT, occupational therapists; PA, physical activity; SB, sedentary behaviour; N/A, not available; IG, intervention group; CG, control group; T, time bout; F, frequency; D, duration.

strength exercises performed 3 times a day. The structured training was also taught by care managers with similar frequency and duration.

Three RCTs evaluated combined programmes including structured training and lifestyle-integrated basic functional exercises [37–39]. One of these RCTs [37] aimed at preventing functional decline in nursing home residents. Structured training including practise of transfers, walking, functional balance, and strength exercises, was taught by physio- and occupational therapists within individual supervised sessions (frequency and duration were not specified). Additionally, residents were taught on self-administered training and incorporating the functional exercises into daily routines. Exercises were selected based on individual treatment goals and taught by physio- and occupational therapists (frequency and duration not specified).The intervention was compared with usual care within a 3-month trial.

The 2 other RCTs on combined training [38, 39] aimed at improving mobility and quality of life of older adults living in long-term residential care using the Promoting Independence in Residential Care (PIRC) training. PIRC focuses on basic functional exercise training (e.g., chair rising and walking during daily routines). Exercises are designed to increase strength, balance, and endurance. They are performed either fully integrated into daily routines or supervised at least twice a day. Exercise intensity depends on participant's capabilities and is upgraded during the course of the intervention (e.g., increasing repetitions). In the 2 RCTs [38, 39], exercise frequency and duration were not specified. Gerontology nurses and healthcare assistants implemented PIRC based on individuals' treatment goals and functional performance level. An activity programme displayed in the participant's room was used to encourage residents' engagement. Both RCTs compared PIRC to controls receiving usual care over a period of 6 [39] and 12 months [38].

Dropouts from Study

For LiFE, the number of dropouts was lower (5 [35, 36] to 18% [26]) compared with structured training (7.5 [35] to 21% [26]) and passive controls (25%) [25], and identical to an active control group (18% [26]) (Table 2).

For combined programmes, 1 RCT reported higher dropouts in the intervention (32%) compared with controls (29%) [38], while 2 reported lower dropouts for the intervention (13.7% [39], 15.9% [37]) compared with controls (19.1% [37], 19.7% [39]). Main factors for dropouts were unrelated to the programme, including death

[37–39], illness [25, 26], health problems [25, 26], or moving [25, 26, 37], while some were related to the intervention, such as pain or lack of training partners [26].

Adherence

For LiFE, adherence was measured through an activity planner, in which participants documented their daily LiFE activities. One study compared adherence in LiFE with adherence in structured training. Completing predefined LiFE activities for ≥3 days/week or structured home exercises 3 times a week was rated as 100% adherence [50]. Results showed significantly higher adherence to LiFE (64% of participants) compared with structured training (53%) [26]. Poor adherence (<25%) was apparent in 7% of LiFE and 19% of structured training participants [26]. In 2 other RCTs, adherence was reported as the number of days of LiFE practice or structured training per week, respectively [35, 36]. During the intervention period, adherence for LiFE was higher (4.91 days/week) compared to structured training (4.42) [35, 36]. Four months after the intervention, adherence to both programmes was similar (3.62 vs. 3.66) [36]. During follow-up, 1 study reported significantly higher adherence to the LiFE programme (64% of participants), in comparison with structured exercising (53%). Three studies did not report adherence [25]. For combined programmes, adherence was not reported [37–39].

Adverse Events

In an RCT with 317 participants, 1 participant in the LiFE group was diagnosed with a pelvic stress fracture and attributed this to increased walking and stair climbing, but continued with the programme [26]. In the structured comparison group, 1 participant had a surgery for an inguinal hernia and withdrew from the programme, but it was unclear whether this was related to the intervention.

An RCT on PIRC reported fatigue in 31% of the intervention group and 43% of controls [39]. No adverse events were reported in other RCTs [25, 35–38].

Effectiveness on Motor Performances

Table 3 summarises the effects on outcome measures.

Balance. LiFE was more effective for improving some, but not all, balance outcomes during short-term (8 weeks) and long-term assessments (6 and 12 months) compared with structured training [26, 35, 36], passive controls [25]), or control exercise [26]. Inconsistent results were found for combined programmes, with 1 study reporting significant improvement in the intervention group compared with usual care [37], while others did not [38, 39].

Lower-Limb Strength. Effects for lower-limb strength varied. One RCT reported greater improvements for some (i.e., ankle), but not all (i.e., knee and hip) strength measures for LiFE compared with structured training during short- and long-term assessment [26]. No additional effects for LiFE, compared with structured training, were found in 2 studies [35, 36]. Compared with inactive controls, LiFE significantly increased knee [25], but not hip strength. For combined programmes, effects were either insignificant [38, 39] or not measured [37].

Functional Performance. LiFE was more effective for improving functional performance, measured by performance-based tests or self-report measures shown in Table 3, compared with structured training. For combined programmes, 1 RCT reported significantly improved functional leg muscle strength, measured by timed chair rises, in the intervention while controls deteriorated [37]. Within PIRC, effects on self-reported function were only present in the subsample of cognitively intact participants [38, 39].

Effectiveness for Increasing PA

One RCT showed greater effects of LiFE on PA and energy expenditure compared with structured training [26]. Another RCT did not report increased PA after LiFE compared to passive controls [25].

An RCT evaluating a combined programme reported significant improvements in PA, energy expenditure, and life space (i.e., distance travelled between and within home) in the intervention compared with usual care [37].

Effectiveness for Reducing Falls

For LiFE, a significant reduction in fall rate (31%) in comparison with controls (gentle and flexibility exercises) was reported [26]. Descriptive data showed a non-significant lower rate of falls in LiFE (172 falls) as compared with structured exercise (193) at 12-month follow-up [26]. Another RCT showed a significantly reduced relative risk for falls in LiFE (RR = 0.21) in comparison with controls [25]. For combined programmes, effects were either insignificant [38, 39] or not measured [37].

Studies Using an NRS Design

NRS studies are shown in Table 2. Three before-after studies evaluated the feasibility of LiFE in different settings (i.e., restorative home care [40]), different target populations (i.e., visually impaired [42]), or different administration mode (i.e., group-based [41]). One of them

Table 3. A summary of results reported in the 10 trials with regard to main physical outcome dimensions and measurements

First author [Ref.]	Outcome dimension	Outcome measurements	Outcomes: post-intervention	Outcomes: long-term follow-up		
Randomised controlled trials						
Burton [35, 36]			IG vs. CG:	IG vs. CG:		
	Balance	Functional reach Tandem walk Tandem walk errors	Functional reach: ns Tandem walk: IG↑ Tandem walk errors: IG↑	Functional reach: ns Tandem walk: IG↑ Tandem walk errors: IG↑		
	Muscle strength	Chair rise	Chair rise: ns	Chair rise: ns		
	Functional mobility	TUG	TUG: ns	TUG: ns		
	Self-efficacy	FES ABC Scale	FES: ns ABC Scale: IG↑	FES: ns ABC Scale: IG↑		
	Health-related outcomes	Vitality Plus Scale	Vitality Plus Scale: IG↑	Vitality Plus Scale: IG↑		
	Function	LLFDI	LLFDI: IG↑ for limitation, function total, basic and advanced lower extremity	LLFDI: IG↑ for basic and advanced lower extremity		
Clemson [25]			IG vs. CG:	IG vs. CG:		
	Balance	Static balance (tandem stand, one-leg stand) Dynamic balance (tandem walk)	Static balance: ns Dynamic balance: IG↑	Static balance: ns Dynamic balance: ns		
	Strength	Static hip strength Static knee strength Static ankle strength	Static hip strength: ns Static knee strength: IG↑ for left knee Static ankle strength: ns	Static hip strength: ns Static knee strength: ns Static ankle strength: ns		
	Falls	Number of falls	Number of falls: IG↑	Number of falls: IG↑		
	Self-efficacy	FES (modified) ABC Scale	MFES: IG↑ ABC Scale: ns	MFES: ns ABC Scale: IG↑		
	Health-related outcomes	Markus Exercise Self-Efficacy Scale SF-36	Markus Exercise Self-Efficacy Scale: ns SF-36: ns	Markus Exercise Self-Efficacy Scale: ns SF-36: ns		
	Physical activity	Life Space Index	Life Space Index: ns	Life Space Index: ns		
Clemson [26]					IG1 vs. CG	IG2 vs. CG
	Balance	Five level balance scale (SPPB) Eight level balance scale Tandem walk	–/–	5-level balance scale: *d*, sig 8-level balance scale: *d*, sig Tandem walk: *d*, sig	0.55↑ 0.63↑ 0.42↑	0.33 ns 0.29 ns 0.49↑
	Strength	Maximal isometric lower hip strength Maximal isometric knee strength Maximal isometric ankle strength		Static hip strength: *d*, sig Static knee strength: *d*, sig Static ankle strength: *d*, sig	N/A, ns N/A, ns 0.40↑	N/A, ns N/A, ns 0.17 ns
	Falls	Number of falls		Number of falls: IRR, sig	0.69↑	0.81 ns
	Self-efficacy	ABC scale		ABC Scale: *d*	0.38↑	0.37↑
	Function	Late Life Disability Index (LLDI) Late Life Function Index (LLFI) NHANES independence measure for ADL		LLDI: *d*, sig LLFI: *d*, sig NHANES: *d*, sig	0.73↑ 0.49↑ 0.54↑	0.41 ns 0.17↑ 0.26 ns
	Health-related outcomes	EQ-VAS EQ-5D PASE		EQ-VAS: *d*, sig EQ-5D; *d*, sig PASE: *d*, sig	0.34↑ N/A, ns 0.25↑	0.06 ns N/A, ns 0.05 ns
	Physical activity	Paffenberger physical activity index Life Space Index		Paffenberger index: *d*, sig Life Space Index: *d*, sig	0.62↑ N/A, ns	0.36↑ N/A, ns
Grönstedt [37]			IG vs. CG			
	Activities of daily living	Functional Independence measure (FIM) BBS	FIM: ns BBS: IG↑			
	Balance	Nursing Home Life Space Diameter (NHLSD)	NHLSD: IG↑			

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Table 3 (continued)

First author [Ref.]	Outcome dimension	Outcome measurements	Outcomes: post-intervention	Outcomes: long-term follow-up		
	Physical activity	10 m indoors walking or wheelchair propulsion	Walking or wheelchair propulsion: ns			
	Mobility	Physiotherapy Clinical Outcome Variables (COVS)	COVS: IG↑			
	Strength	Dynamometer Chair rise	Dynamometer: ns Chair rise: ns			
	Falls Self-Efficacy	FES, Swedish version	FES-S: ns			
Kerse [38]			IG vs. CG:	IG vs. CG:		
	Function	LLFDI TUG EMS FICSIT-4-balance test	LLFDI: IG↑ (cognitively normal group) TUG: ns EMS: ns FICSIT-4-balance test: ns	LLFDI: ns TUG: ns EMS: FICSIT-4-balance test: ns		
	Quality of life	EuroQol instrument Life Satisfaction Index (LSI)	EuroQol instrument: ns LSI: ns	EuroQol instrument: ns LSI: ns		
	Fall-related outcomes	Number of falls Modified fear of falling scale	Number of falls: ns Modified fear of falling scale: #	Number of falls: ns Modified fear of falling scale: #		
	Psychological outcomes	Geriatric depression scale	Geriatric depression scale: IG↓ (cognitively impaired group)	Geriatric depression scale: IG↓ (cognitively impaired group)		
Peri [39]			IG vs. CG:	IG vs. CG:		
	Mobility	EMS TUG	EMS: ns TUG: ns	EMS: ns TUG: ns		
	Health-related outcomes	SF-36	SF-36: IG↑ for physical component	SF-36: ns		
	Psychological outcomes	LSI	LSI: ns	LSI: ns		
	Falls	Number of falls	Number of falls: ns	Number of falls: ns		
Non-randomised studies						
Opdenacker [43–45] Van Roie[a] [46]			IG1 vs. IG2:	IG1 vs. IG2:		
	Physical activity	Accelerometer Daily steps Flemish Physical Activity Computerized Questionnaire (FPACQ)	Accelerometer: ns Daily steps: IG1↑ FPACQ: IG1↑ for active transportation	Accelerometer: ns Daily steps: IG1↑ FPACQ: ns		
	Psychological measures	Rosenberg Self-Esteem Scale Physical Self-Perception Profile (PSPP) Self-Efficacy questionnaire	Rosenberg Self-Esteem: ns PSPP: ns Self-efficacy: ns	Rosenberg Self-Esteem: ns PSPP: ns Self-efficacy: ns		
					Pretest	Posttest
	Cardiorespiratory fitness	Maximal exercise test	Maximal exercise test: IG2↑	Maximal exercise test:	ns	IG2↓
	Muscular fitness	Static knee strength Dynamic knee strength Total work (strength endurance test)	Static strength: IG2↑ Dynamic strength: IG2↑ Total work: IG2↑	Static strength: Dynamic strength: Total work:	IG2↑ ns ns	IG2↓ IG2↓ IG2↓
	Functional performance	Arm curl test Chair rise Vertical jump	Arm curl test: ns Chair stand test: ns Vertical jump: ns	Arm curl test: Chair rise: Vertical jump:	IG1↑ IG1↑ ns	IG2↓ IG2↓ IG2↓
Burton [40]	Balance	Functional reach Tandem walk Tandem walk errors	Functional reach: ns Tandem walk: ↑ Tandem walk errors: ns	–/–		
	Muscle strength	Chair rise	Chair rise: ns			
	Functional mobility	TUG	TUG: ns			
	Falls	Number of falls	Number of falls: ↑			
	Self-efficacy	FES ABC Scale	FES: ↑ ABC Scale: ns			

Table 3 (continued)

First author [Ref.]	Outcome dimension	Outcome measurements	Outcomes: post-intervention	Outcomes: long-term follow-up
	Health-related outcomes	Vitality Plus Scale LLFDI	Vitality Plus Scale: ns LLFDI: ↑ for function total	
	Function	PASE	PASE: ↑	
	Physical activity	Actical accelerometer	Actical accelerometer: ns	
Fleig [41]	Mobility	SPPB	SPPB: ns	–/–
	Psychological outcomes	Intention to engage in balance and strength Self-efficacy Action planning Action control Coping planning Automaticity Habit strength Self-identity	Intention: ns Self-efficacy: ns Action planning: PE # Action control: PE # Coping planning: ns Automaticity: PE# Habit strength: PE# Self-identity: PE#	
	Subjective health	EQ5D-5L	EQ5D-5L: ns	
Keay [42]	Mobility Function Falls Self-Efficacy	SPPB LLFDI Short FES-I	SPPB: ns LLFDI: ↑ for function Short FES-I: ↑	–/–

d, effect size (Cohen's *d*) for discriminating between different intervention groups; IRR, incidence rate ratio; PE, positive effect; NE, negative effect; #, insufficient or contradictory data and/or analyses; ↑, significant improvement; ↓, significant deterioration; ns, not significant; N/A, not available; TUG, Timed Up and Go test; FES, Falls Efficacy Scale; ABC, Activities specific Balance Confidence; LLFDI, Late Life Function and Disability Index; PASE, Physical Activity Scale for the Elderly; SPPB, Short Physical Performance Battery; EQ5D/EQ-VAS, health-related quality of life; SF-36, Short-form health survey; BBS, Berg Balance Scale; ADL, activities of daily living; EMS, Elderly Mobility Scale. [a] Results of the study were reported in 4 articles focusing on different outcome dimensions.

additionally evaluated effects on behaviour change [41]. One controlled trial compared a combined "Home-Based Lifestyle" (HBL) intervention and a gym-based structured exercise programme [43–46].

Sample sizes ranged from 8 [40] to 86 participants [43–46], mean age from 63.3 [43–46] to 80.8 years [40], and percentage of women from 50 [43–46] to 100% [41].

Interventions

Two feasibility studies [40, 42] adapted LiFE to different settings and target populations. One implemented LiFE in a restorative home care service. Allied healthcare managers (health professionals and nurses) delivered the programme over a short intervention period of 8 weeks (instead of 6 months) [40]. The other adapted LiFE for visually impaired fallers by providing the written manual and/or an additional audio version. LiFE was taught by orientation and mobility staff during 7 home visits over a 3-month period, with 1 follow-up phone call after 5 months.

A third study tested the feasibility of group-based LiFE [41]. Instead of individual teaching, a team (exercise physiologist, health psychologist, personal trainer) taught LiFE within 7 group sessions over a 4-month period. During group sessions, participants learned LiFE activities and developed an individual activity plan. Participants practised LiFE unsupervised in their everyday environment, similar to the original LiFE concept.

One controlled trial evaluated the HBL concept aimed at improving PA, cardiorespiratory and muscular fitness, and functional performance in sedentary older adults [43–46]. HBL is a combined programme including integrated functional exercise (e.g., climbing stairs, squatting while gardening), integrated PA (e.g., walking instead of taking the bus), and structured exercises focusing on balance (e.g., one-leg stand while standing behind a chair), strength (e.g., arm curls), and endurance (e.g., jogging, cycling, or hiking). Structured balance and strength exercises were performed for 8–20 repetitions 2–3 times a week, and endurance training at least 20 min, 3 times a week.

In the controlled trial, HBL was taught during an initial home visit by an exercise psychologist, 16 booster phone calls, and 5 monthly collective group sessions over a period 11 months [43–46]. Information on exercise content and behaviour change were provided by the trainer, a brochure, and a participants' manual. HBL was compared to a group-based structured, supervised programme including balance, strength, flexibility, and endurance exercises performed 3 times a week for 60–90 min in a gym. The control group, recruited separately (not randomised), did not receive any intervention [43–46].

Dropouts from Study

For LiFE, the percentage of dropouts ranged between 6.3% [42] and 23.1% [41] and was related to health problems [40, 41] and family emergencies [41], both unrelated to the programme. Dropout rates were similar for the HBL group (23%) compared with the gym-based exercise (18%) [43–46] and were related to health problems unrelated to the programme or a lack of motivation [43–46] (Table 2).

Adherence

No LiFE studies reported on adherence. For HBL, adherers were defined as those having completed 80% of their programme (not further specified), whereas participants in the gym-based group had to complete 5 out of 6 training sessions in 2 consecutive weeks [43–46]. Adherence was similar for HBL (78%) and gym-based exercise (80%) [43–45].

Adverse events

No study reported on adverse events.

Feasibility of the Intervention

LiFE was feasible in different settings and target populations given that adjustments to particular activities were made [40–46]. Care managers and clients found the LiFE manual clear and easy to understand, but tools for tailoring and monitoring the intervention were perceived as too time-consuming and were replaced by a routine functional assessment performed during home care visits in a subsequent RCT [35, 36].

For visually impaired, LiFE was generally suitable and easy to undertake [42]. Most of participants valued the improvements in balance, strength and overall performance in daily tasks. The delivery through their orientation and mobility instructors and the programme's focus on physical technique were especially emphasised. They appreciated being able to make their own decisions regarding appropriate, but also challenging, exercises and the integration into daily life, increasing the sustainability after completing the programme. However, participants commented on the excessive paper work and some found the manual too long. Both instructors and participants reported difficulties related to reduced vision which prevented participation in specific LiFE activities, including "stepping in different directions," "leaning side to side," and "leaning forwards and backwards." These activities were either too difficult to teach, or participants were unable to perform them, or they were perceived as uncomfortable due to a greater sensation of falling and sense of vulnerability related to their vision impairment. Instructors recommended increasing the number of sessions and enlarge the recording sheets in this specific target population.

For group-based LiFE, most participants valued the group format, appreciating the opportunity of social interaction and exchanging ideas about LiFE activities [41]. Some participants criticised the group setting as they experienced a slowdown in individual progress. Some requested individual face-to-face sessions. Among the different LiFE components (functional assessment, exercise demonstration, behavioural change, documentation), exercise demonstrations were rated as the most important aspects, emphasising the importance of an exercise physiologist in the team. While most participants valued action planning, using LiFE activity sheets, some criticised the administrative effort, as reported in other studies [40]. Most participants valued the behavioural change approach, particularly the contextual cues to overcome problems with remembering exercising during the day. In the controlled trial, feasibility of the intervention was not analysed.

Effects on Motor Performances

Feasibility studies on LiFE [40–42] reported exercise effects, although they were not specifically designed for measuring the effectiveness of the programme.

Balance. One LiFE study reported significant improvements in dynamic balance [40], whereas the others did not [41, 42]. The HBL study did not measure balance [43–46].

Lower-Limb Strength. One LiFE study measured lower-limb strength, but did not obtain effects [40]. For HBL, the gym-based exercise group showed significantly greater improvements in knee strength during short- [46] and long-term assessment [45] compared to HBL and controls.

Functional Performance. Two LiFE studies measured self-reported functional performance and reported significant improvements [40, 42]. In the HBL study, both intervention groups (HBL and gym-based) significantly improved in functional performance (chair rise, and vertical jump) compared to controls [46], but effects were sustained only in the HBL group [45].

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Effects for Increasing PA

One LiFE study measured PA and reported significant improvements [40]. For HBL, both intervention groups (HBL and gym-based) significantly improved in PA compared to controls, but effects were sustained only in the HBL group [43].

Effects for Reducing Falls

One LiFE study measured fall rate, reporting a significant reduction ($t(7) = -2.65$, $p = 0.033$) [40]. The HBL study did not measure falls [43–46].

Effectiveness of the Behavioural Change Component

The group-based LiFE induced changes in habit strength and related psychosocial determinants, including automaticity of exercising, self-identity (integration of exercises into one's self-concept), action planning, action control, increase in autonomy, awareness of health-related benefits of exercising, and skills to anticipate potential barriers. No changes were found for the intention to exercise, exercise-related self-efficacy, and planning [41]. No other studies reported this outcome.

Discussion

This systematic review evaluated studies which integrated functional exercises into daily life of older adults. We found some evidence suggesting that integrated training has advantages including higher adherence and effectiveness compared with structured training in selected populations such as community-dwelling older fallers, although the number of RCTs is low. Furthermore, we found studies which combined structured exercise with integrated training, feasible and effective, particularly in impaired target populations such as nursing home residents. Both approaches increased PA level, related to the specificity of the integrated training content aiming to foster everyday activities.

RCT Designs

Long-term training is crucial to modify individuals' behaviour, promote self-efficacy, and gain full health benefits from exercise training. Long-term adherence has often been reported as challenging for structured exercise programmes [15, 16]. In this context, integrated training concepts have been specifically designed to increase adherence by embedding exercises into daily routines. Most RCTs showed that integrated training led to higher adherence rates, compared with structured training in the short [26, 35] and long term [26], while single studies reported similar adherence for both programmes in the long term [36]. One reason for the differences in long-term adherence might be the duration of the intervention (8 weeks [36] vs. 6 months [26]), being crucial for modifying individuals' behaviour (fostering behavioural change).

Importantly, there is no consensus on how adherence should be compared between integrated and structured training. The approach of Clemson et al. [26] was defining 100% adherence when LiFE was performed for ≥3 days/week, although participants were asked to practise daily to make LiFE activities habitual [25, 26]. Moreover, no information was provided about the daily frequency, duration, and intensity of LiFE training, and the exact exercise dosage remains unclear [25, 26]. While dosage can be estimated for structured training, this is difficult for integrated training as participants perform multiple short bouts of activities over the course of a day (e.g., knee bends each time when picking something up), making it hard to count the number of repetitions and estimate intensity. Theoretically, participants could try to document this information, but this would require time-consuming paperwork. Effort for documentation was often mentioned as a drawback in studies [40–42]. A potential solution for future trials might be the use of ICT technology such as smartphones or smartwatches for documenting adherence. Such an approach is currently developed within the EU project PreventIT (www.preventit.eu).

In studies comparing structured with integrated or combined training, very few adverse events were reported [26, 39]. While these results suggest that all approaches are generally safe, the number of adverse events reported in studies was too low to compare different training modes regarding safety. Furthermore, reporting of adverse events differed among studies with some using their own definitions (self-reported muscular aches and pains, fatigue, number of falls [38, 39]) and others not reporting adverse events, hampering comparability. Our findings are in line with a review showing that nearly 20% of exercise trials report no information on adverse events and 25% do not accurately define severity [51].

Structured programmes include fixed exercise sets, standardised according to type, frequency, intensity, and duration. Besides teaching participants correct exercise performance, little knowledge is needed for successful participation in these programmes. In contrast, integrated concepts require participants to understand the theoretical underpinnings, activity principles, implementation strategies, activity planning, and documentation of adherence. When compared to structured programmes, integrated concepts can be seen as more complex interventions which require self-management strategies. Despite this increased complexity, our review shows that the interventions are feasible and acceptable to older adults [25, 26, 35–39]. Current studies suggest that successful delivery of integrated training requires well-qualified therapists, skilled in both exercise delivery and behavioural change theory [41].

Effectiveness of the Interventions

Effectiveness represents a major criterion for exercise programmes and therefore stands out within evaluation criteria. For effectively improving motor performances and reducing fall risk, exercise programmes need to be adequately challenging and progress in intensity over time [52]. For structured exercise programmes, established guidelines define optimal training modalities such as number of repetitions, and frequency [49].

While integrated training included principles for exercise progression [25, 26, 35, 36, 38, 39], frequency and number of repetitions are not specifically defined. Rather, they are determined by the frequency of the daily task in which an activity is integrated. A key question is whether these single bouts of exercises spread out over the course of the day are similarly effective compared with structured training.

We found several studies showing that LiFE training is similarly effective for improving motor performance when compared with structured training [26], and superior for selected outcomes related to balance [26, 35, 40], strength (i.e., ankle [26]), functional performance [26, 35, 36], and PA [26]. Authors discussed that the added value of LiFE might be related to the increased training dosage due to daily practice, increased level of PA (e.g. stair climbing), and higher adherence during long-term training interventions [26]. The additional effect of LiFE was particularly prominent for balance, but less for strength [25, 26, 35, 36]. For strength, an added value of integrated training is less clear, which might be related to a lack of standardised set of repetitive movements, as supposed in the strength training literature [14].

In structured programmes, participants often perform rather artificial movements, such as isolated knee extensions with weights, to improve strength of a particular muscle group. By comparison, integrated activities are functional and embedded into daily tasks, focusing on improving relevant activities of daily living such as crossing an obstacle or climbing stairs. For LiFE, studies showed that integrated training is superior to structured training for improving overall function and disability in daily life tasks [26, 35, 36], which suggests that integrated training is directly transferable into older adults' daily life and fosters mobility-related independence.

One pilot RCT on LiFE showed a reduction in falls by 80% compared with inactive controls [25]. Findings should be interpreted with caution due to a small, unrepresentative sample not allowing a generalisation of effects. Nonetheless, these findings were the impetus for a second and larger RCT which showed that LiFE reduced falls by 31% compared with active controls receiving gentle and flexibility exercises. This is comparable to effects reported for structured home exercise programmes in community-dwelling older adults (21%) [53].

Results showed that combined programmes were effective for improving balance [37–39], functional performance [37–39], PA [37], but neither strength [38, 39] nor fall-related outcomes [37–39]. While positive results on functional performances are comparable to other RCTs on integrated training in community dwellers, limited effects on strength [38, 39] and falls [38, 39] may suggest that it is more challenging to effectively implement these programmes in institutionalised older adults. Several participants complained about fatigue, which might be a potential barrier to adopting integrated exercises into everyday activities. Also, contamination effects related to the location of the RCT (nursing home) might have biased the results. The intervention and control groups were located in the same nursing home. It was not possible to prevent control participants from participating in the intervention group activities [39]. An advantage of combined programmes was the social interaction during sessions [41]. In contrast, lack of training partner was mentioned as a drawback of the LiFE programme [26]. In combined programmes, participants could share their experiences about integrated training and practise together during group sessions. On the same note, none of the combined exercise RCTs analysed whether the integrated component provided an added value compared with practising in a structured-only format. This could be evaluated in future trials.

NRS Designs

Integrated training is a rather novel concept and the number of RCTs is low. We therefore included NRS to provide additional information about feasibility and effectiveness, although they have lower evidence levels compared with RCTs.

Feasibility studies showed that LiFE was applicable in more impaired populations [40, 42] and implementable into restorative home care services [40]. However, modifications were required, including downgrading some exercises for safety reasons [40], increasing the script size and providing audio material to compensate for vision loss [42], and reducing the amount of paperwork [40]. On the same note, it remained unclear whether these adjustments were generic or specific, as no comparison to other programmes was made [40–42]. Feasibility studies partly confirmed positive effects on motor performance [40, 42] and PA [40] compared with RCTs. However, results were limited to before-after studies. Future RCTs are needed to evaluate the modified version of the LiFE programme found in this systematic review.

Interestingly, 1 study transferred LiFE to a group format. Participants established their individual activity plan during group sessions (and not during individual home visits). Based on this activity plan, participants practised LiFE in their everyday environment. Authors discussed that the presence of a team of trainers with different backgrounds, including sports science and psychology, had advantages for teaching the exercise and behavioural change component of LiFE. Social interaction, which has been reported beneficial for behavioural change in previous studies [20], was particularly valued by study participants. The study on group-LiFE was limited to a before-after study design and did not compare group-based with individual teaching.

Inducing behavioural change is a major aim of integrated training [41]. However, our review suggests that evidence for behavioural change and automatised integration of functional exercise into daily life is limited. Only 1 before-after study evaluated the behavioural change paradigm related to LiFE and reported positive changes in habit strength and related psychosocial determinants. This proof of concept study indicates that participants are generally able to perform integrated exercises subconsciously after 4 months of practice [41]. Results may suggest that the concept of behavioural change, which is typically implemented in other areas such as dietary behaviour [54, 55], dental hygiene [56, 57], or chronic pain [58], can be transferred to the area of functional exercise training. However, study results are limited to a 4-month period, without long-term follow-up, and a sample of young-old (mean age: 66 years) in which behavioural change is less challenging than in older adults [59].

A controlled trial compared a combined training programme (HBL) with a gym-based exercise training. Positive effects on functional performance and PA measured at post-test were sustained only in the HBL group. Results suggest that HBL is more effective in the long term compared with structured gym-based exercise training. HBL includes a behavioural change approach for fostering integration of training into daily routines, and results suggest that this leads to increased sustainability of effects. Results are in line with the findings from RCTs on LiFE training [26, 36] insofar as the HBL training also led to high sustainability of functional training effects in sedentary older adults. This might be attributed to the principle of training specificity (i.e., HBL is closely aligned to daily tasks [29]). In contrast, the gym-based exercise group performed rather artificial movements focusing on muscular strength, not being directly transferrable into functional daily life activity. Gym-based exercises have been found highly effective for improving lower-limb strength [45, 46], functional performance [46], and PA [46] in several studies. Maintaining training effects requires constantly visiting the gym. If this is difficult for participants, they have to find other ways of being physically active. In such cases, integrated training might be a complement to gym-based training as it allows to continue the training routine adopted during the intervention.

Limitations

Studies included used different designs (RCTs vs. NRS), intervention types (integrated vs. combined approaches), intervention aims (effectiveness, feasibility), and control groups (usual care; passive; gentle and flexibility exercises; structured exercises). This heterogeneity limited the comparability of identified articles and did not allow performing additional analyses such as meta-analysis. Additionally, a lack of quality rating for NRS and a high risk of bias in selection and performance contribute to a lower evidence level of NRS compared with RCTs. However, NRS reported important aspects about feasibility and acceptance (i.e., delivery mode, adaptability of approaches to different populations). These aspects are helpful for designing future RCTs on integrated training.

Conclusion and Recommendations for Future Research

This systematic review provides a comprehensive overview of the available evidence concerning integrated functional exercise training in older adults. Some studies reported advantages of this training concept compared to structured exercise training, including higher adherence, increased effectiveness for improving selected motor performances, and simultaneously increasing PA and reducing falls. However, the number of RCTs was low, and studies used different training concepts hampering their comparability. NRS provided some evidence about the effectiveness of the behavioural change concept and the feasibility of integrated training in impaired target populations. More RCTs are required for generating a higher level of evidence.

This review helps to inform the design of future trials. Understudied target groups are young-older adults ("baby boomer" generation) as well as substantially impaired populations, such as nursing home residents or rehabilitation patients. One study questioned the feasibility of implementing integrated training in cognitively impaired older adults due to the requirement of self-regulation imposed upon participants [25]. Future research may test specifically adjusted programmes to fully or at least partially sustain the idea of integrated training in this population. For example, we found concepts using nursing home staff for supporting the arrangement and management of integrated training [37–39]. Though it was not specifically evaluated whether this approach fostered adherence. Extending this concept, for instance by placing prompts on objects in institutionalised settings to reinforce automatisation of training, might be an avenue for successful implementation.

Teaching an integrated training to participants within a group was found to be feasible [41], but future studies need to evaluate whether the group format is similarly effective compared to individual teaching and potentially more cost effective.

RCTs in young-older adults aged 60 to 70 years are lacking. The EU project PreventIT (www.preventit.eu) is currently developing an integrated training programme for this population including ICT-based behavioural change paradigm.

In summary, we found that integrated training represents a promising alternative or complement to structured exercise programmes, but future studies are needed to evaluate the true potential of this concept.

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Manuskript 4

Boulton E, **Weber M**, Hawley-Hague H, Bergquist R, Van Ancum J, Jonkman N, Taraldsen K, Helbostad J, Maier A, Becker C, Todd C, Schwenk M. Proof of concept of an adapted LiFE (aLiFE) programme specifically developed for young-older adults: perceptions of participants and trainers *(submitte*d).

Proof-of-concept of the adapted LiFE (aLiFE) programme developed for 60-70 year olds: perceptions of participants and trainers

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Conflict of Interest

We have no conflict of interest to declare.

Abstract

Introduction: Time commitments, limited access, or unwillingness to join a group are some of the reasons for low adherence to structured exercise in older adults. A promising alternative has emerged, integrating exercise into daily routines. This study exploredwhether an adapted Lifestyle-integrated Functional Exercise (aLiFE) programme is suitable for delivery in adults aged 60-70 years.

Design and Methods: The proof-of-concept was evaluated by interviews and focus groups with both participants and trainers at the end of a 4-week pre-post pilot study. For data analyses, the framework approach was used. Codes were generated using NVivo, and subsequently organised in overarching themes.

Results: Thirty-one participants aged 66.4 ± 2.7 years (60% women) and five trainers (30.0±6.2 years; 100% female) participated in the study. Both participants and trainers were positive about the programme. The possibility to individually adjust the programme, the preventive approach and the support of the trainers were well received by participants. Trainers acknowledged the flexible approach and valued the peer support between trainers. However, both participants and trainers disliked the extensive paperwork and reported some challenges to integrate activities into daily routines, due to the busy and varied lifestyles.

Discussion and Implications: Overall acceptability of aLiFE was high in adults aged 60-70 years. Trainers were especially relevant as motivators and support. Participants noted habitualisation of some activities within the short intervention period, even without continuous self-monitoring. The feasibility and effectiveness of this approach should be tested in a randomised controlled trial.

Key words: Feasibility study, intervention, healthy aging, physical activity, qualitative research

Introduction

Being active brings physiological and psychological benefits to older adults, reducing illness, improving functional ability and well-being (Baker, Atlantis, & Fiatarone Singh, 2007). However, for many older adults structured exercise or sporting activities are not appealing (E. Boulton, 2014; Costello, Kafchinski, Vrazel, & Sullivan, 2011). This is for extrinsic reasons such as transportation, limited access to facilities (Schutzer & Graves, 2004), time commitments (N. W. Burton, Khan, & Brown, 2012; Chao, Capri, & Farmer, 2000; Cohen-Mansfield, Marx, & Guralnik, 2003), or intrinsic reasons such as unwillingness to join a group (N. W. Burton, et al., 2012), or aversion to exercise because it does not fit with their identity (e.g. not perceiving themselves as 'sporty' (E. Boulton, 2014; Hawley-Hague et al., 2013). Studies have highlighted older adults' preference for lifestyle activities, such as cleaning or gardening, rather than performing specific exercises (E. Burton, Lewin, & Clemson, 2014).

The integration of exercises into daily life is a promising alternative to structured programmes (Clemson et al., 2012; Clemson et al., 2010). Integrated programmes turn daily routines into opportunities for exercise. Some studies focus on increasing daily walking time, for instance by getting off the bus earlier, or climbing the stairs instead of taking an elevator (Bravata et al., 2007; Dunn, Andersen, & Jakicic, 1998). Other studies have expanded this approach to integrate functional exercises for improving balance and strength (Liu, Shiroy, Jones, & Clark, 2014; Weber et al., 2018). Functional exercises are performed with the purpose of enhancing basic activities of everyday living, e.g. stair climbing or rising from a chair, and focus on specificity of training (Liu, et al., 2014). Functional exercise training has been found to be effective because the exercises are linked to specific outcomes of relevance to daily life (i.e. enable someone to get up and down stairs more easily) (Chou, Hwang, & Wu, 2012; Liu, et al., 2014). One advantage of integrated training is that it can be performed at any time, without having to put specific time aside.

As older adults' participation in exercise and physical activity relates to intrinsic factors (Hawley-Hague, et al., 2013), behaviour change is an important component of any intervention. Structured programmes typically do not include a behavioural change concept for fostering long-term adherence and habitualisation of exercise (Rejeski, Brawley, McAuley, & Rapp, 2000). Lifestyle-integrated approaches for those not interested in structured exercise, which include behavioural change concepts, have been shown to be attractive to older adults (Chao, et al., 2000; Clemson et al., 2004; Clemson, et al., 2010). It has been proposed that integrated training may become habitual after a period of regular practice (Clemson, et al., 2012; Clemson & Munro, 2016; Clemson, et al., 2010).

There is growing research on the feasibility and effectiveness of integrated training for older adults living in the community as well as in restorative home care (Weber, et al., 2018). The most extensively evaluated programme in this context so far is the Lifestyle-integrated Functional Exercise (LiFE) programme which focusses on embedding functional exercises into daily life and enhancing overall level of physical activity (Clemson, et al., 2012; Clemson, et al., 2010). LiFE provides functional balance and strength exercises, embedded within daily routine, resulting in improved balance, strength, and a significant reduced fall rate by 31% (Clemson, et al., 2012; Clemson, et al., 2010). The original LiFE programme was conducted in community-dwelling older adults aged 70+ with a history of falls (Clemson, et al., 2012; Clemson, et al., 2010). LiFE is underpinned by concepts of habit formation, self-efficacy, skills training and outcomes gained. Habit Formation Theory (HFT) states that new behaviours must first be planned and visualised in a specific location and situation. Then, the behaviour should be performed repeatedly, in the same location and situation, until it has become habitual (Lally & Gardner, 2013). To increase the likelihood of habitualisation, prompts and cues can be used to remind the participant to perform the behaviour. Clemson et al. (2012) found that LiFE had better adherence levels than structured training.

The original LiFE programme was designed for older adults aged 70+, focusing specifically on falls. However, LiFE has the potential to be adapted for other populations and outcomes. There has been no research undertaken to identify whether LiFE or an adapted LiFE (aLiFE) would benefit a younger age group, who are functioning at a higher level; whether adapted exercises (e.g. more challenging) and behaviour change techniques (e.g. action planning; self-montoring) are feasible to deliver. Through the PreventIT project (www.preventit.eu) we have piloted aLiFE over a 4-week period and quantitative methods indicate that aLiFE is largely feasible and acceptable 60-70 year olds (Schwenk et al., 2018). In the present study, we focus on participants' and trainers' experiences and perceptions of aLiFE, in order to improve the design of the intervention before a feasibility randomised controlled trial.

Design and Methods

This study was conducted as part of the PreventIT project, aiming to evaluate the aLiFE programme, designed to prevent functional decline in the specific population of young-older adults aged 60 to 70 years. The present study uses data from the PreventIT pilot study, which is a pre-post test study with a 4 week intervention period, conducted within the 14-month preparation phase of the project (January 2016 - February 2017). The pilot study aimed to evaluate the proof-of-concept of an adapted LiFE (aLiFE) programme specifically developed for 60-70 year olds, as perceived by both participants and trainers. Ethical approval from the local institution review boards as well as written informed consent from participants were obtained in all three study centres. The study is registered on the ISRCTN Registrary, where outline details of trial design, inclusion criteria etc can be obtained (ISRCTN37750605) (Schwenk, et al., 2018).

Intervention

The aLiFE programme includes three different activity modules: balance, strength and physical activity. Within each module, participants are encouraged to plan and perform activities to improve their balance (e.g. one leg stand; leaning to the limits of stability), increase their strength (e.g. squatting; lunging), to move more (e.g. walk further) and to sit less (e.g break up sitting at regular intervals). Participants can choose from a range of activities that target their needs as well as align with their preferences. Further detail about the content of the programme is reported elsewhere (Schwenk, et al., 2018). The programme is underpinned by a behaviour change framework, using theory and techniques to support participants to turn their intention to be more physically active into action (Michie et al., 2013; Schwarzer, 2008). The aLiFE programme is designed to make strength, balance and physical activities habitual, through a conscious process of planning and practise. The development of this behaviour change framework is reported elsewhere (E. R. Boulton, Horne, & Todd, 2018).

The aLiFE programme documentation includes a 105 page participant manual, containing an introduction to the aLiFE programme, guidance for planning and performing the activities, a Daily Routine Chart for identifying opportunities for integrating activities, and an Activity Planner and Counter for recording and monitoring activities.

Participants were visited at home by programme trainers, who assisted in planning and performing up to four new activities each week, for four weeks, in order to investigate the acceptability of the activities and the feasibility of the programme. Trainers were provided with the participant manual, an instructor's manual and attended a two-day training course prior to delivering the programme.

Participants

For the purpose of evaluating the proof-of-concept of aLiFE in 60-70 year olds, we included a convenience sample of 31 community-dwelling young-older adults. Inclusion criteria for this study were: community-dwelling older adults aged between 60 and 70 years; able to walk independently; no cognitive impairment (Montreal Cognitive Assessment (Nasreddine et al., 2005) >26 points). Participants were excluded if they reported severe cardiovascular, pulmonary, neurological, or mental disease; attended exercise classes more than twice per week or exercised independently for more than two hours per week. Participants were recruited in Germany (Robert-Bosch Hospital, Stuttgart), Norway (Norwegian University of Science and Technology), and the Netherlands (Vrije Universiteit Amsterdam). Each site recruited two trainers to deliver the programme to participants. Trainers' professional backgrounds were: medical doctor (n=1), medical student (n=1), physiotherapist (n=2) and exercise scientist (n=2).

Data collection

Basic demographic data and medical history were collected at baseline by trained research staff. All older participants and trainers were approached to take part in a semi-structured one-to-one interview or focus group after the final intervention contact. The researcher who conducted the interview/focus group was involved neither in the assessment nor the training, to avoid their role influencing the focus groups and introducing bias. Topics discussed included views about the structure and content of the aLiFE intervention; training and instruction; using the manual and monitoring materials; behavioural change; and suggestions for improvements to the intervention.

We conducted eight interviews and nine focus groups at the three different research centres. All interviews/focus-groups were audio recorded and transcribed verbatim in the original language. Transcripts were subsequently translated into English, so that the data could be pooled for analysis. Data from the participants were analysed separately from those of the trainers.

Data analysis

We used the Framework approach (Ritchie & Spencer, 1994). Three authors (EB, HHH, MW) individually familiarised themselves with the transcripts and performed the initial coding of the transcripts, using NVivo qualitative data analysis Software, QSR International Pty Ltd. Version 10. The authors compared applied labels, and agreed on a set of codes. Based on this working analytical framework two raters (EB, MW) independently coded all transcripts generating a matrix in a Microsoft Excel spreadsheet. The authors discussed the spreadsheets, compared and agreed on coding allocations. As codes were compared and contrasted, overarching themes emerged from the data analysis. Data source triangulation was carried out through the comparison of participant and trainer data and codes (Carter, Bryant-Lukosius, DiCenso, Blythe, & Neville, 2014).

Results

A total of 31 participants aged 66.3±2.7 (range, 60-70 years; 64.5% female) were recruited. Participant characteristics are summarised in Table 1. Five trainers aged 30.0±6.2 (range, 25-40 years; 100% female) delivered the aLiFE intervention.

Data from participants were organised into two overarching themes, with five sub-themes. The same data analysis process was undertaken for the trainer data, being organised into two overarching themes, including seven sub-themes.

For validation, extracts from the data, matched to themes, sub-themes and codes, were presented to the researchers who facilitated the focus groups and interviews. This process enabled us to check that the translation and analysis of the data in English still reflected the participants' and trainers' views and contributions. Feedback received resulted in some recoding of the data, but largely supported the analysis. The final framework was agreed by three authors (EB, HHH and MW) and a summary is presented in Table 2. Exemplar quotes are presented in the following sections, with participants identified by gender and age (e.g. F68, M69), and trainers identified by number only (e.g. TR1, TR2).

Participants' views

Programme and content

Overall programme: All participants were positive about the overall programme. They understood the concept of integrating muscle strength, balance and physical activities into their daily lives and thought that it was "a well thought out programme; quite extensive, well constructed" (M67). They appreciated the flexible approach, that you were "able to adjust it to your own capabilities" (M68) and valued the personalised nature of the programme. However, the nature of the four-week pilot study, with its aim to gain feedback on all of the activities within the programme, caused some difficulties. Participants reported that the study period was too short, that "there needs to be more time to implement all of the things, because I really want to, but I don't think I can manage" (F69). Participants were asked to add new activities each week and, by the end of the study, had too many to practise. When asked for suggestions for improvements to the programme as a whole, many participants recommended *"reducing the number of activities"* (F66) to be practised concurrently.

Activities and progression: All participants talked about activities that they liked such as "that standing on one leg, I liked that" (F65), and those which they did not like such as "walking on the heels; really did not like it" (F66). The activities that were disliked were often related to those that they found were too difficult for them, were not perceived as helpful, were viewed as 'unnatural' or that they felt were pointless. "I just don't see the point in walking on my heels. It just, you don't get going" (F66). Conversely, useful and purposeful activities were appreciated. Walking more should not be aimless, but "you should go somewhere and have a goal" (M68). Some participants enjoyed challenging themselves "to try to make it more difficult for myself" (M67) and also said that "the parts that were the most physically challenging were the ones I liked best" (M69). When asked about additional activities, which they would like to see added to the programme, many participants suggested exercises "for the arm muscles and the muscles in your hand." (F68).

Documentation: In the main, participants found the manual helpful, finding the explanations and photographs of the functional exercises "very clear" (M67). However, many found the manual to be too long, with even those who were very positive about it, confessing that they had not read it all: "I haven't read much in it. I haven't the patience to sit down and read it" (F68). Suggestions for improving the manual included "shortening it" (M67), having a "loose sheet system with the exercise programme as its own little part" (M69), and more and clearer pictures. Some participants really valued the paperwork designed to help them plan and monitor their activities: “I placed [the Activity Planner] in the living room, where I always see it. I can look something up as a reminder” (F62). However, many found daily recording of activities undertaken too onerous.

Behavioural change

Motivation and barriers: Many participants described their motivation to take part in the programme arising from a realisation that they were experiencing functional decline: “We’re all afraid of not being able to do this anymore, and that’s why” (F65). Having begun the programme, most participants were motivated to continue by the benefits gained such as “walking more confidently” (F62) and that their “balance has improved” (F62). Support from the trainers was also reported as a strong motivator within the programme. Participants valued the home visits and the clear instruction from trainers, whom they regarded as “really, really friendly” (F61), “helpful” (F66), “motivating” (M67), “competent and precise” (M69). Some participants talked about their trainer’s good sense of humour and how important it was to have fun during the programme. Being able to share the experience with someone else provided important social support to continue. There were some clear barriers to performing some of the activities in the programme, notably the embarrassment that many participants felt when performing activities outdoors*:* “Lunging, well it looks a little weird. At home I could do it, but not in the park” (F66). “One dreads to do things which makes neighbours wonder what you are doing” (M67). However, one participant had overcome this problem by telling his neighbours that he and his wife were involved in the progamme to explain “why we are acting the way we are!” (M67). Another barrier often reported was pain, either caused through performing the activities or an unrelated pre-existing pain. Some strength activities were found to be hard on the knees for some participants and caused them anxiety about continuing with them: “I am convinced it is a good exercise, but I am unsure about my knees, how good it is for my knees” (F67).

Habit formation and integration: Within this pilot programme, all participants were able to identify some opportunities to integrate activities into daily life, finding that “there are so many exercises you can easily integrate into your daily routine” (M70). Fixed and regular routines such as tooth brushing, shaving, or kitchen work were easiest to integrate aLiFE activities within. By contrast, irregular routines got in the way of integrating activities, as the cues to perform the activities were not encountered regularly or consistently. This was perceived to be a problem for some participants who had busy and varied lifestyles: "I don't really know what a normal routine will be for a retired person" (M67). Although for others, it was simply a case of adapting and keeping to the more fixed routines, such as "waiting for the kettle to boil" (F62). While the four week pilot study was not intended to provide sufficient time for activities to become habitual, there were some participants who reported that habitualisation had occurred: "There are many exercises I've gotten into habit. Getting out of bed in the morning, brushing teeth" (M69). For the most part, however, there was recognition that a focus on fewer activities and opportunities, and a longer period of practice, would be required before the activities became automatic: "Standing up for example. You need to think of it. It will increasingly happen with everyday practice" (M70). In the meantime, many participants continued to require and use reminders, "I have some notes sticking where you're likely to think about it more often. That's down my alley. I think about it more often when I read it" (F67).

Trainers' views

Reviewing the programme

Positive about the programme: All of the trainers were positive about the overall programme, finding it fun and interesting to deliver. They could see that there would be benefits to the target group, and that "a lot of people will be interested in this way of being active" (TR5), particularly as there are people "who don't pack their sports bag to go to the gym or a sports group" (TR3). The trainers recognised that there were clear differences in the abilities and preferences of the participants that they were working with. The flexibility of the aLiFE programme enabled them to personalise the programme to suit individuals, thereby encouraging them all to participate. "I just have to deliver what is most relevant to get them to feel it is relevant themselves" (TR5).

Activities: The trainers thought that they had the greatest success with integrating balance activities into participants' daily routines, because "balance in this age group is something where they realise they may have problems… and therefore have an understanding of why they should train" (TR3). Trainers started with an activity that "maybe was easy to integrate, because I already had good experiences with it" (TR6). Activities that were perceived as meaningful were also easier to introduce, particularly if a physical reaction was experienced: "The one with sitting against the wall, for example, became very popular. It was like everyone thought it was [meaningful]. Because it makes your thighs burn, you know" (TR5). Some trainers reported that participants had combined different activities "because some activities lead onto another one" (TR4). Starting with leaning and moving onto a heel walk was one example of participants sequencing their activities.

Behavioural change; All of the trainers were able to support the participants in finding opportunities within daily life to integrate the activities. In the beginning, this was easier, as there were fixed routines which everyone can latch onto, such as teeth cleaning and getting dressed. Towards the end of the four week pilot study, trainers reported that this had become much more difficult. The large number of activities to test within the pilot study meant that for some "the whole morning routine consists of exercises" (TR2). Some participants found it easier than others to identify opportunities throughout the day, which was a challenge for the trainers in terms of creativity. Trainers reported some participants "really absorbed it and structured their daily life looking for opportunities to integrate the programme, then they really internalised it" (TR4). Some others "maybe never quite understood it" (TR5). Reviewing participants' progress each week and providing them with positive feedback, regardless of their performance was important to trainers: "There was always something to praise. For example that they had managed to do the exercise more times" (TR6). When participants were able to see improvements and demonstrate them to the trainers, this was highly motivating.

Training and support; All of the trainers felt that the training and written materials they received prepared them well to deliver the programme, feeling they were "well trained, only of course that in practice it is different" (TR1). The professional background and experience of the trainers had an impact on their confidence and experience of visiting participants at home, with those lacking that experience leaning more on the written guides for each home visit: "It was good to have it, the structured points and what I was supposed to do. So I just went through it systematically" (TR6). Some trainers' previous training and experience made it easier for them to advise on pain and exercise dose, which became an issue we needed to address in later stages of the study: "I often said don't do it if it hurts, but I think it is different if you are a physiotherapist or that you are a medical student" (TR2). Peer support between trainers in each site was highly valued, but this was not formalised in regular meetings: "Maybe we could have been better coordinated you and I, or just had a few more conversations like that before we went out" (TR5). Similarly, a supervision meeting every few weeks with colleagues in each site would have been valuable.

Challenges with implementation

Facing barriers: Whilst the flexibility and personalised nature of the programme had distinct benefits, this also presented challenges to the trainers, who had to adapt the programme to each different participant: "Small women in our study didn't manage to climb two stairs at a time because of the angle. Then I suggested to climb stairs on toes or balls of the feet" (TR3). Trainers reported difficulties in advising participants to incorporate more physical activity (walk more often, walk longer distances) into their daily routines when they were often already very active. They were "already walking more than 5km per day, so it is difficult to say walk even further, we have said to them try to walk faster. Also interrupting the sitting, because they say, yeah but I never sit" (TR2). Trainers were reluctant to push participants in these situations: "If I notice someone does not want it, I'm bad at pushing and saying you must do this" (TR1).

Putting training into practice: The programme is multi-faceted and there is "a lot of information" (TR2): "The instructions actually were good. But of course it becomes something completely different when you start doing it for real" (TR6). The programme requires participants to try a new activity in the location where it will be performed, but this was not always possible or appropriate when participants “did not like that I went upstairs and went to the bedroom” (TR2). There were occasions when trainers and participants felt uncomfortable demonstrating an activity: “He feels stupid, I feel stupid and although you always try to do it, it didn’t always work according to the book as we’ve learned it” (TR3). Another challenge for trainers was talking about long term goals. This process was formalised in the documentation and training and is an essential element of the aLiFE approach. Whilst participants were motivated by the benefits received, they tended to see these as more immediate (being able to stand on one leg for longer; not getting out of breath as quickly when walking up the stairs) as opposed to the much longer term goals of being able to maintain independence or go on a hiking holiday. Due to the focus on trying out as many different activities as possible during the pilot study, the link with more aspirational long term goals became somewhat lost.

***Documentation*:** Trainers in all three sites reported that the Daily Routine Chart had not been used as the programme intended. Rather, opportunities for integrating activities into daily routines were identified “through a conversation” (TR3). Only the Activity Planner was actively used by all participants, although to varying degrees: “You always saw that the crosses were filled in the Activity Planner, but that they had put exactly the same curls with the same pen” (TR2). Trainers stated that participants had disliked counting their activities and that, in fact, “the more they live the programme and the more they internalise it, the more difficult it is for us to adhere to structured documentation” (TR3). There was consensus amongst trainers that there was too much paperwork in the study. Whilst some of this was integral to the aLiFE programme, much of it was related to the piloting of the programme and placed a high burden on trainers and participants alike: “I’m not sure how we can find a solution, but that was that for a bit, it was not entirely right for my feelings” (TR1).

Discussion

Overall, both participants and trainers reported the aLiFE programme was acceptable, that it was flexible and could be integrated into everyday life. Participants felt that the activities had to have a purpose relevant for them and be perceived as achieavble and easily intergrated or they were less enthusiastic in adopting them. They also discussed the number of activities and how these were, at times, difficult to fit into daily routines.

Previous literature looking at group-based exercise has found that individually adapted content was important to enhance adherence to the exercise programme (Farrance, Tsofliou, & Clark, 2016). Studies exploring the adoption of the LiFE programme have also outlined the importance of relevant activities that are appropriate to each individual (Keay et al., 2015). Findings from the focus groups with trainers supported participants' feedback, illustrating how the trainers actively tailored the programme, so it was most relevant to each individual. An important suggestion from participants is the fact that upper-body and upper-limb activities were not considered within the aLiFE programme, because the original LiFE programme focused on lower limb activities generated from evidence-based fall preventing programmes. Including upper body and limb activities may be important in helping participants achieve their long-term goals in future.

The documentation as part of the programme was found to be too onerous, by both the participants and the trainers, and had a potentially negative impact on adherence. During each home visit, participants were asked to review their aLiFE programme documentation (Activity Planner and Counter) as well as complete a study evaluation. The latter would be unnecessary in any roll out of the programme, so perceptions of the paperwork burden may differ. Our need for study evaluation may have biased the findings regarding acceptability of the programme. However, Burton et al. (2013; 2014) also found that documentation for the original LiFE programme was too time consuming.

Participants also discussed the paperwork, in relation to it becoming less relevant as the activities started to become habitual (one of the long-term aims of the programme). Even in this short 4-week timeframe, participants were able to create new habits, integrating some activities into their daily routines, and found reporting on those to be an unnecessary inconvenience. We will be able to explore the relationship between habit formation and adherence reporting further in the PreventIT feasibility Randomized Controlled Trial (RCT), thus adding to the emerging evidence on habit formation (Gardner, Phillips, & Judah, 2016).

Participants stated that they took up the programme to improve their functional performance and reduce their risk of decline. Once they started to see improvements, this motivated them to continue. This very much emulates the existing exercise literature where achieving outcomes has been found to be particularly important to continuation (Farrance, et al., 2016; Hawley-Hague, Horne, Skelton, & Todd, 2016). Trainers did feel that over the short-term pilot, short-term achievements of goals and physical improvements experienced were more important than the achievement of long-term aspirations, which could not be assessed and were not seen as relevant. For some participants, pain was a barrier to carrying out their activities and is a common factor cited in previous studies (Horne, Skelton, Speed, & Todd, 2013) which again supports the importance of tailored and individualised activities. The trainer was cited as a key source of support and motivation by participants and the trainers also discussed the ways in which they provided support to participants. Previous research has found the trainer to play a very important role in participant's uptake and adherence to exercise (Farrance, et al., 2016; Hawley-Hague, et al., 2013; Hawley-Hague, et al., 2016). In this study, we established that their role was important in terms of support to carry out the activities but also from a social perspective. The trainers had an important role in reaffirming self-efficacy for participants by allowing them to demonstrate the activities they had been doing and receive positive feedback. Trainers were also able to assist participants in tailoring the programme to fit in with their physical needs, preferences and individual lifelstyles. Trainers supported participants to look for alternative activities and situations to overcome barriers such as embarrassment, dislike, or failure to connect an activity with expected benefit.

Strengths and limitations

Overall, this pilot study gives us insight into the experiences of both participants and trainers participating in aLiFE across three different European countries. The pilot study was designed to include a convenience sample and, as such, the majority of included participants were already physically active and open to increasing their activities. Whilst we did include people who did not regard themselves as 'sporty', we did not capture the experiences of those resistant to any kind of physical activity.

There are limitations, due to our relatively small sample of trainers, it is hard to establish a full picture of the experience of delivery, and we are not able to reliably comment on whether professional background influences delivery. The short delivery time of the intervention also limits the applicability of the findings as we do not know whether participant experience may have changed over time. Although participants did discuss some of the activities starting to become habitual and this is promising, it is almost impossible to test whether activities have become truly habitual over such a short period and with a limited sample.

The main limitiation in this paper is related to the nature and design of the pilot study. Since we wanted to pilot as many of the activities as possible before use in our feasibility Randomised Controlled Trial, participants were expected to plan a large number of activities and both the trainer and participant found this burdensome. Any roll out of this approach would not involve the same quantity of different activities being planned and undertaken concurrently.

Implications

To further assess the feasibility of the aLiFE programme, and also to establish whether the activities become habitual for participants in the long term, a longer study is required. This pilot has informed the development and planning of a feasibility RCT which is currently underway (Taraldsen et al., 2018).

Changes to the paperwork for both trainers and participants and changes to trainers' training have already been made to reflect suggestions from this pilot study. The content was rationalised and reduced, to shorten the instruction manual. Authors of intervention guidance should ensure that material is organised clearly and with minimal duplication of information. Instruction on how to understand and manage types of pain has been added to the manual and training materials to provide the guidance which participants and, to some degree the trainers, found lacking. When developing guidance for interventions which participants or the general population will use independently, authors should provide clear information about pain and how to recognise and manage different types of pain (e.g. acute pain indicating injury being different to expected muscle pain following physical activity).

As participants particularly valued the support that they received from trainers, future interventions should take into account the need to incorporate support at both the social and instructional level. Overall, the qualitative data from the pilot study has suggested mostly positive experiences across European multiple sites and the intervention is currently being tested as part of a feasibility RCT.

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Table 1 Characteristics of the participants (n=31)

	Mean (SD)[a] or % (n)
Country	
Germany (Stuttgart)	35.5 (11)
Norway (Trondheim)	32.3 (10)
The Netherlands (Amsterdam)	32.3 (10)
Age, years	66.3 (2.7)
Women	20/31
Body-Mass-Index, kg/m^2	29.8 (6.5)
Comorbidities, number	1.7 (1.2)
Reported falling within last 12 months	22.6 (7)
One fall	85.7 (6)
Two falls	14.3 (1)

[a] Standard Deviation.

Table 2 Summary of data analysis framework

Overarching theme	Sub-theme	Example codes
Participants		
Programme and content	Overall programme	Flexible approach; liked the programme; personalised; too short for effects.
	Activities and progression	Activities liked; activities disliked; suggestions; unnatural activities; making things more difficult.
	Documentation	Helpful manual; lot to read; monitoring; suggestions for change.
Behavioural change	Motivation and barriers	Benefits gained; embarrassment; fun; noticed decline; pain; trainer support;.
	Habit formation and integration	Easy to integrate; finding opportunities; irregular routines; lack of time.
Trainers		
Reviewing the programme	Positive about the programme	Benefits to target group; enjoyable; personalisation; programme suggestions.
	Activities	Activity preferences, combining activities; easiest to integrate; meaningful activities.
	Behavioural change	Finding opportunities; integration into daily life; reviewing progress and performance.
	Training and support	Peer support, trainer background; well trained.
Challenges with implementation	Facing barriers	Adapting the programme; difficult to advise on physical activity finding opportunities; reluctant to push participants.
	Putting training into practice	A lot to remember; different in practice; difficult to talk about long term goals; location practice not easy.

	Documentation	Monitoring activities; participants disliked counting activities; too much paperwork.