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The impact of school-based nutrition interventions on the nutrition knowledge of children and their parents

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LIST OF ABBREVIATIONS

Abbreviation	Full name
NCDs	Non-Communicable Diseases
BMI	Body Mass Index
HPS	Health Promoting School
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
MeSH	Medical Subject Headings
RCT	Randomized controlled trials
Non-RCT	Non-randomized controlled trials
EPHPP	Effective Public Health Practice Project
SD	Standard Deviation
95% CI	95% Confidence Interval
CVI	Content Validity Index
ANOVA	Analysis of Variance

1. INTRODUCTION

Schools are among the most important settings for the delivery of nutrition and other health interventions. This thesis aimed to assess the impact of school-based nutrition interventions on the nutrition knowledge of children and their parents, with emphasis on the context of Saudi Arabia. This chapter describes the determinants of eating behaviors, the importance of learning about healthy diets during childhood, and the use of school settings for nutrition and health interventions. In addition, the definition of nutrition knowledge, the tools used to assess nutrition knowledge, and the association between nutrition knowledge and dietary intake are presented. As the second and third objectives of the thesis focus on Saudi Arabia, the section that follows provides a general overview of the nutritional situation in Saudi Arabia. A description of nutrition education at schools in Saudi Arabia and the Saudi Dietary Guidelines are also delineated. This chapter concludes by identifying the gaps in the existing literature and the study aims.

1.1 Determinants of eating behaviors

The dietary habits of the global population are diverse and constantly changing, as they are influenced by many interrelated factors (Popkin 1996; Singh et al. 2020). During the past few decades, many regions of the world have witnessed a nutrition transition, in which traditional regional foods have been replaced by diets that are highly processed and rich in fat, sodium sugar, and animal food products, accompanied by a decrease in physical activity level (Baker et al. 2020; Popkin and Ng 2022). This transition has been followed by an increase in rates of obesity and diet-related non-communicable diseases (NCDs) (NCD Risk Factor Collaboration 2017; Popkin and Ng 2022), especially in developing countries (Popkin and Gordon-Larsen

2004). Allied to the increasing efforts to combat these diseases, it is important to understand the determinants of eating behaviors.

A growing number of studies have sought to explain the determinants of dietary behaviors, and researchers in this field have recently paid more attention to the potential role of environmental factors in influencing eating habits (Brug et al. 2008; Chen and Antonelli 2020; Dixon et al. 2021; Marcone et al. 2020).

Various classification schemes have been developed to identify the determinants of eating behaviors. Contento (2008) categorized these factors into four interrelated groups of personal and environmental factors: (i) biological factors, (ii) factors related to experiences with food, (iii) personal factors, and (iv) environmental factors. Biological factors such as a genetic predisposition, feelings of hunger and satiety, and the sense of taste play a very important role in influencing food choices and dietary intake (Contento 2007, pg. 38). For example, children tend to have an innate dislike of bitter foods and preference for sweet foods (Mennella and Bobowski 2015). A liking of particular foods, however, can be influenced by frequent or repeated exposure to such foods (Elmas and Kabaran 2023) and this leads to the second group, experiences of food. The third group, personal factors, can be divided into intra- and inter-personal factors. Intra-personal factors include beliefs, attitudes, norms, knowledge, and skills, while inter-personal factors comprise family and social networks. Environmental factors, on the other hand, consist of physical, sociocultural, economic, and information environments (Contento 2008). The physical environment refers to food availability in a given environment, such as the home and school. Sociocultural factors that may influence a person's dietary habits encompass social relations and cultural norms, while economic factors are those that may affect individuals' access to foods, such as resources, food prices, and the time related to food preparation and consumption (Brug et al. 2008; Contento 2007, pg. 40-44). Finally, the

information environment refers to exposure to food-related messages through the media and advertisements (Contento 2007, pg. 44-43).

1.2 The importance of learning nutrition during childhood

The first years of a child's life are crucial, as they learn and acquire habits that may continue into adolescence and adulthood. A systematic review by Craigie et al. (2011) found that the physical activity and dietary patterns established during childhood may last into adulthood. Similarly, Movassagh et al. (2017) noted that healthy eating habits developed during childhood and adolescence lasted moderately into adulthood.

Nutrition education may help children and adolescents make informed decisions about their food choices and establish good eating habits (Meiklejohn et al. 2016). Furthermore, good nutrition may help improve children's wellbeing and their learning capacities, which can result in better school performance (Nicklas and Johnson 2004; Pérez-Rodrigo and Aranceta 2001). Another important reason for providing children with nutritional information is that they can communicate what they have learned to their parents and the rest of their family. For instance, a systematic literature review on school-based stroke education interventions found evidence that students communicated stroke information to their parents (Beal et al. 2016). However, despite considerable data on the impact of school-based nutrition and health interventions on children, research examining the potential impacts of these interventions on the families of children who receive the interventions is lacking (see thesis objective 1).

1.2.1 School settings for nutrition interventions

Schools present a crucial setting for delivering nutrition and other health interventions. According to the United Nations Children's Fund (2022) the global adjusted net primary education attendance rate in 2021 reached 87%, which makes schools ideal settings to reach

large numbers of children. In addition, schools can serve as effective and efficient channels to reach students' families, school staff, and other community members (Pérez-Rodrigo et al. 2001; World Health Organization 2018a). Children spend large parts of their days at school, which possibly makes it one of the key influential environments for dietary and other health behaviors beyond the home environment. For instance, some studies have suggested an association between the availability of unhealthy food items at schools (e.g., sugar-sweetened beverages) and their consumption (Mâsse et al. 2014; Rocha et al. 2021).

Over the past few decades, numerous systematic reviews and meta-analyses have evaluated the effectiveness of school-based nutrition and health interventions on children and adolescents. Although outright consensus has not been reached, considerable evidence suggests that school-based health and nutrition interventions can positively impact the dietary intake (Evans et al. 2012; Nury et al. 2022; Vézina-Im et al. 2017) and anthropometric measurements, such as body mass index (BMI), of schoolchildren (Jacob et al. 2021; Nally et al. 2021). Nevertheless, these positive impacts may be influenced by the characteristics of the interventions (Leger et al. 2007). For example, multicomponent health interventions that involve more than one domain have been found to be more effective in influencing health behaviors and health outcomes than those with a single component (Amini et al. 2015; Leger et al. 2007). Direct or indirect family involvement is another important aspect that may influence the effectiveness of school-based interventions (Hingle et al. 2010). Direct parental involvement includes training or education sessions for parents that require their attendance, while indirect family involvement may comprise communicating intervention messages to families by, for example, mailing letters, newsletters, and text messages, family participation in intervention-related activities and events, and children's homework activities or tasks that should be accomplished with their family/parents (Hingle et al. 2010). Other important intervention characteristics that may

strengthen the impact of school-based interventions are the intensity and duration of the interventions and community outreach (Leger et al. 2007).

The World Health Organization's Health Promoting School (HPS) framework supports a multicomponent approach to school-based health interventions. This framework was developed in 1980 and involves modifications to three areas in schools: (i) school curriculums, (ii) the ethos and environment of schools, and (iii) family involvement (Langford et al. 2014). This holistic approach has been shown to be successful in improving health-related outcomes, such as BMI, fruit and vegetable consumption, and physical activity, among schoolchildren (Langford et al. 2014; Lee et al. 2005). Although the Health Promoting School has been adopted by a large number of countries worldwide, the extent to which it is implemented varies greatly between and within countries (Ogasawara et al. 2022; Turunen et al. 2017).

1.3 Nutrition knowledge

The definition of nutrition knowledge varies depending on the context and perspective applied. Generally, nutrition knowledge refers to the understanding and awareness of at least the following three nutrition-related areas: nutritional recommendations, the association between food, health, and disease, and the sources of nutrients in food (McKinnon et al. 2014; Miller and Cassady 2015; Moorman 1996). Some studies have included nutrition knowledge as one of the components of nutrition literacy, where nutrition literacy is used to describe both knowledge and skills around food and nutrition (Ashoori et al. 2021). These skills can be categorized into three types: (i) functional skills (the capability to acquire, understand, and apply nutrition information), (ii) critical (the capability to evaluate nutrition information), and (iii) interactive (the capability to interact with others to gain or share nutrition information) (Al Tell et al. 2023).

While research has shown that the level of nutrition knowledge and nutrition literacy are positively associated (Mengi Çelik and Semerci 2022), the focus of this thesis is mainly on nutrition knowledge.

Several factors, among them, age, gender, and educational and socioeconomic status, may influence an individual's nutrition knowledge (Parmenter et al. 2000; Spronk et al. 2014). For example, middle-aged individuals tend to have greater nutrition knowledge than younger or older people (Hendrie et al. 2008a; Parmenter et al. 2000; Spronk et al. 2014). Similarly, women tend to be more knowledgeable about nutrition than men (Hendrie et al. 2008a; Parmenter et al. 2000; Spronk et al. 2014), and higher educational level and socioeconomic status have been found to be positively related to nutrition knowledge (Dallongeville et al. 2001; Parmenter et al. 2000; Spronk et al. 2014).

1.3.1 Relationship between nutrition knowledge and dietary habits

Nutrition knowledge is one of the personal factors that may influence an individual's dietary intake. However, studies on the relationship between nutrition knowledge and dietary intake have shown inconsistent results. This has been explained by the different tools and methods used to assess nutrition knowledge as well as the use of tools that have not previously been validated (Wardle et al. 2000). Furthermore, dietary habits can be influenced by many factors other than nutrition knowledge; thus, higher nutrition knowledge may not always indicate better dietary behaviors.

A systematic review reported a weak, positive association between nutrition knowledge and dietary intake among adults, especially between higher nutrition knowledge and fruit and vegetable intake (Spronk et al. 2014). Similarly, another systematic review suggested that individuals with good nutrition knowledge tend to use nutrition labels more frequently and that better nutrition knowledge may lead to a better understanding of the nutrition facts on these

labels (Miller and Cassady 2015). Food label use has also been found to be associated with a healthier diet (Anastasiou et al. 2019). Importantly, both the nutrition knowledge of children and parents' nutrition knowledge may influence the dietary intake of children (Asakura et al. 2017; Variyam et al. 1999).

It is paramount to have well-designed studies that employ validated tools to improve the understanding of the possible association between nutrition knowledge and dietary intake. However, despite the potential for nutrition knowledge to influence dietary intake, it is recommended that attempts to change dietary practices include not only nutrition education but also consideration of other personal and environmental factors that may facilitate healthier choices (Contento 2007, pg.39).

1.3.2 Tools for measuring nutrition knowledge

Valid and reliable tools for assessing nutrition knowledge are essential before designing or assessing nutrition-related interventions. These tools should be tailored to the target population and age groups. Some nutrition assessment tools are designed to measure general nutrition knowledge, while others are focused on specific aspects of nutrition knowledge. The Parmenter and Wardle General Nutrition Knowledge Questionnaire is among the most widely known nutrition knowledge tools. It was developed and validated in 1994 for the adult population in the United Kingdom. This tool has been translated and adapted for several countries, including Australia (Hendrie et al. 2008b), China (Gao et al. 2021), Japan (Matsumoto et al. 2017), and Turkey (Alsaffar 2012). In 2014, a systematic literature review on the association between nutrition knowledge and dietary intake reported that few studies had used both valid and reliable tools to assess nutrition knowledge (Spronk et al. 2014). Similarly, the results of another systematic review showed a lack of reporting of the psychometric properties of tools that measure nutrition knowledge among children and adolescents. The authors emphasized

the need for more valid and reliable tools to assess specific aspects of nutrition knowledge (Newton et al. 2019).

1.4 The nutritional situation in Saudi Arabia

In recent decades, Saudi Arabia has undergone a substantial nutrition transition characterized by the traditional diet being replaced by a Westernized diet, increased consumption of sugar-sweetened beverages, and physical inactivity (Adam et al. 2014; DeNicola et al. 2015). Urbanization, modernization, economic growth, and social transformation are among the main drivers of this transformation (Salem et al. 2022). The changes in nutritional patterns have led to an increase in the burden of obesity, one of the key risk factors for NCDs (Salem et al. 2022). According to the 2019 World Health Survey, the prevalence of overweight and obesity among adults in Saudi Arabia is estimated at 38% and 20%, respectively (Saudi Ministry of Health 2020). Similarly, a high prevalence of overweight and obesity with an increasing trend has been reported among children (5–19 years) in Saudi Arabia; the prevalence increased from 25.1% and 9.8% in 2000 to 35.6% and 17.4% in 2016 for overweight and obesity, respectively (World Health Organization 2017). Moreover, 73% of deaths in Saudi Arabia are attributable to NCDs (World Health Organization 2022). Among them, 37% are related to cardiovascular diseases, followed by cancers and diabetes at 10% and 7%, respectively (World Health Organization 2018b). NCDs therefore represent a major burden to both public health and the economy of the country (Albejaidi and Nair 2021).

In 2016, the government of Saudi Arabia introduced a comprehensive national framework, Vision 2030, which includes important multisectoral reforms aimed at transforming the country's economy and society. One of the health objectives of Vision 2030 is to prevent health risks. Among the strategic pillars of this objective is to reduce the prevalence of risk factors for NCDs (Kingdom of Saudi Arabia 2021).

As part of the effort to achieve the goals of the 2030 vision related to NCDs, the Saudi Food and Drug Authority launched a healthy food strategy that aims to promote healthy lifestyles and limit the consumption of salt, sugar, and saturated and trans fats (Bin Sunaid et al. 2021). The healthy food strategy comprises numerous nutritional reforms that are intended to increase nutritional awareness among the general population. Despite all these efforts, however, the need remains for nutritional interventions to improve nutrition-related knowledge among the general population (Bin Sunaid et al. 2021), which in turn highlights the need for valid and reliable tools to assess different aspects of nutrition knowledge among different groups of the population (see thesis objective 2). Identifying the current level of nutrition knowledge among the population is essential to inform the development of nutrition-related interventions (see thesis objective 3)

1.4.1 Nutrition education and the food environment at schools in Saudi Arabia

Although nutrition is not taught as an independent subject in schools in Saudi Arabia, some lessons on nutrition are included as part of the curriculum. For example, upper primary school students receive a few lessons on nutrition as part of the family and life skills subject. These lessons cover basic nutrition information, such as food groups and the nutrient content of food. Nonetheless, in a recent nationwide cross-sectional study, students aged 10–19 years were asked whether they receive nutrition education at school, and 68% reported that they did not receive any nutrition education at school (Bookari 2022). Similarly, an earlier cross-sectional study asked children about their sources of knowledge about health and diseases, and only 28.6% of the boys and 32.5% of the girls reported schools as their source of knowledge (Alsubaie 2017).

In 2020, the Saudi Ministry of Education in cooperation with the Saudi Ministry of Health updated the Regulations of Health Conditions for School Canteens, which were first developed

in 2004 and revised in 2013. These regulations address many aspects related to school canteens, such as food safety and hygiene, food storage and handling, and the food items that can be sold. They also include a list of banned food items, such as soft drinks, fruit nectars with less than 30% fruit content, fried foods, all meat products, chocolates and biscuits, and potato chips (Saudi Ministry of Education and Saudi Ministry of Health 2020).

1.4.2 Dietary guidelines for Saudis

In 2012, the Saudi Ministry of Health launched the Dietary Guidelines for Saudis (Saudi Ministry of Health 2012). These guidelines aimed to increase food awareness among the population within the Kingdom and emphasize the connection between health, nutrition, and physical activity. The Saudi Dietary Guidelines are graphically presented as the Healthy Food Palm (Figure 1), which was chosen due to its cultural, religious, and economic significance to the Saudi population. The food groups are presented in the palm trunk and leaves from the bottom to the top in the order of their recommended intake. The food group at the bottom of the trunk and leaves represents the food group that should be consumed the most (i.e., the cereal group), while that on the top represents the food groups that should be consumed the least (i.e., the sugar and oil groups). In addition to food groups, water is displayed on the palm trunk below the cereal group to emphasize its significance, especially given the Saudi weather, which is characterized by extreme heat at various times of the year (Saudi Ministry of Health 2012). The guidelines further emphasize variety, balance, and moderation as key elements of a healthy diet.

Figure 1: The Healthy Food Palm

Source: (Saudi Ministry of Health 2012)

1.5 Identified research gaps

Globally, NCDs account for 74% of all deaths (World Health Organization 2022). A growing body of evidence shows that the risk factors for developing NCDs begin in early childhood (Yan and Mi 2021). Starting nutrition and other health interventions from an early age is therefore highly recommended. Schools have been identified as effective and efficient settings for delivering nutrition and health interventions (World Health Organization 2018a); thus, more nutrition interventions are being implemented in school settings (Aloia et al. 2016). Furthermore, due to the potential role of nutrition knowledge in improving dietary intake, many of these interventions aim to improve health or nutrition knowledge. However, despite considerable data on the effectiveness of these interventions among schoolchildren, research regarding the potential impact of such interventions on parents and the families of the children who receive these interventions is lacking.

When designing and assessing nutrition interventions aimed at enhancing nutrition knowledge, it is imperative to have valid and reliable tools to assess the current state of knowledge and to capture any potential changes related to the intervention. These tools should be tailored for use in specific contexts and age groups. There is, however, consensus in the literature on the lack of valid and reliable tools for assessing nutrition knowledge (Newton et al. 2019; Spronk et al. 2014).

In Saudi Arabia, the situation is not entirely different to that globally, as NCDs pose significant challenges to public health and the economy (Albejaidi and Nair 2021). The government of Saudi Arabia is seeking to reduce the prevalence of the risk factors of NCDs as part of Vision 2030 (see sub-chapter 1.4 of this thesis for more details). The need therefore exists for well-designed health and nutrition interventions to be put in place. However, no valid and reliable tools are currently available to assess nutrition knowledge among primary schoolchildren in Saudi Arabia (see thesis objective 2). The availability of such a tool is important to assess the

current level of nutrition knowledge among children and to identify areas of nutrition knowledge that need specific emphasis when developing future interventions (see thesis objective 3).

1.6 Objectives

The general aim of this thesis was to assess the potential of school-based nutrition interventions to improve nutrition knowledge among schoolchildren and their parents.

The specific objectives were:

1. to determine whether school-based nutrition interventions have an impact on the nutrition knowledge, dietary intake, and health outcomes of schoolchildren's parents or other household family members;
2. to develop a valid and reliable nutrition knowledge questionnaire for upper primary schoolchildren in Saudi Arabia; and
3. to determine the level of nutrition knowledge among upper primary school female students in Jeddah.
    (a) to assess whether there are differences in the nutrition knowledge between students attending public and private schools in Jeddah.

The second and third objectives of the thesis are specifically focused on the Kingdom of Saudi Arabia. No instrument is currently available to evaluate the state of nutrition knowledge among primary schoolchildren in Saudi Arabia. The data gained through the use of a valid and reliable tool to determine the current state of nutrition knowledge in the country will serve as a cornerstone when designing and evaluating school-based nutrition interventions aimed at enhancing nutrition knowledge.

2. METHODOLOGY

2.1 The impact of school-based nutrition interventions on parents and other family members (objective 1)

This sub-chapter presents the methodology applied to address thesis objective 1. The first section describes the study design applied. The section that follows outlines the eligibility criteria of the included studies, followed by the study selection process, the data extraction procedure, and the quality assessment.

Note: Some aspects and texts in this sub-chapter are based on the associated publication (Abderbwih et al. 2022).

2.1.1 Study design

To address the study objective, a systematic literature review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Page et al. 2021).

2.1.2 Inclusion and exclusion criteria

Studies that investigated the impact of school-based nutrition interventions were eligible for inclusion in this review if they:

i. were controlled trials (randomized or non-randomized) or natural experiments;
ii. were aimed at schoolchildren and/or adolescents aged 5–18 years with or without the presence of the parental component;
iii. were conducted in school settings;
iv. assessed interventions primarily focused on nutrition;

v. measured one or all of the following three parental/family outcomes: (a) nutrition knowledge, (b) dietary intake, and (c) health outcomes; and

vi. were published in any language without any date restrictions.

Studies were excluded if they:

i. were targeted solely at parents, preschoolers, or at children with health-related issues such as overweight or obesity; or

ii. assessed interventions focused on eating disorders or oral health.

2.1.3 Search strategy

A comprehensive search strategy was developed to identify the relevant literature. PubMed, Web of Science, PsycINFO, EconLit, and Cochrane Reviews were systematically searched using a search strategy that comprised two steps. First, the search strategy was developed for PubMed to identify and inform the targeted search index. The search terms included both keywords and medical subject headings (MeSH) and were identified based on the following concepts: (i) setting, (ii) intervention, and (iii) target population. Following that, the search strategy was adapted as needed to the rest of the databases. Table 1 presents the search strategy used for the different databases. The searches were first conducted in December 2019 and updated in June 2021.

Google Scholar was also searched using the same search strategy to identify relevant gray literature. This search was conducted stepwise by screening 50 hits at a time until no more relevant articles could be identified. Finally, reference lists of the included studies were searched manually to identify further records that had not been identified in the previous steps.

Table 1: Strategy applied to search the different databases

Setting related terms	Intervention related terms	Target population related terms
PubMed	AND	AND
("Schools" [Mesh] OR primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	"Health Education" [Mesh] OR "Health education"	parent OR father OR mother OR caregiver OR family
("Schools" [Mesh] OR primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	"Intervention "	parent OR father OR mother OR caregiver OR family
("Schools" [Mesh] OR primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	Nutrition education OR "Diet, Food, and Nutrition/education" [Mesh]	parent OR father OR mother OR caregiver OR family
Web of Science	AND	AND
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health OR nutrition) NEAR/5 Education	parent* OR father* OR mother* OR caregiver* OR famil*
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health OR nutrition) NEAR/5 Intervention	parent* OR father* OR mother* OR caregiver* OR famil*
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health OR nutrition) NEAR/5 promotion	parent* OR father* OR mother* OR caregiver* OR famil*
PsycINFO and EconLit. through EBESCO	AND	AND
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health Education OR nutrition Education)	parent* OR father* OR mother* OR caregiver* OR famil*
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health Intervention OR nutrition Intervention)	parent* OR father* OR mother* OR caregiver* OR famil*
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health promotion OR nutrition promotion)	parent* OR father* OR mother* OR caregiver* OR famil*
Cochrane Reviews	AND	AND
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health Education OR nutrition Education)	parent* OR father* OR mother* OR caregiver* OR famil*

Setting related terms	Intervention related terms	Target population related terms
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health Intervention OR nutrition Intervention)	parent* OR father* OR mother* OR caregiver* OR famil*
(primary school* OR secondary school* OR "School based" OR "school centered" OR "school centred")	(Health promotion OR nutrition promotion)	parent* OR father* OR mother* OR caregiver* OR famil*

source: (Abderbwih et al. 2022)

2.1.4 Study selection and data extraction

All the retrieved records were imported into the reference manager software Endnote X9 (EndNote Team 2013). First, duplicates were removed, and the remaining records were then imported into Rayyan QCRI, a web-based software program for managing systematic reviews (Ouzzani et al. 2016). The titles and abstracts of these records were screened for eligibility. In the second stage, the full text of the articles selected from the title and abstract screening were assessed for eligibility.

A data extraction sheet with the relevant information was constructed and piloted. The data were extracted according to the following categories: first author, study title, year of publication, country, study design, sample characteristics (i.e., sample size, age, grade), conceptual framework, intervention components and duration, outcome measures, follow-up duration, response rate, and main findings.

2.1.5 Quality assessment

The Effective Public Health Practice Project (EPHPP) quality assessment tool for quantitative studies (Effective Public Health Practice Project 1988) was used to assess the risk of bias in the included studies. This tool evaluates study quality using six criteria: selection bias, study design, confounders, blinding, data collection procedures, and dropout. Based on the predetermined criteria provided in the tool's dictionary, each of these components was

classified as “strong,” “moderate,” or “weak.” The quality assessment was applied to the parental/familial-related components only, and the overall quality assessment rating was then established based on the ratings of the six aforementioned components as “strong” (none of the components has a weak rating), “moderate” (one of the components has a weak rating), or “weak” (two or more components have a weak rating).

2.2 Assessment of the level of nutrition knowledge among primary school children in Saudi Arabia (objectives 2 and 3)

This sub-chapter presents the methodology applied to address thesis objectives 2 and 3. The initial sections describe the study design, study setting, participant selection, and sample size. The subsequent sections describe the questionnaire used in this study and elucidate the process of developing and testing its psychometric properties. Finally, the statistical analysis process is described.

Note: Some aspects and texts in this chapter are based on the associated publication (under review) (Abderbwih et al. 2023).

2.2.1 Study design and study setting

A cross-sectional design was used in this study. The quantitative data were collected between March and June 2022 using the questionnaire that was developed for this study, and the study sample comprised students from 11 public and private schools (see the subsequent sections for more details). The study was conducted in the city of Jeddah, which is located on the western coast of the Kingdom of Saudi Arabia and is the second-largest city in the country after the capital city Riyadh.

In Saudi Arabia, most educational institutions, such as schools and universities, are gender-segregated facilities. Generally, only female researchers are allowed into female-only schools and vice versa. For this reason, female-only schools were selected for this study. Based on the statistics guide of the General Directorate of Education in Jeddah (2021), the total number of female primary schools was 348 (240 public and 108 private), and the estimated total number of students in these schools was 147,876 (137,394 students in public schools and 10,482 students in private schools) . There are four educational centers in Jeddah: north, south, middle,

and east. Each public and private school follows one of these four educational centers based on their geographical location within the city. Figure 2 shows the location of Jeddah on the map of Saudi Arabia.

Figure 2: The location of Jeddah on the map of Saudi Arabia

2.2.2 Participants and Sample size

The target population for this study was female upper primary school students (fourth, fifth, and sixth graders) in Jeddah. The inclusion criteria were female upper primary students who attended the selected schools and who had returned the signed consent and assent forms. Students were excluded if they were attending the first, second, or third grades or if they did not return the signed consent and assent forms.

The 11 public and private schools from which the study sample was drawn were selected randomly from the four different regions of Jeddah. The number of public schools in Jeddah is more than double the number of private ones; thus, two public schools and one private school were selected from each region. The only exception was the south region, in which only one public school and one private school were randomly selected due to major reconstruction in that area.

A sample size of approximately 600 students was calculated to detect a 1.2 ± 4 point difference in the total scores between the groups (public and private) with a power of 80% and a significance level of 0.05 (Figure 3) (Matthews et al. 2002, pg. 137-146). This sample was further increased to 1700 students to account for non-responses. A response rate of 30%–40% was anticipated based on a previous school-based study on adolescents in Jeddah (Mumena et al. 2022). Additionally, the data collection was carried out during the COVID-19 pandemic; thus, a low response rate was expected.

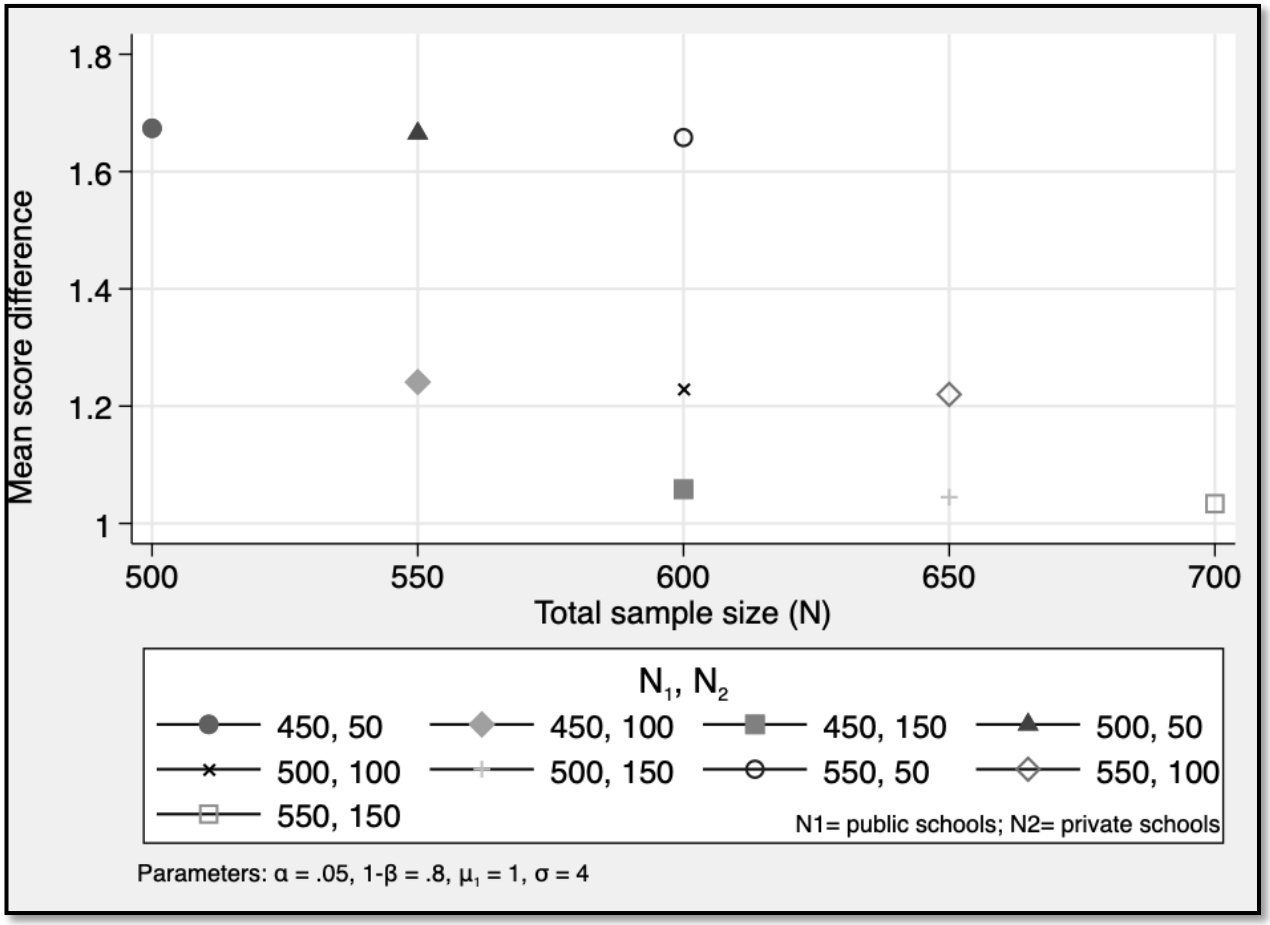

Figure 3: Sample size estimation based on mean scores differences

2.2.3 Questionnaire development and validation

Based on the general definition of nutrition knowledge, three main constructs were identified: (1) food groups and their recommended daily intake, (2) food sources of nutrients, and (3) the effects of food on health and disease. The items in each construct were either created or obtained/adapted from questionnaires used in previous studies that targeted similar age group (Asakura et al. 2017; de Villiers et al. 2016; Habib-Mourad et al. 2014). After selecting the items for the survey, they were assessed and adapted to both the Saudi culture and the dietary recommendations in the Dietary Guidelines for Saudis published by the Saudi Ministry of

Health (2012). For example, only food items that are familiar to Saudi culture were included in the questionnaire items. Finally, items in English were translated into Arabic.

The first draft of the questionnaire was initially revised by the author and another Saudi dietitian. The questionnaire was then assessed for content validity, which refers to the degree to which the questionnaire items are relevant to the questionnaire's intended constructs (Gleason et al. 2010). To determine the content validity, an expert panel comprising five dietitians from Saudi Arabia reviewed the preliminary questionnaire items by rating each item for relevancy on a four-point Likert scale: 1 = very irrelevant, 2 = irrelevant, 3 = relevant, and 4 = very relevant. Qualitative feedback was also collected from the expert panel, and changes were made to the questionnaire based on the panel's ratings and responses. In the next stage, the questionnaire was pretested using a convenience sample of five students. These students were interviewed after they had completed the questionnaire to determine the questionnaire's face validity (clarity and relevance of the items) and the time required to complete the questionnaire.

2.2.4 Description of the questionnaire and scoring

The final version of the questionnaire comprised 29 items, which covered the three main constructs, as well as the first part of the questionnaire, which asked the students to provide their general demographic information, such as their age, school name, nationality, and grade. The first construct (food groups and their recommended daily intake) contained 11 questions (q1–q11) to assess the children's knowledge about different food groups and whether they were able to classify food items based on different food groups. It further assessed the children's knowledge about the recommended intake of some food items, such as fruits, vegetables, and fats. The second construct (food sources of nutrients) contained eight questions (q12–q19) and

asked the children about dietary sources of nutrients, such as carbohydrates, fats, proteins, salt, fibers, and some vitamins and minerals. The third construct (effect of food on health and disease) contained 10 questions (q20–q29), which address the effects of major nutrients on health conditions. The complete Arabic questionnaire is presented in Appendix I. All the items in the questionnaire were multiple-choice questions. Some questions had three possible answers, whereas the others had four; however, each question had only one correct answer. Correct responses received a score of one (1), while incorrect ones and "I'm not sure" responses received a score of zero (0). Thus, the maximum possible score that could be achieved was 29. The total scores were determined for each domain separately. The maximum total scores were 11, 8, and 10 for the first, second, and third domains, respectively.

2.2.5 Questionnaire reliability

To assess the reliability of the questionnaire, the internal consistency and test–retest reliability were determined. Internal consistency reliability describes how different items in a questionnaire are correlated. In other words, it assesses whether different items in a questionnaire measure the same parameter (Tavakol and Dennick 2011). The internal consistency reliability was measured for the entire sample (636 students); however, only a subsample of 69 students completed the questionnaire twice, and their data were therefore used to assess the test–retest reliability. The purpose of assessing test–retest reliability is to ensure the consistency or stability of the results over time (Lohr 2002). In this study, the time between the administration of the two tests was ten days. During this time interval, it was assumed that the children would have forgotten their previous responses, but the time frame was not considered sufficient for them to gain new knowledge (Parmenter and Wardle 2000). The steps for the questionnaire development and validation are summarized in Figure 4.

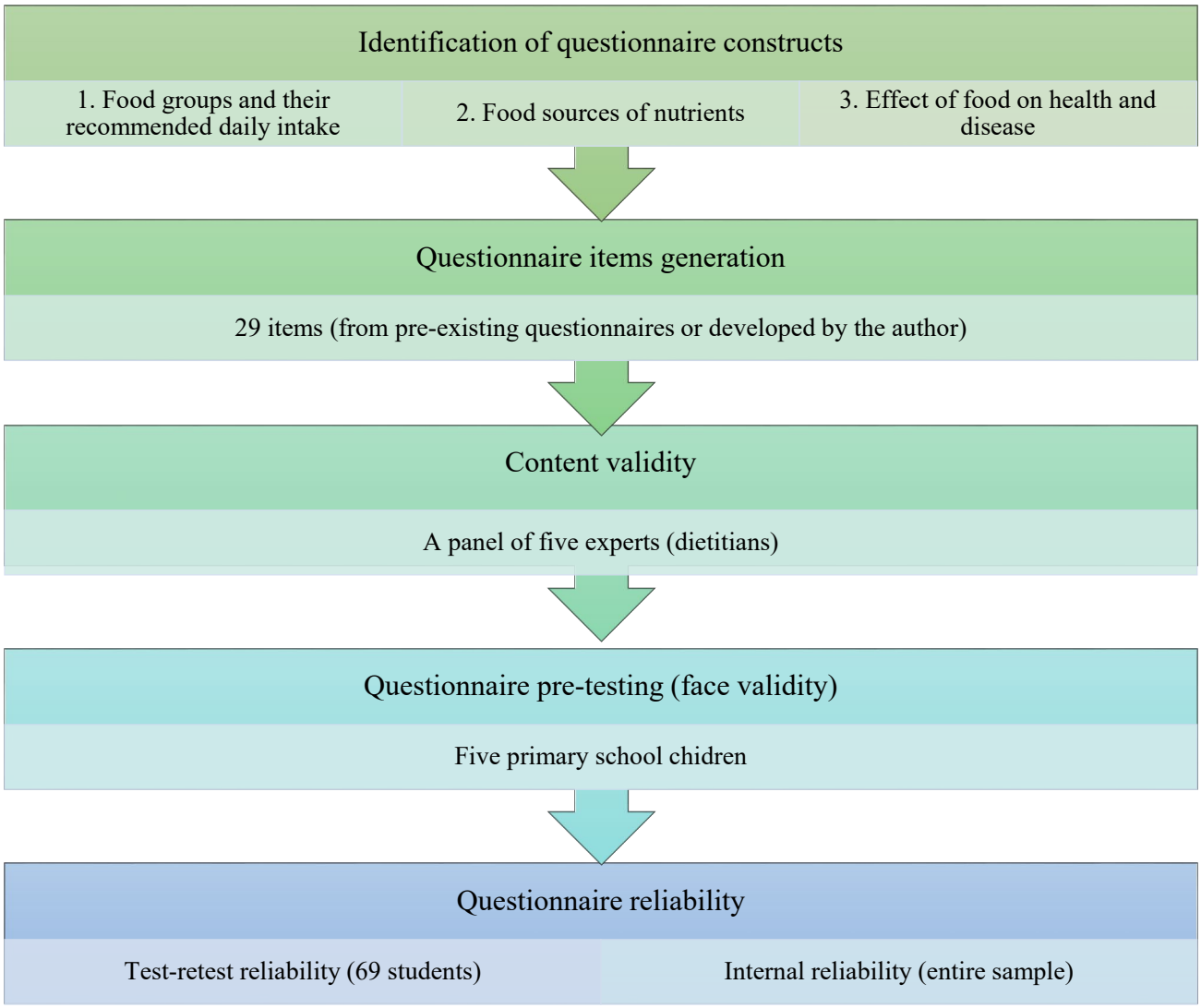

Figure 4: Steps for questionnaire development and validation

2.2.6 Statistical analysis

The data were double-entered using Epi-data software (EpiData Association, Odense, Denmark), and the statistical analyses were performed using Stata software version 17.0 BE (Stata Corporation, College Station, Texas) as well as Microsoft Excel (Microsoft Corporation, Redmond, Washington). For all the statistical analyses, a p-value < 0.05 was considered statistically significant.

The characteristics of the study participants were summarized using descriptive statistics, such as frequencies, percentages, medians, means, and standard deviations (SD).

Validity

To assess the questionnaire's content validity, the content validity index (CVI) of each item was determined. This was calculated as the number of experts who provided a relevancy rating of 3 or 4 divided by the total number of experts. Items with values ≥ 0.8 were regarded as having acceptable content validity (Polit et al. 2007; Trakman et al. 2017).

Reliability

The internal consistency reliability of the questionnaire was determined using Cronbach's alpha, with values ≥ 0.70 indicating acceptable reliability (Bland and Altman 1997). The test–retest reliability of each individual item was assessed using the kappa statistic. The cut-off values suggested by Landis and Koch were used to interpret the results, where a kappa value < 0.00 represented poor agreement, 0.00–0.20 slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–1.00 almost perfect agreement (Landis and Koch 1977). In addition, the Pearson correlation coefficient was used to assess the association between the scores (the total scores and the scores of each domain) at the two time points that the questionnaire was administered. Although there is no clear agreement on how to interpret the Pearson correlation coefficient, it is recommended that values ≥ 0.70 indicate good reliability (Kurpius and Stafford 2006, pg. 124-125).

Item analysis

The item difficulty and the discrimination indices of each item were determined for the overall sample as well as for each grade. The item difficulty index (percentage of correct answers) describes how difficult each item is. In this study, items with values between 0.10 and 0.90 were considered to have an appropriate level of difficulty (Dwyer et al. 1981; Whati et al. 2005). Values ≤ 0.10 indicated that the item was answered by 10% or less of the sample, and

it was thus considered too difficult, whereas values ≥ 0.90 indicated that the item was answered by 90% or more of the sample, and it was deemed too easy.

Item discrimination refers to the ability of an item to differentiate between students who score in the upper quartile and those who score in the lower quartile. It was calculated by subtracting the percentage of students in the lower quartile who answered an item correctly from the percentage of those in the upper quartile who answered the same item correctly. Values ≥ 0.02 were deemed acceptable (Aiken 1979).

Finally, to estimate whether there was a linear trend between the independent variable (i.e., grade, continuous) and (i) item difficulty and (ii) item discrimination, a regression analysis was performed.

Variables

In this study, the continuous variable (total knowledge score) was considered the dependent variable. The total knowledge scores for the overall questionnaire and for the individual domains were classified as "good" (scores above the mean) or "poor" (scores below the mean). The independent variables were age, nationality, school type, grade, and the educational center of the school.

Comparisons of the knowledge scores between the different participants' categories

The differences in the total scores between the different groups were assessed using parametric one-way analysis of variance (ANOVA) and an independent t-test. The following assumptions were checked before using these tests: the normality of the data and homogeneity of variance. The former was assessed using histograms and the Kolmogorov–Smirnov test, whereas the homogeneity of variance was checked using Levene's test. In cases where the assumptions of the parametric tests were violated, a non-parametric Kruskal–Wallis H test was used. A post-

hoc test (Bonferroni) was performed to compare the mean scores between each pair of groups. Finally, multiple regression was used to estimate the relationship between the total scores and the explanatory variables (grade, school type, school's educational center, and nationality).

Missing data

For item discrimination and item difficulty indices, missing data were considered wrong answers. However, a complete case analysis was employed for all other analyses.

2.2.7 Ethical consideration

This study was approved by the ethical committee of the medical faculty of the University of Heidelberg (S-069/2022). Permissions were obtained from the Saudi Arabian Ministry of education, General Directorate of Education in Jeddah, Directors of education offices, as well as schools principals. Written informed consents were obtained from participants' parents/legal guardians. Finally, written assents were obtained from students to participate in the study.

3. RESULTS

3.1 The impact of school-based nutrition interventions on parents and other family members (objective 1)

This sub-chapter presents the results of the systematic literature review on the impact of school-based nutrition interventions on parents and other family members (thesis objective 1). First, the results of the literature search are presented. The characteristics of the included studies, the results of the quality assessment, and the findings based on the different outcomes are described in the subsequent sections.

Note: Some aspects and texts of this sub-chapter are based on the associated publication (Abderbwih et al. 2022).

3.1.1 Literature search results

The literature search identified 20,095 articles. Of these, 5724 duplicates were removed. The titles and abstracts of the remaining 14,371 studies were screened, yielding 464 potentially eligible articles for full-text assessment. As a result, 22 articles met the eligibility criteria and were included in the review. Reasons for excluding articles were irrelevant outcomes; insufficient analyses of the outcome of interest; different study design, population, intervention, and setting; and double publications. Articles devoted to process evaluation, protocols, and feasibility studies were also excluded.

The current review included only one non-English (Chinese) study that met the eligibility criteria (Dong et al. 2019). In addition, two studies reported different outcomes for the same sample (He et al. 2016; He et al. 2015), and one study (Tak et al. 2009) presented the long-term outcome of another study (Tak et al. 2007). Figure 5 presents the PRISMA flow diagram of the study selection process.

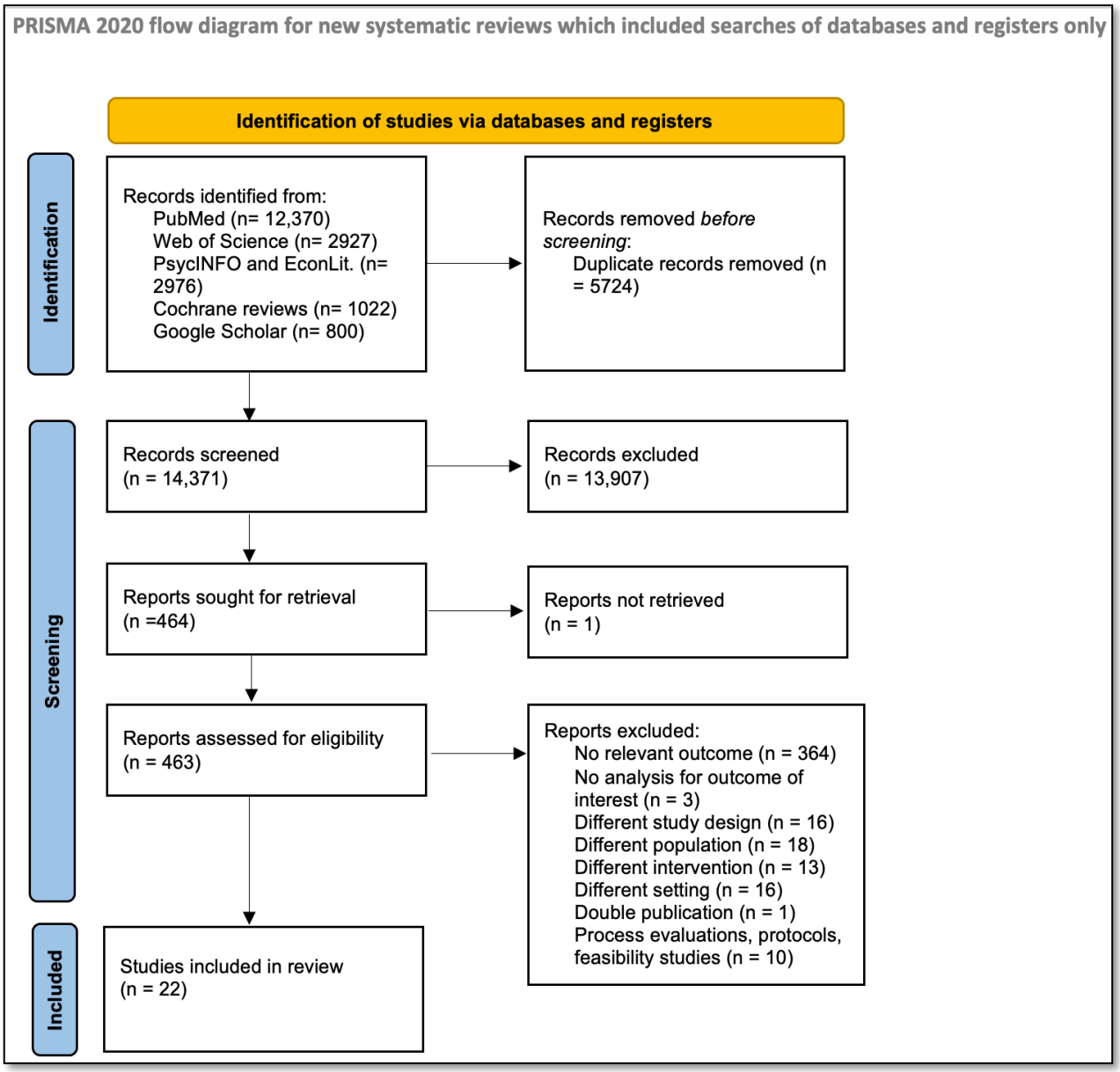

Figure 5: PRISMA flow diagram of study selection

Source: (Abderbwih et al. 2022)

3.1.2 Study characteristics

Table 2 presents the main characteristics of all the included studies. To improve text readability, each of the included studies was assigned an ID that was used to identify the studies in the subsequent sections (Table 2).

Table 2: General characteristics of included studies

Authors Year, Country	Study ID	Design	Participants	Theoretical Framework	Intervention duration	Intervention Components	Parental/ family outcomes of Interest
(Bjelland et al. 2015) Norway	1	CRCT	Sixth-grade students: *n* = 1,418; Mothers: *n* = 849; Fathers: *n* = 680	NR	20 mo.	Classroom components, home/parents' components, school wide components, and leisure time activities	Parental intakes of sugar-sweetened soft drinks and sugar-sweetened fruit drinks; Intake of FV
(Blom-Hoffman et al. 2008) USA	2	Non-RCT	Kindergarten and first-grade students: *n* = 297; Parents: *n* = 80	NR	16 mo.	Morning announcements highlighting the FV of the day and an associated fact; posters; Dole CD-ROM during computer special or in the classroom; and assignments and take-home books	Parental knowledge of the "5 a Day" message
(Burgess-Champoux et al. 2008) USA	3	Non-RCT	Fourth- and fifth-grade students/ parent pairs: I: *n* = 67, C: *n* = 83	SCT	5 mo.	Five-lesson classroom curriculum, school cafeteria menu modifications, and family involvement	Parental self-reported intake of refined- grain/ whole grain foods
(Crockett et al. 1989) USA	4	Non-RCT	Parents of third-grade students: *n* = 465	SLT	5 wk.	Hearty Heart and Friends: a third-grade curriculum; Hearty Heart Home Team: a five-week parent-taught intervention that is mailed to students' homes; Hearty Heart and Home Team: both school and parent-taught; and Control group: no intervention	Parental knowledge about diet and its relationship to CVD and dietary intake

Authors Year, Country	Study ID	Design	Participants	Theoretical Framework	Intervention duration	Intervention Components	Parental/ family outcomes of Interest
(Dong et al. 2019) China	5	CRCT	Fourth-grade students: I: *n* = 1361, C: *n* = 1364; Parents: I: *n* = 1306, C: *n* = 1340 C	NR	8 mo.	Educational materials for salt reduction; watching popular science movies and children's animations; six monthly salt reduction training sessions for students; publicity boards, campus radio, newspapers, etc. for publicity; winter vacation activities; and salt reduction theme activity and family component.	Parental knowledge of salt intake
(Gewa et al. 2013) Kenya	6	CRCT	First-grade students and siblings: vegetarian group: *n* = 80, meat group: *n* = 96, milk group: *n* = 101, control: *n* = 63; Parents: vegetarian group: *n* = 79, meat group: *n* = 91, milk group: *n* = 100, control: *n* = 72	NR	24 mo.	Daily distribution of snacks to the school children based on the assigned group. Vegetarian supplement, milk supplement, meat supplement, and control (no food supplement provided).	Change in energy intake and markers of dietary quality among parents
(Gunawardena et al. 2016) Sri Lanka	7	CRCT	Mothers of eighth-grade students: I: *n* = 152, C: *n* = 156	NR (own experience)	12 mo.	Intervention group students were trained by facilitators through a series of discussions to acquire the ability to assess noncommunicable disease risk factors in their homes and take action to address them	Mothers' weight, BMI, and self-reported consumption of food items
(He et al. 2015) (He et al. 2016) China	8 9	CRCT	Fifth-grade students: I: *n* = 141, C: *n* = 138; Adult family members: I: *n* = 278, C: *n* = 275	NR	3.5 mo.	Children in the intervention group were educated on the harmful effects of salt and how to reduce salt intake within the schools' usual health education lessons. Children then relayed these salt reduction messages to their families	Salt intake (as measured by 24-hour urinary sodium excretion), BP, and iodine consumption among adult family members

Authors Year, Country	Study ID	Design	Participants	Theoretical Framework	Intervention duration	Intervention Components	Parental/ family outcomes of Interest
(Katz et al. 2011) USA	10	CRCT	Second- to fourth-grade students: I: *n* = 628, C: *n* = 552	Social-Ecological Model	NR	Five mini-lessons and family outreach	Dietary pattern of parents
(Knight et al. 1991) Jamaica	11	Non-RCT	Fourth- and fifth-grade students: I: *n* = 423, C: *n* = 199; Mothers/guardians: I: *n* = 90, C: *n* = 47	NR	During the school year	Bi-weekly teacher training sessions to review what should be taught in the following two weeks and to assist in developing the curriculum. Action-oriented lessons for children	Mothers' nutritional knowledge
(Newell et al. 2004) Australia	12	Non-RCT	Third- to sixth-grade students: I: *n* = 307, C: *n* = 85; Parents: *n* = 613	NR	2 yr.	Multi-strategy program including classroom-oriented strategies, parent-oriented strategies, school environment-oriented strategies, and school canteen-oriented strategies	Parental knowledge about recommended FV intakes
(Øvrum and Bere 2014) Norway	13	Natural experiment	First- to seventh-grade students; Parents: *n* = 1423	NR	NR	Free daily fruit or vegetable or subscription to one fruit or vegetable per day at a subsidized price	Parents' FV intake
(Perry et al. 1998) USA	14	CRCT (matched pair)	Fourth-grade students; Parents: *n* = 324	SLT	7 mo.	Behavioral curricula in the fourth and fifth grades, parental involvement/education, school foodservice changes, and industry involvement and support	Parents' FV intake
(Reynolds et al. 2000) USA	15	CRCT	Fourth-grade students; Parents: *n* = 1698	SCT	Fall/winter 1994/95	A classroom component with 14 lessons curriculum, in addition to booster sessions delivered during the second year; a parent component; and a food service component	Parents' FV intake, knowledge of 5 a day and knowledge of low-fat food preparation
(Sharma et al. 2016) USA	16	Non-RCT	First-grade students. Parent-child dyads: I: *n* = 407, C: *n* = 310	SCT, TPB	16 wk.	Weekly distribution of fresh produce; nutrition education in schools and for parents; and weekly recipe tastings	Parents' FV intake

Authors Year, Country	Study ID	Design	Participants	Theoretical Framework	Intervention duration	Intervention Components	Parental/ family outcomes of Interest
(Shi-Chang et al. 2004) China	17	Non-RCT	Third- to fifth-grade primary students: *n* = 2575; First- and second-grade secondary students: *n* = 4277 (baseline survey); Parents and guardians: *n* = 998	NR	18 mo.	School-wide health promotion activities, including school-based working groups; nutrition training for school staff; distribution of materials on school nutrition; nutrition education for students; student competitions; school-wide health promotion efforts; and outreach to families and communities	Nutrition knowledge of parents and guardians
(Tak et al. 2007) (Tak et al. 2009) Netherlands	18 19	Non-RCT.	Fourth-grade students: *n* = 953; Parents: *n* = 705 Fourth-grade students: I: *n* = 346, C: *n* = 425; Parents: I: *n* = 148 I, C: *n* = 287	NR	NR	Improvement of FV availability and accessibility, bi-weekly free FV distribution at the mid-morning break, and school curriculum aimed at increasing knowledge and skills related to FV consumption	Parental knowledge about recommendations for fruit
(Te Velde et al. 2008) Spain, Norway and the Netherlands	20	CRCT	Fifth- and sixth-grade students; Mothers or female guardians: I: *n* = 415, C: *n* = 838 (baseline survey)	NR	NR	A classroom component, a school component, a family component, and one optional component, which differed slightly between intervention sites	Total intake of FV and the intake of FV separately among mothers or female guardians
(Wang et al. 2016) China	21	CRCT	Parents of seventh-grade students: I: *n* = 62, C: *n* = 61	NR	6 mo.	Health-promoting school intervention consisting of a wide range of health promotion activities in different domains including, School environment, curriculum, and Family involvement	Parents' weekly frequency of consumption of food items, and nutrition knowledge
(Woodhouse et al. 2012) UK	22	Non-RCT (pilot)	Primary school students; Parents: I: *n* = 47 intervention (baseline survey)	NR	20 mo.	FV stall operated in the school playground twice a week, added initiatives (a loyalty card, 100 challenge week), family cooking sessions, and children's tasting sessions	Parents' FV consumption

Source: (Abderbwih et al. 2022)

Abbreviations: RCT = Randomized controlled trial, CRCT = Cluster randomized controlled trial; I = Intervention; C = Control; mo. = month; wk. = week; FV = Fruits and vegetables; BMI = Body mass index; SCT = Social Cognitive Theory; SLT = Social Learning Theory; TPB = Theory of Planned Behavior.

3.1.2.1 Geographical locations and study design

The included studies covered multiple geographical locations. Seven studies (32%) were carried out in the United States (ID: 2–4,10,14,15,16), five (23%) in China (ID: 5,8,9,17,21), and five in Europe, with some covering multiple European countries (three in Norway (ID: 1,13,20), three in the Netherlands (ID: 18,19,20), and one in Spain (ID: 20)). Finally, one study was conducted in each of the following countries: Kenya (ID: 6), Sri Lanka (ID: 7), Jamaica (ID: 11), Australia (ID: 12), and the UK (ID: 22).

Regarding study designs, 11 studies were randomized controlled trials (RCT) (ID: 1,5–10,14,15,20,21), 10 had non-randomized controlled trial designs (non-RCT), among which, nine had pre-post (ID: 2,3,4,11,16,17,18,19,22) and one post-study design (ID: 12). Only one article utilized a natural experiment study design (ID: 13).

3.1.2.2 Participants and interventions characteristics

Participating students were recruited from grades one through eight. In one study, a sample of kindergarten and primary school children was included (ID: 2). Both parents were included in the majority of the studies, except for three that included mothers only (ID: 7,11,20), and two included an adult family member (ID: 8,9). Finally, parents and siblings were included in one of the studies (ID: 6). However, outcomes related to siblings from this study were not included, as they were combined with the outcomes of school children.

There was a wide variation in the sample size of parents and families, ranging from 47 (ID: 22) to 1,698 (ID: 15). In 16 interventions, more than one component was incorporated, including classroom, school, family, and community elements, whereas the remaining interventions consisted mainly of a single element, such as the distribution of daily snacks (ID: 6), free or reduced-price fruits and vegetables (ID: 13), and offerings of education and/or training to students (ID: 7, 11).

Parental and family components were presented in the majority of the interventions (n = 16). Of these, nine interventions utilized indirect involvement strategies (e.g., mailing letters, newsletters, text messages, pamphlets, and other educational materials; assigning cooperative homework and activities for students to complete with their parents; and holding parent meetings and events) (ID: 1,2,4,8,9,10,14,15,20). The remaining seven interventions utilized direct involvement strategies (e.g., educational, training, or counseling sessions for parents that required their attendance) (ID: 3,5,12,16,17,21,22). Only six of the studies reported the utilization of theoretical frameworks, such as The Social-Ecological Model (ID: 10), Theory of Planned Behavior (ID:16), Social Cognitive Theory (ID: 3,15,16), and Social Learning Theory (ID: 4,14), to inform interventions.

3.1.3 Quality assessment

Of the 22 included studies, six were rated as "strong" (ID: 4, 7–9, 15, 21), five as "moderate" (ID: 3, 13, 14, 16, 20), and eleven as "weak" (ID: 1, 2, 5, 6, 10–12, 17–19, 22). Table 3. presents the results of the quality assessment of each included study.

Regarding the selection bias component, five studies were deemed "weak" (ID: 2, 3, 12, 16, 22), mostly due to the low or insufficient reporting of the participation rate and improper representation of the sample to the target population. For the study designs, four studies were rated as "weak," as their study designs were not stated explicitly (ID: 2, 11, 17, 22). In addition, one study was rated as "moderate," as it had a natural experiment study design (ID: 13). With respect to the confounder component, six studies were deemed "weak," mainly due to insufficient reporting on controlling for potential confounding factors (ID: 2, 5, 10, 12, 17, 22). Regarding the blinding component, one study received a "weak" rating as blinding was not applied to the study subjects nor to the outcome assessors (ID: 6). All remaining studies received a "moderate" rating primarily due to insufficient reporting regarding the degree of

blinding of outcome assessors and/or study subjects. Ten studies received a "weak" rating for the data collection method component, primarily due to the insufficient reporting of the psychometric properties of the data collection methods (ID: 1, 2, 5, 6, 11, 13, 14, 18, 19, 22). Finally, nine studies were deemed "weak" for the withdrawal and dropout component due to low or unreported completion rates (ID: 1, 2, 10, 12, 17–20, 22).

Table 3: Summary table of the quality assessment using the EPHPP tool

Study ID	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals & Dropouts	Overall rating
1	+	++	+	+	–	–	–
2	–-	–	–	+	–	–	–
3	–	++	+	+	+	+	+
4	+	++	++	+	++	+	++
5	+	++	–	+	–	+	–
6	+	++	+ +	–	–	++	–
7	++	++	++	+	+	++	++
8	+	++	++	+	++	++	++
9	+	++	++	+	++	++	++
10	+	++	–	+	++	–	–
11	+	–	++	+	–	++	–
12	–	++	–	+	+	–	–
13	+	+	++	+	–	+	+
14	+	++	++	+	–	++	+
15	+	++	++	+	++	+	++
16	–	++	++	+	+	+	+
17	+	–	–	+	+	–	–
18	++	++	++	+	–	–	–

Study ID	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals & Dropouts	Overall rating
19	++	++	++	+	–	–	–
20	+	++	++	+	++	–	+
21	+	++	++	+	++	++	++
22	–	–	–	+	–	–	–

++ Strong + Moderate – Weak

Adapted from: (Abderbwih et al. 2022)

3.1.4 Parental and family outcomes

Among the included studies, 15 studies reported the impact of school-based interventions on parental dietary intake, ten on nutrition knowledge, and two on health outcomes. Table 4 presents the main findings.

Table 4: Parental involvement, outcome of interest, outcome measures, and findings on parental/ familial outcomes of interest

Study ID	Parental involvement	Outcomes of interest	Outcome measures	Findings
1	Indirect	Parental intakes of sugar-sweetened soft and fruits drinks; Intake of FV	Self-administered questionnaire	Non-significant increase in maternal mean intake of fruits in the intervention group (mean = 9.1servings/week) as compared to control group (mean = 8.4 servings/week) ($p = 0.06$).
2	Indirect	Knowledge of the "5 a Day" message	Parental interview using structured questionnaire	When compared to baseline, parents of the experimental group had higher percentage of correct answers about the "5 a Day" message at 1 year post baseline (21.6% higher, $p < 0.05$) and at 2 years post baseline (43.3% higher, $p < 0.001$). When compared to parent of the control group, they also had higher percentage of correct answer at 1 year post baseline (20.8% higher, $p < 0.05$), and at 2 years post baseline (40.1% higher, $p < 0.001$).
3	Direct	Self-reported intake of refined- and whole-grain foods	12-item food frequency section modified from the Block FFQ (Intake over the past month)	Self-reported intake of refined-grain foods decreased significantly for parents in the intervention school (pre-post difference: −0.3, $p < 0.05$) compared to those in comparison school ($p < 0{\cdot}01$) post-intervention. No significant group differences were found in whole grain intake.
4	Indirect	Knowledge about diet and its relationship to cardiovascular disease	Self-administered questionnaire (Three scales)	Home Team alone group and the Hearty Heart and Home Team group had significantly greater knowledge scores as compared to the control group and Hearty Heart alone groups across all three scales.
		Dietary intake	Willett FFQ (Intake over the past two months)	There were no significant differences in dietary intake among the groups.

Study ID	Parental involvement	Outcomes of interest	Outcome measures	Findings
5	Direct	Change in knowledge of salt intake	Self-administered questionnaire	After the intervention, intervention group parents had significantly higher awareness of the salt reduction knowledge than those of the control group ($p < 0.01$)
6	No parental involvement	Change in energy intake and markers of dietary quality among parents	Three non-consecutive 24 h recalls	A general decline in food quality and quantity was reported among parents of all groups. The decline in food quantity was only significant for the parents of the vegetarian group. Significant declines on at least one of the markers of dietary quality were seen among parents of vegetarian, meat, and control group.
7	No parental involvement	Mothers' weight and BMI	Weight and height were measured by research team	Intervention group mothers had a significantly lower mean weight and BMI than as compared to control group ($p < 0.0001$); mean effect (95% CI) −2.49 (−3.38 to −1.60) kg for weight and −0.99 (−1.40 to −0.58) kg/m^2 for BMI.
		Mothers' self-reported consumption of FV, whole-grain product, pulse as main dish, deep fried foods, and sugar-sweetened beverages	27- item self-administered FFQ	No significant difference in individual-level food consumption between mothers of the two groups after the intervention.
8	Indirect	Salt and iodine consumption among adult family members	24-hour urinary sodium and iodine excretion	The mean effect (95% CI) on salt consumption for adults in the intervention group compared to control group was −2.9 g/day (−3.7 to −2.2g; $p < 0.001$), representing a 25% reduction. The mean effect on iodine was −11.4% ($p = 0.03$).
9		BP among adult family members	Trained researchers measured BP and pulse rate using a validated automatic blood pressure monitor	Compared to baseline, adults in both groups had an increase in systolic and diastolic BP. The increase in systolic BP was smaller in intervention group. The mean effect (95% CI) on systolic BP was −2.3 mmHg (−4.5 to −0.04 mmHg; $p < 0.05$). The effect on diastolic BP was not significant.

Study ID	Parental involvement	Outcomes of interest	Outcome measures	Findings
10	Indirect	Dietary pattern of parents	Harvard Services FFQ	No significant improvements in dietary patterns from baseline between the parents of students in either group.
11	No parental involvement	Mothers' Nutritional knowledge	Interviewer- administered questionnaire	Mothers or guardians in the intervention group had significantly higher improvement in the mean nutrition score (from 4.17 to 5.10) compared to those from the control group (from 4.45 to 4.57) $p < 0.05$.
12	Direct	Parents' knowledge about recommended fruit and vegetable intakes	Self-administered survey	Significantly more intervention school parents as compared to control parents correctly identified recommended daily fruit intake of two servings (72% vs. 63%; continuity adjusted $\chi2 = 4.313$, $p < 0.05$) and recommended daily vegetables intake of three servings (48% vs. 28%; continuity adjusted $\chi2= 17.062$, $p < 0.0001$).
13	No parental involvement	Parents' FV intake	Internet survey	Parents of children who received free fruit at school ate on average 0.19 more portions of fruits daily or 12.5% more fruits than parents of children who attend schools with no fruit arrangement ($p = 0.04$). No significant differences in vegetable intake between groups were found.
14	Indirect	Parents' FV intake	Telephone survey (Single item measured average FV intake)	No significant differences in average fruit and vegetable consumption between groups were observed.
15	Indirect	Parents' FV intake,	Self-administered questionnaire (FV items from Health Habits and History Q)	Post-intervention: intervention group parents consumed more servings of FV combined compared to control parents (+ 0.29, $p < 0.04$); When examined separately, the difference between conditions was significant for vegetables (+ 0.17, $p < 0.04$) but not for fruit consumption; 1-year post-intervention: No differences were observed for parental FV consumption.

Study ID	Parental involvement	Outcomes of interest	Outcome measures	Findings
		Parental knowledge of 5 a day & knowledge of low-fat food preparation	Self-administered questionnaire	Post-intervention: a significant positive effect on knowledge of five a day serving among intervention group. No significant differences on knowledge of low-fat preparation among intervention and control groups. 1-years post intervention: no significant differences on nutrition knowledge between groups
16	Direct	Parents' FV intake	The validated 10-item FV Screener by the National Institutes of Health (Intake over the past month)	Intervention group parents had a significant increase in fruit consumption from baseline to midpoint (8 weeks follow up) (+.25 servings-day, $p = 0.03$) and post intervention (16 weeks follow up) (+0.25 servings-day, $p = 0.01$) compared to those in the control group. A significant increase in vegetable (+0.30 servings/day, $p = 0.04$) and in total FV consumption (+0.53 serving/day, $p = 0.007$) was also seen among parents of the intervention groups compared to those in the control group at midpoint assessment, but not post-intervention.
17	Direct	Nutrition knowledge	Questionnaires	Parents and guardians of the pilot schools demonstrated higher knowledge gain than those of the control schools in three areas: nutrients and their functions, Chinese dietary guidelines and adequate dietary principles. They also increased their knowledge in the areas of nutritional deficiencies and their symptoms (from 35% to 66.2%, $p < 0.01$) and nutrient-rich foods (from 38.8% to 66.8%, $p < 0.01$), while knowledge of these areas did not change significantly amongst parents and guardians at control schools.
18 19	No parental involvement	Knowledge of parent about recommendations for fruit	Self-administered survey	No significant differences were observed between groups at the first- and the second- year follow-ups.

Study ID	Parental involvement	Outcomes of interest	Outcome measures	Findings
20	Indirect	Total intake of FV and the intake of FV separately among mothers or female guardians	24-hour recall	No significant intervention effects were observed regarding FV intake of the mothers at the first- and second-year follow-ups.
21	Direct	Frequency of consumption of food items among parents	FFQ (intake over the past seven days)	No significant differences were observed in parents' consumption of different food items between the HPS School and the control school.
		Parents' nutrition knowledge	Self-administered questionnaire	Significant difference in parents' awareness rate of eight knowledge items (out of ten) between the HPS School and the Control School after intervention ($p < 0.05$).
22	Direct	Parents' FV intake	Self-administered survey	At the first follow-up, the mean portions of FV consumed by parents of the pilot school increased significantly from 2.4 to 3.1 ($p = 0.03$) for fruits and from 2.7 to 3.4 ($p \leq 0.001$) for vegetables. The increase in fruits consumption was significantly higher than that of the comparison school ($p = 0.02$); At the second follow-up, the average of FV consumption by parents/carers at pilot school was not significantly different from either the baseline or the comparison school.

Adapted from: (Abderbwih et al. 2022)

Abbreviations: RCT= Randomized controlled trial, CRCT = Cluster randomized controlled trial; I= Intervention; C = Control; mo. = month; wk. = week; FV = Fruits and vegetables; BMI= Body mass index; SCT = Social Cognitive Theory; SLT = Social Learning Theory; TPB= Theory of Planned Behavior; NR= Not reported; BP: Blood pressure; HPS= Health Promoting Schools.

3.1.4.1 Dietary intake

The 15 studies that assessed the impact of school-based nutrition interventions on the dietary intake of parents reported inconsistent results.

Among these, seven studies reported no significant effects of interventions on this outcome (ID: 1, 4, 7, 10, 14, 20, 21). Conversely, seven other studies reported significant positive effects of interventions on the parental dietary intake (ID: 3, 8, 9, 13, 15, 16, 22,). Four of these studies reported changes in the consumption of fruits and vegetables among parents. In one of these four studies, a significant increase in fruits, vegetables, and fruits and vegetables combined was reported among the parents of the intervention groups eight weeks post-baseline as compared to those of the control group. Nevertheless, only a positive impact was seen among the intervention group for fruit consumption post-intervention (ID: 16). One other study reported a significant difference in the intake of vegetables and fruits and vegetables combined between the intervention and control groups immediately post-intervention. However, no intervention effect was reported for fruit consumption at both follow-ups and for vegetables and for fruits and vegetables combined at one year-post intervention (ID: 15). The third study reported a significant increase in the mean portions of fruits and vegetables consumed by the parents of the pilot schools at the first follow-up. The increase in fruit consumption was higher than that in the comparison school. However, the average fruit and vegetable consumption by parents at the pilot school at the second follow-up was not significantly different from that of either the baseline or the comparison school (ID: 22). The fourth study reported that the parents of children who received the intervention consumed significantly more fruits than those of children without the intervention. However, vegetable consumption was not significantly different between the parents in both groups (ID: 13).

Of the three remaining studies that found a positive effect on the dietary intake outcome, one study (two articles) found that family members in the intervention group consumed

significantly less salt than those in the control group, which resulted in a decrease in iodine intake. Nevertheless, the iodine consumption remained sufficient (ID: 8, 9). In the third study, parents in the intervention school reported significantly less consumption of refined grains foods than those in the comparison school. No significant differences were reported for whole grain intake between the study groups (ID: 3).

Finally, the fifteenth study reported an overall reduction in diet quality and quantity among parents of students from all intervention groups who received one of the supplementary snacks (vegetarian- meat-milk) at schools as well as parents of the control group students. However, this reduction in food quantity was statistically significant only among the parents of students who received vegetarian snacks. Parents in the vegetarian, meat, and control groups all had significant decreases in at least one dietary quality marker (ID: 6).

Dietary intake assessment methods

Different dietary assessment methods were used among the 15 studies in this group. Self-report techniques, such as 24-hour dietary recall, food frequency questionnaires (FFQ), and questionnaire items were the most used methods. Biological markers (i.e., 24-h urinary sodium and iodine excretion) were used in two studies to assess sodium and iodine consumption (ID: 8, 9).

3.1.4.2 Nutrition knowledge

Among the ten studies that reported the impacts of school-based nutrition interventions on parental nutrition knowledge, seven studies found significant positive intervention effects (ID: 5, 2, 4, 11, 12, 17, 21). One other study reported positive intervention effects on one knowledge domain (five-a-day servings) but not on the other domain (low-fat preparation) immediately post-intervention. However, no significant intervention effects were reported one-year post-

intervention. The remaining study (two articles) reported no significant intervention effects on nutrition knowledge at both follow-ups (ID: 18, 19).

Questionnaires were employed in all ten studies to assess participants' nutrition knowledge. Seven of these were self-administered (ID: 4, 5, 12, 15, 18, 19, 21), while two were administered by interviewers (ID: 2,11). The remaining study failed to report the questionnaire mode of delivery (ID: 17).

3.1.4.3 Health outcomes

The effects of school-based nutrition interventions on parental and family health outcomes were only reported in two of the included studies. In the first study, the intervention group's mothers showed a significant reduction in weight and BMI compared to those of the control group. Body weight and height were assessed by trained study team members at baseline and immediately following the intervention (ID: 7). In the second study, the variations in blood pressure between the intervention and control groups were assessed in response to the intervention. Both groups displayed higher systolic and diastolic blood pressure following the intervention. However, the intervention group exhibited a less pronounced rise in systolic blood pressure than the control group (mean effect: −2.3 mm Hg, 95% confidence interval: −4.5 to −0.04 mm Hg). Diastolic blood pressure did not differ significantly between the groups. In this study, blood pressure was measured by trained researchers using validated automatic pressure measuring devices (ID: 8).

3.2 Assessment of the level of nutrition knowledge among primary school children (objectives 2 and 3)

This sub-chapter presents the results corresponding to thesis objectives 2 and 3. First, the characteristics of the study participants are presented. The following sections present the questionnaire's psychometric properties and categorization of the nutrition knowledge scores. The last section compares the knowledge scores among the different group categories.

Note: Some aspects and texts of this sub-chapter are based on the associated publication (under review)(Abderbwih et al. 2023).

3.2.1 Characteristics of study participants

A total of 1763 fourth-, fifth-, and sixth-grade female students were invited to participate in the study. Of these, 636 (36.1%) returned the signed consent and assent forms. The response rate of public school students (39.4%) was higher than that of private-school students (27.4%). The students' ages ranged from 9 to 13 years, with a median age of 11 years and a mean age of 10.9 years (SD = 1.03). The majority of students were Saudi (71.3%), and only 28.7% of students had other nationalities. The number of study participants attending public schools was more than three times higher than that of participants attending private schools. The number of study participants based on educational centers was 218, 171, 162, and 85 for the East, North, Middle, and South centers, respectively. Table 5 presents the characteristics of the study participants for the overall sample and for each grade separately. Further information on the characteristics of the participating schools can be found in Appendix II.

Table 5: Characteristics of the study participants

	4th grade	5th grade	6th grade	Overall
Number of participants	179[a]	268[b]	189[c]	636
(%)	(28.1%)	(42.1%)	(28.7%)	
Mean age*	9.9	10.9	11.9	10.9
(SD)	(0.61)	(0.63)	(0.64)	(0.99)
Median age*	10	11	12	11
Educational centers n (%)				
• North	57 (31.8%)	57 (21.3%)	57 (30.2%)	171 (26.9%)
• South	32 (17.9%)	25 (9.3%)	28 (14.8%)	85 (13.4%)
• Middle	47 (26.3%)	73 (27.2%)	42 (22.2%)	162 (25.5%)
• East	43 (24%)	113 (42.2%)	62 (32.8%)	218 (34.3%)
Nationality n (%)	176	265	187	628
• Saudi	130 (73.9%)	188 (70.9%)	130 (69.5%)	448 (71.3%)
• Non-Saudi	46 (26.1%)	77 (29.1%)	57 (30.5%)	180 (28.7%)
School types n (%)				
• Public	132 (73.7%)	215 (80.2%)	155 (82%)	502 (78.9%)
• Private	47 (26.3%)	53 (19.8%)	34 (18%)	134 (21.1%)

a= 16 students had at least 1 missing value; b= 40 students had at least 1 missing value; c: 24 students had at least 1 missing value

* 4 students reported their age > 13 years; the data from these students was combined with data of students aged 13 years. 1 student reported her age < 9 years; the data from this students was combined with the data of students aged 9 years.

3.2.2 Psychometric properties of the questionnaire

3.2.2.1 Item analysis

The item difficulty and item discrimination indices of individual items were analyzed for the overall sample and for each grade. The item difficulty indices for the overall sample ranged from 0.32 to 0.94, with three questions (q13, q20, q21) having values ≥ 0.90 and thus considered too easy. In q13, 91% of the students were able to identify food items that contain the higher amounts of fats, whereas 93% of the students correctly answered q20, which asked whether eating breakfast could improve their performance in school. Most children (94%) correctly answered q21, which asked about the impact of eating sweets and sugar-sweetened beverages on dental health. None of the items were found to be extremely difficult, with a difficulty index ≤ 0.10. However, four questions were correctly answered by less than 50% of the students (q2, q3, q14, q27). The question asking about the recommended daily servings of fruits and vegetables (q2) was only answered correctly by 34% of the students. Similarly, only 33% and 31% of the students correctly answered q3 and q27, respectively. Both questions asked about carbohydrates. Only 31% of the students correctly identified the foods that contained more fibers in q14.

The items in the questionnaire had discrimination indices ranging from 0.11 to 0.68. Four items (q2, q20, q21, q27) were less discriminating than the others, with values ≤ 0.20. The question asking about the recommended daily servings of fruits and vegetables (q2) was the least discriminating item, with a value of 0.11. Table 6 presents the complete questionnaire with the difficulty and discrimination indices for each individual item. Appendix III. presents the psychometric properties of the questionnaire for each grade separately.

Table 6: The nutrition knowledge questionnaire for the fourth-,fifth-, and sixth-grade students and its psychometric properties

Item	Response Options	CVI	DI	Disc. index	Test-retest Reliability
Food groups and their recommended daily intake					
Q1. Which of the following statements about food groups is true?	1) A healthy diet should contain a variety of foods from all food groups; 2) A healthy diet should contain only fruits and vegetables; 3) I'm not sure	1	0.71	0.45	0.55
Q2. How many servings of fruits and vegetables should we eat every day?	1) 2 only; 2) At least 5; 3) At least 10; 4) I'm not sure	1	0.34	0.11	0.56
Q3. Which of the following statements about carbohydrates (starchy foods) is true?	1) Carbohydrates are our bodies main source of energy; 2) We should avoid eating carbohydrate because they are harmful to our health; 3) I'm not sure	1	0.33	0.35	0.54
Q4. What food group are eggs in?	1) Grains; (starchy foods); 2) Protein food; 3) Fats, oils, and sweets; 4) I'm not sure	1	0.80	0.39	0.49
Q5. What food group are spinach and lettuce in?	1) Grains (starchy foods); 2) Protein food; 3) Vegetables; 4) I'm not sure	1	0.88	0.23	0.17
Q6. Which of the following food items are in the Grain Group?	1) Rice; 2) Chicken; 3) Grapes; 4) I'm not sure	1	0.79	0.38	0.48
Q7. The best fluid for my body?	1)Water; 2) Milk; 3) Juice; 4) I'm not sure	0.80	0.71	0.35	0.61
Q8. From which type of food, we should eat the least?	1) Fats, oils, and sweets; 2) Meat, chicken, and egg; 3) Bread and rice; 4) I'm not sure	1	0.87	0.26	0.35
Q9. Choose the food group that our bodies use to build muscles?	1) Fruit and vegetable; 2) Protein foods; 3) Grains (starchy foods); 4) I'm not sure	1	0.51	0.48	0.38
Q10. Choose a food group that contains foods with lots of vitamins?	1) Fruits and vegetables; 2) Fats, oils, and sweets; 3) Protein foods; 4) I'm not sure	1	0.78	0.42	0.23
Q11. Which of the following statements about fats is true?	1) It is important to include small amounts of healthy fats in our diet; 2) We should avoid eating fats completely; 3) I'm not sure	1	0.70	0.51	0.57
Overall			**0.67**	**0.35**	**0.60***
Food sources of nutrients					
Q12. Which of the following foods contain less fat?	1) Boiled potatoes; 2) Fried potatoes; 3) I'm not sure	1	0.82	0.41	0.36
Q13. Which of the following foods contain more fat?	1) Bread; 2) Donuts and cake; 3) I'm not sure	1	0.91	0.23	0.35
Q14. Which of the following foods contain more fiber?	1) Fruits such as apples and pears; 2) Fish; 3) I'm not sure	1	0.31	0.26	0.51
Q15. Which of the following foods contain more sugar?	1) Milk; 2) Orange juice; 3) I'm not sure	1	0.80	0.19	0.57
Q16. Which of the following foods contain more salt?	1) Instant noodles (such as Indomie); 2) Yogurt; 3) I'm not sure	1	0.84	0.30	0.53

Item	Response Options	CVI	DI	Disc. index	Test-retest Reliability
Q17.Which of the following foods should be consumed when we need vitamin C?	1) Kiwifruits, sweet peppers, oranges 2) Cheese, milk, butter; 3) I'm not sure	1	0.53	0.58	0.63
Q18. Which of the following foods should be consumed when we need calcium?	1) Cheese, milk, butter; 2) Carrots, tomatoes, apples; 3) I'm not sure	1	0.52	0.56	0.55
Q19. Which of the following foods should be consumed when we need protein?	1) Bread, rice, pasta; 2) Milk, chicken, legumes; 3) I'm not sure	1	0.59	0.47	0.46
Overall			**0.66**	**0.37**	**0.59***
Effect of food on health and disease					
Q20. Eating breakfast improves our performance at school	1) Yes; 2) no; 3) I'm not sure	1	0.93	0.19	0.58
Q21. Excess intake of sweets and sugar sweetened beverages cause dental carries	1) Yes; 2) no; 3) I'm not sure	1	0.94	0.14	0.31
Q22. What you eat affects the condition of your health.	1) Yes; 2) no; 3) I'm not sure	1	0.50	0.47	0.56
Q23. Vitamin A is essential for good vision	1) Yes; 2) no; 3) I'm not sure	1	0.49	0.39	0.45
Q24. Eating too much food, may cause health problem in children	1) Yes; 2) no; 3) I'm not sure	1	0.74	0.47	0.41
Q25. Eating fruit and vegetables every day is important because they help our bodies to fight against illnesses like colds and flu	1) Yes; 2) no; 3) I'm not sure	1	0.85	0.26	0.22
Q26. People who are thinner or fatter than average tend to get sick more easily	1) Yes; 2) no; 3) I'm not sure	0.80	0.59	0.52	0.45
Q27. The main function of carbohydrate is to build muscles	1) Yes; 2) no; 3) I'm not sure	1	0.31	0.20	0.47
Q28. Fiber in food is important because it makes us feel full and keeps our digestive system healthy	1) Yes; 2) no; 3) I'm not sure	1	0.64	0.60	0.51
Q29. Calcium deficiency can cause bone fractur, particularly late in life	1) Yes; 2) no; 3) I'm not sure	1	0.64	0.68	0.60
Overall			**0.63**	**0.39**	**0.58***
Average values for the complete questionnaire			**0.65**	**0.37**	**0.75***

Source: (Abderbwih et al. 2023)

CVI: content validity index; DI: difficulty index; Disc. index: discrimination index; * Pearson correlation of the total scores of each domains; all p values < 0.001.

Finally, A linear trend was found for grades and item difficulty indices, whereas no trend was found for item discrimination indices (Table 7).

Table 7: Linear trend model for Item difficulty and Item discrimination with grades

	Item difficulty		**95% Confidence interval**	**Item discrimination**		**95% Confidence interval**
	Coefficient	p value		Coefficient	p value	
Grade	0.06	< 0.001	0.05–0.08	-0.00	0.816	-0.04–0.37
Constant	0.54	< 0.001	0.51–0.57	0.37	0.001	0.16–0.58

From: (Abderbwih et al. 2023)

3.2.2.2 Questionnaire validity and reliability

All items had a CVI ≥ 0.80 based on the experts' ratings. Moreover, the response options for two questions (q13 and q15) were modified according to the experts' suggestions.

During the pre-testing, the students required an average time of 12 minutes to complete the questionnaire. The CVI values of all the items are presented in Table 6.

The internal reliability consistency of the overall questionnaire, measured by Cronbach's alpha, was 0.73. However, values of 0.51, 0.43, and 0.56 were shown for the first, second, and third domains, respectively.

Overall, the test–retest reliability of each individual item using the kappa statistics showed slight to substantial agreements. Only two questions (q7 and q17) were found to have substantial agreements, with values of 0.61 and 0.63, respectively. Fair agreements with values ranging from 0.22–0.38 were found in seven questions (q8–q10, q12, q13, q21, q25). Slight agreement with a value of 0.17 was found in one question (q5). The remaining 19 questions showed moderate agreement values, ranging from 0.41–0.60. Table 6 shows the kappa statistics values for each individual item.

The test–retest reliability for the total scores of the overall questionnaire using the Pearson correlation was 0.75, indicating good test–retest reliability. Lower values were observed for individual domains, with 0.60, 0.59, and 0.58 for the first, second, and third domains, respectively.

3.2.3 Categorization of nutrition knowledge scores

The level of nutrition knowledge was classified as good or poor based on the mean scores. For the overall questionnaire, the mean score was 19.6 points and thus used as the cut-off point. Accordingly, 45.9% of the sample scored below the mean and was classified as having poor nutrition knowledge. For the individual domains, 45.4%, 51.1%, and 42.2% of the participants had knowledge scores below the mean for the first, second, and third domains, respectively. Table 8 presents the results of the nutrition knowledge scores categorization.

Table 8: Results of nutrition knowledge scores categorization

Domain	Maximum achievable score	Mean (SD)	Median	Good* n (%)	Poor** n (%)
Food groups and their recommended daily intake	11	7.5 (1.94)	8	325 54.5%	271 45.4%
Food sources of nutrients	8	5.3 (1.54)	5	296 48.9%	309 51.1%
Effect of food on health and disease	10	6.7 (1.92)	7	354 57.8%	259 42.2%
Overall questionnaire	29	19.6 (4.32)	20	344 54.1%	292 45.9%

* n (%) of participants with scores ≥ the mean; ** n (%) of participants with scores < the mean

3.2.4 Comparison of the nutrition knowledge scores among different group categories

This section presents a comparison of the nutrition knowledge scores among different group categories of the study population, such as grade, educational center, school type, and nationality.

Grade

Students were grouped into three different categories based on grades (fourth, fifth, and sixth grades). ANOVA test was used to determine whether the total scores differed among students of different grades. Assumptions regarding the normality of the data, as well as homogeneity of variance, were met. There was a statistically significant difference between the mean knowledge scores of the participants from different grades ($p < 0.001$).

The mean score was statistically significantly higher for sixth graders compared to fifth graders ($p < 0.001$) and fourth graders ($p < 0\ .001$). The mean knowledge score for fifth graders was significantly higher than that of fourth graders ($p < 0.001$). Figure 6. presents boxplots comparing the total scores of the different grades.

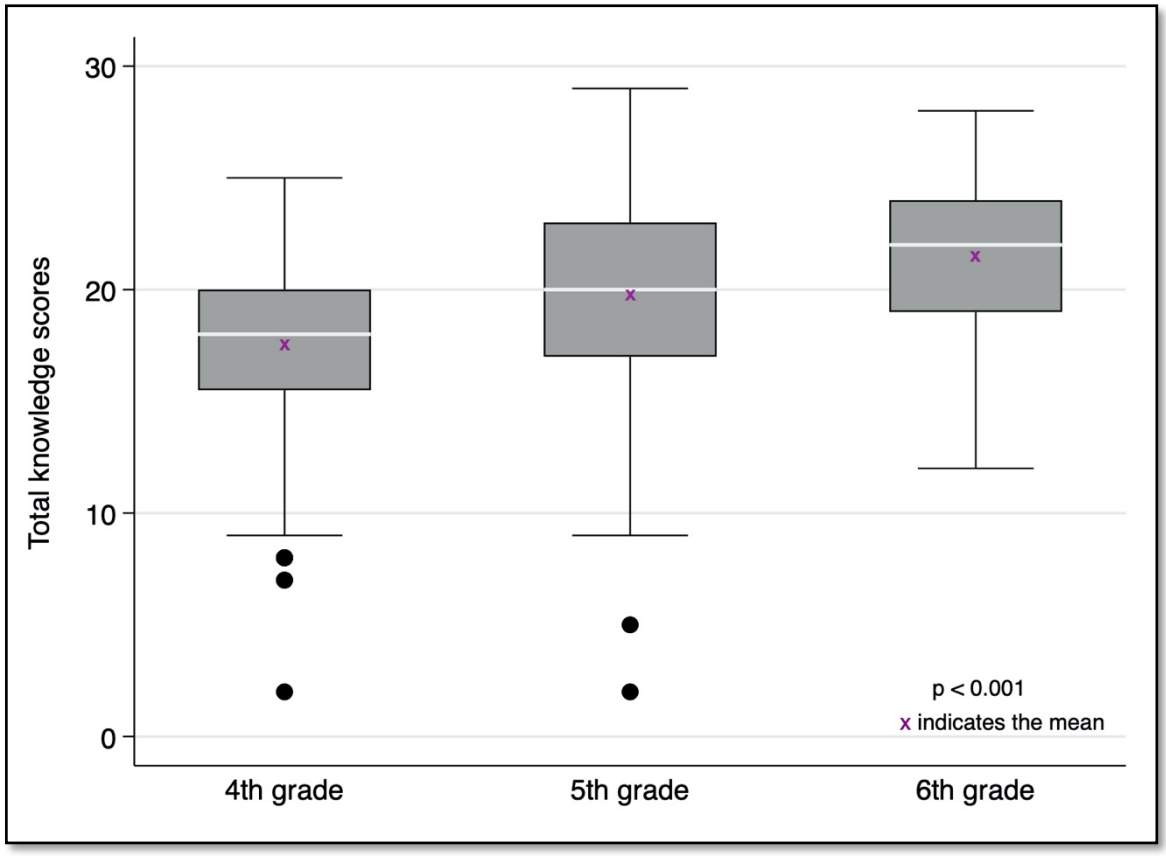

Figure 6: Boxplots comparing the total scores between the grades using ANOVA test

Educational centers

Students were grouped into four groups based on the educational centers their schools follow (North, South, Middle, and East). Levene's test revealed that these four groups were not homogenous ($p = 0.001$); thus, the non-parametric Kruskal–Wallis H test was applied. This test revealed no significant differences in the mean knowledge scores between students based on the educational region ($p = 0.070$). Figure 7. presents boxplots comparing the total scores among the four educational centers.

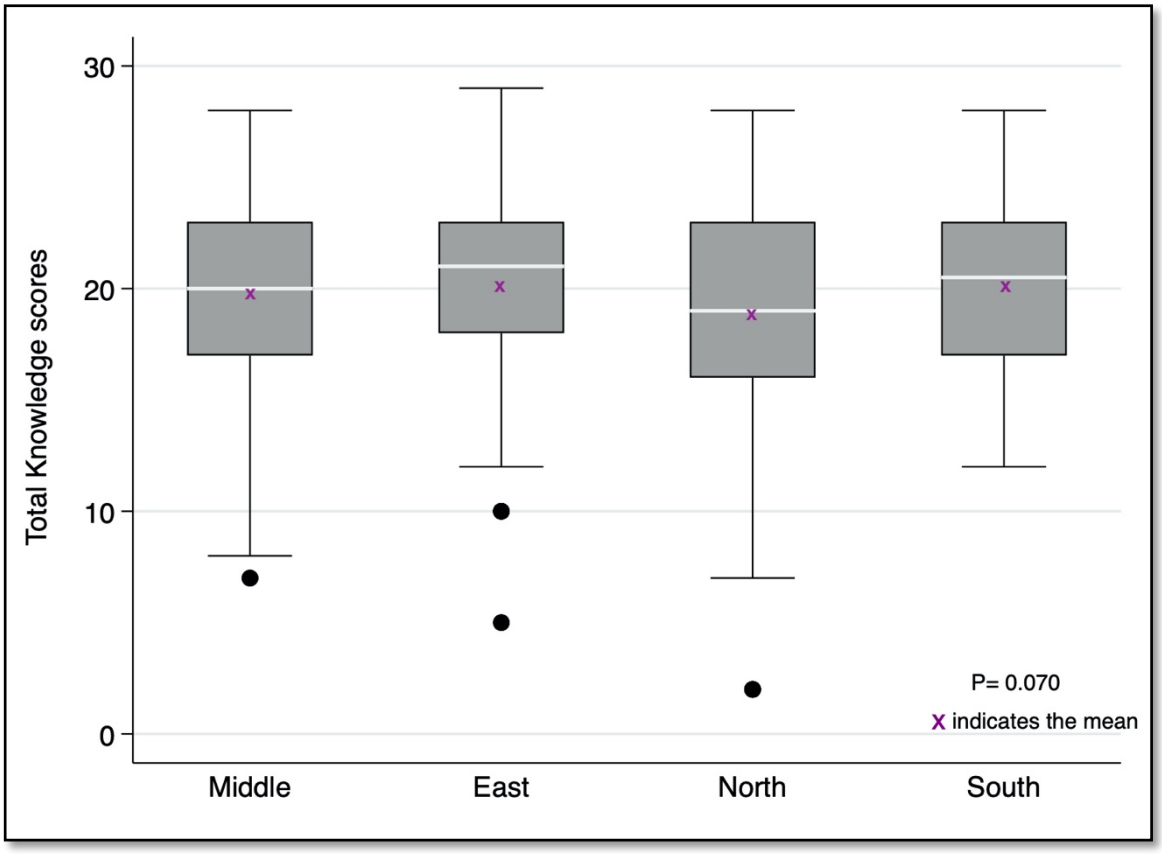

Figure 7: Boxplots comparing the total scores among the different educational regions using Kruskal–Wallis H test

School types

Based on school type, students were classified into two groups (public and private). As the assumptions of normality and homogeneity of variance were met, the independent t-test was used to compare the means between these two categories. The results revealed that the mean knowledge score was significantly lower for students attending public schools compared to their peers from private schools ($p = 0.005$). Figure 8. presents boxplots comparing the total scores among students of public and private schools.

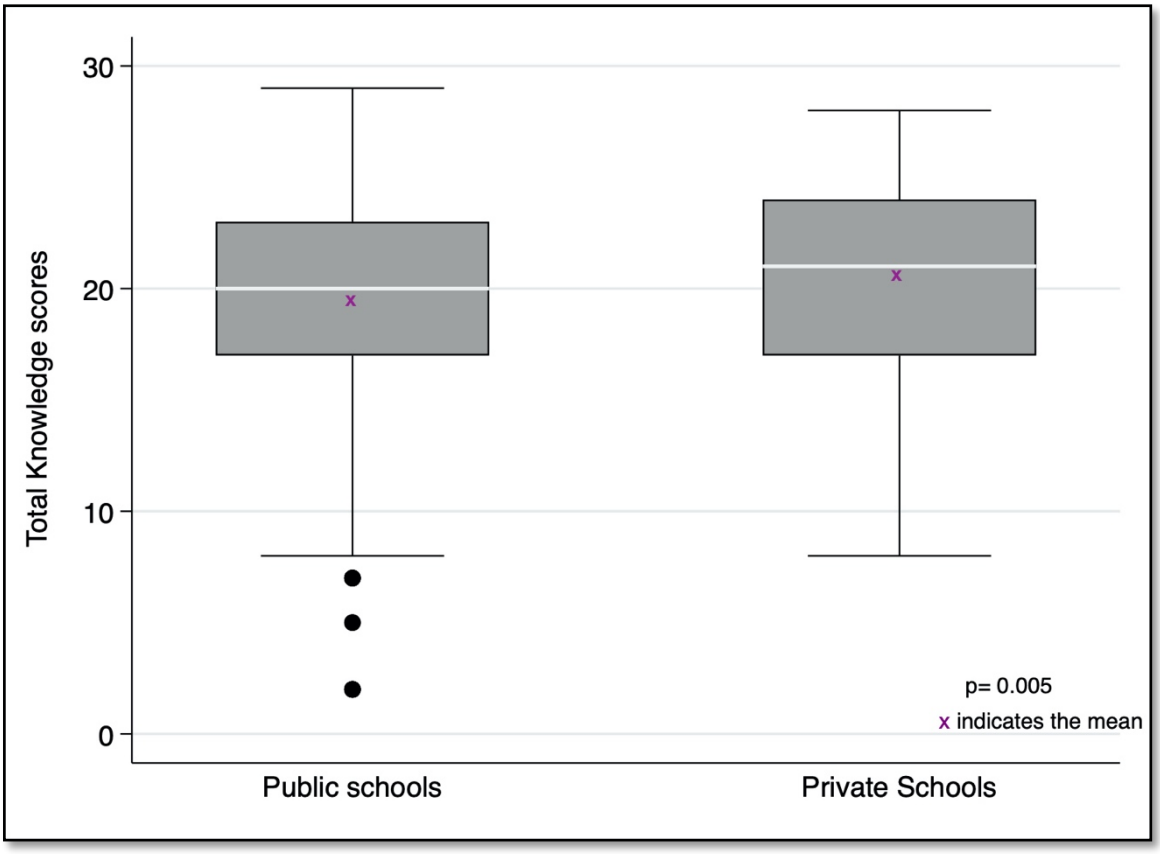

Figure 8: Boxplots comparing the total scores among students at different school types using the independent t-test

Nationality

For the purpose of analysis, the students were divided into two groups based on their nationalities (Saudis and non-Saudis). Based on Levene's test, these two groups were homogenous; thus, an independent t-test was used. The test demonstrated that there were no statistically significant differences in the mean knowledge score between Saudi students and students of different nationalities ($p = 0.30$). Figure 9. features boxplots comparing the total scores of Saudi students and students of different nationalities. Additionally, Table 9 presents the comparisons of the total knowledge score and the scores of individual domains among students belonging to different group categories.

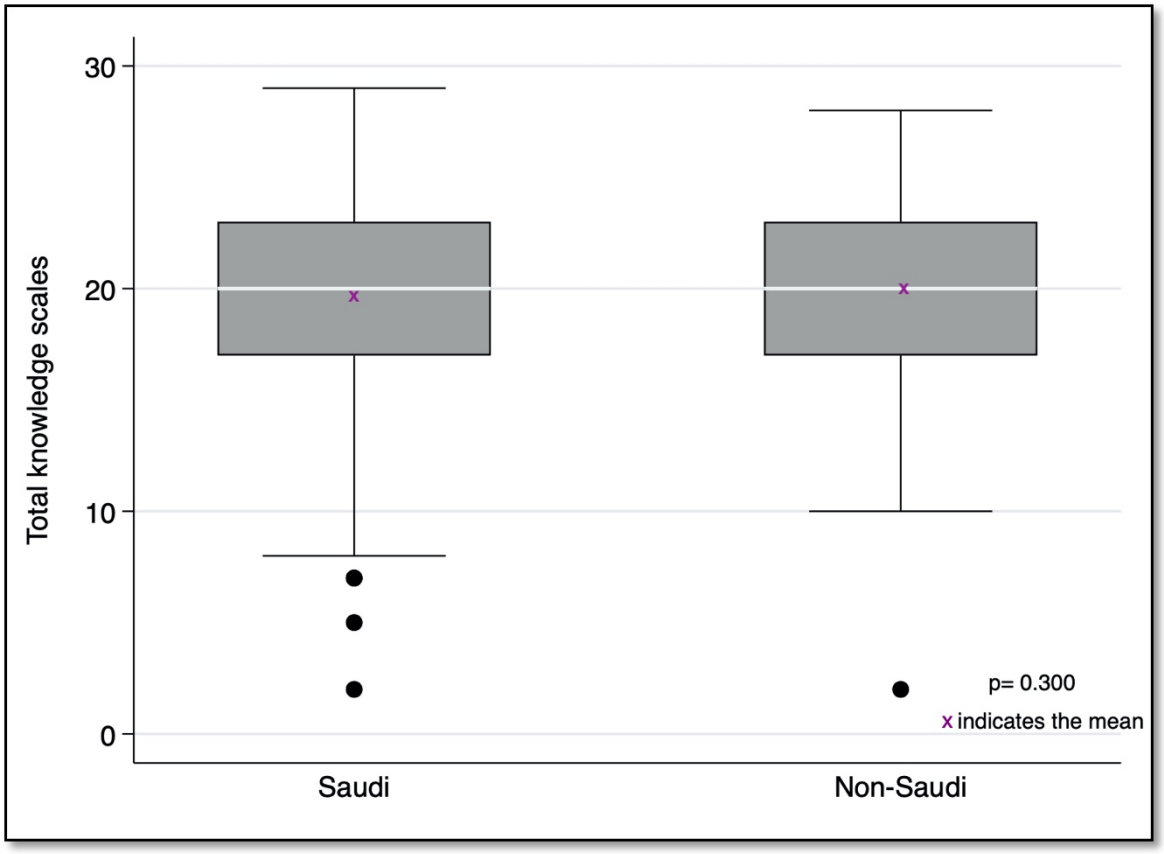

Figure 9: Boxplots comparing the total scores between Saudi students and students of different nationalities using the independent t-test

Table 9: Comparisons of nutrition knowledge scores between different participants' categories

Total scores	Mean (SD)	Median	Minimum	Maximum	P value
Grade					< 0.001
4th grade	17.6 (4.07)	18	2	25	
5th grade	19.8 (4.31)	20	2	29	
6th grade	21.5 (3.68)	22	12	28	
Educational centers					0.070
North	18.8 (5.11)	19	2	28	
South	20.1 (3.88)	20.5	12	28	
Middle	19.5 (4.18)	20	7	28	
East	20.2 (3.79)	21	5	29	
School types					0.005
Public	19.4 (4.30)	20	2	29	
Private	20.6 (4.25)	21	8	28	
Nationality					0.300
Saudi	19.5 (4.43)	20	2	29	
Non-Saudi	19.9 (4.03)	20	2	28	

Abbreviation: SD: Standard deviation

Multiple regression analysis

The multiple regression analysis model including grade, educational centers, school types, and nationality is estimated to explain 16% of the variation in the total scores ($R^2 = 0.16$, $p < 0.001$). Table 10. shows the results of the regression analysis.

Table 10: Multiple linear regression analysis of predictors of nutrition knowledge scores

Independent variables	Coefficient	95% CI	P value
Grade			< 0.001
4th grade	Ref.	Ref.	
5th grade	2.06	1.24–2.88	
6th grade	3.83	2.96– 4.70	
School type			< 0.001
Public	Ref.	Ref.	
Private	1.74	0.88–2.59	
Educational region			0.004
Middle	Ref.	Ref.	
East	0.98	0.05–1.90	
North	-0.61	-1.55– 0.33	
South	0.60	-0.56–1.74	
Nationality			0.048
Saudi	Ref.	Ref.	
Non. Saudi	0.82	0.01–1.63	
Constant	16.8	15.86–17.74	< 0.001

Abbreviations: CI: Confidence interval; Ref.: reference value

4. DISCUSSION

The overarching aim of this thesis was to assess the impacts of school-based nutrition interventions on the nutrition knowledge of school children and their parents, with a special focus on Saudi Arabia. The first objective was to explore the broader impact of these interventions beyond the children themselves (i.e., among parents and other family members) through a systematic literature review. The second objective was to develop and to determine the psychometric properties of a nutrition knowledge questionnaire for female upper primary students in Saudi Arabia, and the third was to capture the current state of nutrition knowledge among this age group in Jeddah by employing the developed and validated questionnaire. The findings of the last two objectives can serve as initial steps toward establishing and evaluating school-based nutrition interventions for students in this age group in Saudi Arabia. In this chapter, the findings of the thesis are critically discussed according to the different objectives, and it concludes by discussing the implications of this work for future research.

4.1 The impact of school-based nutrition interventions on parents and other family members (objective 1)

In this sub-chapter, the findings corresponding to thesis objective 1 are discussed. First, the results of the systematic review according to different parental outcomes are discussed, and the subsequent section explores the impact of parental involvement on the effectiveness of the intervention. This sub-chapter concludes with the strengths, limitations, and conclusion of the systematic review.

Note: some texts or aspects of this chapter are based on the associated publication (Abderbwih et al. 2022).

4.1.1 Parental/family outcomes

The thesis's first objective was to systematically review the literature on the impact of school-based nutrition interventions on the nutrition knowledge, dietary intake, and health outcomes of school children's parents or other family members. Overall, the findings support the potential favorable effects of school-based nutrition interventions on parental outcomes, especially nutrition knowledge. The evidence supporting the positive impacts on dietary intake and health outcomes was insufficient, either due to conflicting results or a lack of studies. Evidence on other family members was scarce.

Dietary intake

The evidence on the impact of school-based nutrition interventions on parental dietary intake was inconsistent. Fewer than half of the studies that investigated this outcome reported any positive effects. One study reported that the parents of children receiving the intervention had a general reduction in diet quality and quantity. However, the study explained this result by the reduced crop production caused by the poor rainy season that year (Gewa et al. 2013).

According to a previous systematic review, school-based nutrition interventions lasting between six weeks and five months were more effective at modifying dietary behaviors in preadolescents and adolescents than interventions with shorter or longer durations (Racey et al. 2016). A comparable pattern was observed among the studies in this systematic review, which found that the majority of the interventions with durations longer than five months were unsuccessful in modifying the dietary intake of the parents.

This review found a lack of reporting on the long-term effects of interventions on parents' dietary intake among the included studies. Thus, it was difficult to ascertain the sustainability of the impact of these interventions over time. This finding aligns with that of an earlier systematic review that indicated insufficient evidence of the long-term impact of school-based nutrition interventions to improve vegetable intake among children (Appleton et al. 2016).

Fruit and vegetable consumption, measured separately or in combination, was the focus of many of the included studies examining interventions' effect on parental dietary intake. However, evidence in this review was inconclusive in determining whether school interventions were more effective in influencing fruit or vegetable consumption. In contrast, a prior systematic review and meta-analysis indicated that school-based nutrition interventions had little influence on children's vegetable intake and were more successful at increasing their fruit intake (Evans et al. 2012).

Nutrition knowledge

In contrast to the dietary intake outcome, the findings on the impact of school-based nutrition interventions on parental nutrition knowledge were promising, with the vast majority of the studies reporting positive intervention effects. Different facets of nutrition knowledge have been investigated, including general nutrition knowledge, understanding of food and disease associations, and knowledge of recommended daily intake of food items, such as fruits, vegetables, fat, and salt. Consequently, different assessment tools were employed across studies. The psychometric properties of which were not reported in all studies. This high heterogeneity among studies and their assessment tools limits the comparability among them. However, the findings of this systematic review support the positive impact of school-based nutrition intervention on parental nutrition knowledge and are in line with those of other systematic reviews that found positive impacts on the nutrition knowledge of school children (Colley et al. 2019; Kyere et al. 2020). It should be noted that most of the studies that assessed the nutrition knowledge outcome had a weak quality rating.

Health outcomes

This systematic review identified only two studies that examined and reported the effect of a nutrition intervention on parental health outcomes, both of which showed encouraging findings and a high degree of methodological quality. However, no firm conclusion can be drawn on this outcome due to the small number of studies. In the first study, the weight of the mothers of children in the intervention group showed a greater reduction in response to the intervention compared to those in the control group (Gunawardena et al. 2016). In the second study, the intervention group's families experienced a significantly lesser rise in systolic blood pressure than in the control group (He et al. 2015). It is noteworthy that the interventions in these two studies did not include any direct parental involvement, yet they showed promising findings. While there is a significant lack of evidence on the impact of school-based interventions on parental outcomes, there is a growing body of evidence assessing the impacts of these interventions on children. For example, a systematic review and meta-analysis of school-based interventions reported significant positive effects of these interventions on adolescents' BMI (Saavedra Dias et al. 2020). Another systematic review and meta-analysis found that nutrition interventions in a school setting were able to reduce the BMI and BMI Z score of the participants. The later review found that parental involvement did not improve the effects of these interventions (Pongutta et al. 2022).

4.1.2 Parental involvement

Parental involvement is an intervention characteristic that may influence the effectiveness of school-based nutrition interventions on children's outcomes. In the present systematic review, most interventions involved indirect parental components. According to the findings, interventions with direct parental involvement appear to result in more favorable effects than those with no or indirect involvement. However, due to insufficient evidence, no clear

association between parental involvement and intervention effectiveness can be identified. Similarly, there is no complete consensus in the literature on whether parental involvement can strengthen or influence the impact of interventions on children's outcomes. One systematic review of school-based nutrition interventions reported that interventions with direct parental involvement were effective in improving children's BMI, physical activity level, and sedentary behaviors (Verjans-Janssen et al. 2018). Inconclusive results on the effect of parental involvement were reported in another systematic review (Van Lippevelde et al. 2012). A further systematic review and meta-analysis found no additional benefits of parental involvement on the impact of school-based nutrition interventions on their children's BMI. Nonetheless, the same review suggested that this result might be due to the low intensity of parental involvement in most included studies (parents engaged directly by attending only one meeting at school and over the course of three months, they were indirectly approached) (Pongutta et al. 2022).

These findings reflect the need for more extensive studies to assess the impact of parental involvement on strengthening the effectiveness of interventions in children or their parents.

4.1.3 Strengths and limitations

A growing number of systematic reviews and meta-analyses have assessed the impact of school-based nutrition interventions on different children's outcomes. However, the potential impact of these interventions on parents or other family members remains understudied. Thus, the fundamental strength of this systematic review is that it is the first to explore the potential impact of school-based nutrition interventions on parents and/or household family members.

Another important strength of this review is the broad search strategy used to identifying all potentially relevant studies. This strategy was used mainly because outcomes related to parents or other family members are always reported in studies as secondary outcomes. In addition to

the above strengths, no restrictions were applied to publication dates, language, or geographical region in this systematic review.

This systematic review had several limitations. First, the inclusion criteria comprised only three parental outcomes; studies that assessed other parental outcomes were excluded. Thus, it is recommended that future reviews to incorporate other parental and familial outcomes.

Second, due to the high level of heterogeneity among the included studies, it was not possible to conduct a meta-analysis. Third, interventions were highly varied, particularly with regard to the interventions' components, assessment methods, durations, and follow-up times. Therefore, no definitive conclusions could be drawn about the impact of these interventions' characteristics on their effectiveness. Finally, most of the included studies had weak to moderate levels of quality ratings. Missing information or a lack of reporting were the major reasons for these weak ratings.

4.1.4 Conclusion

In conclusion, the current systematic review suggests that school-based nutrition interventions may have positive effects on parents, especially in terms of nutrition knowledge. No clear conclusion can be drawn regarding parental dietary intake due to inconsistent results. Similarly, evidence on parental and familial health outcomes was extremely lacking, though the available results were promising. Additional well-designed studies that used validated assessment methods are needed to evaluate the potential impact of school-based nutrition intervention on parents and other household family members and to identify intervention characteristics that may strengthen or influence interventions' impact.

4.2 Assessment of the level of nutrition knowledge among primary school children (objectives 2 and 3)

This sub-chapter discusses the results corresponding to thesis objectives 2 and 3. The first section discusses the psychometric properties of the questionnaire. The following two sections discuss the results of categorizing nutrition knowledge scores and comparing the nutrition knowledge of students in different group categories. This sub-chapter concludes with the strengths and limitations of this part of the thesis.

Note: some texts or aspects of this chapter are based on the following associated publication (under review) (Abderbwih et al. 2023).

4.2.1 Psychometric properties of the questionnaire

The second goal of this thesis was to develop and assess the psychometric properties of a nutrition knowledge questionnaire for upper primary school children in Saudi Arabia. The developed questionnaire demonstrated an acceptable level of validity and reliability, and it may be used to capture the current level of nutrition knowledge among school children. The captured information serves as a cornerstone for designing and assessing the effectiveness of school-based nutrition interventions, especially those with components intended to enhance the level of nutrition knowledge. The questionnaire's reliability was assessed using several methods. The internal consistency reliability of the overall questionnaire, measured using Cronbach's alpha, demonstrated an acceptable value. This finding is in line with other results in the literature (Grosso et al. 2013; Habib-Mourad et al. 2014; Naeeni et al. 2014). However, the values for individual domains showed suboptimal values. This can be explained by the low number of questions in each individual domain, as Cronbach's alpha has been found to be influenced by the number items in the questionnaire (Tavakol and Dennick 2011).

Additionally, these values might suggest that all questionnaire domains should be employed collectively rather than individually.

The Pearson's correlation coefficients of the overall questionnaire indicated a good level of test–retest reliability. As in the case of internal consistency reliability, the test–retest reliability values of the individual domains were lower than that of the overall questionnaire. These results, however, are comparable to those of another questionnaire developed to assess nutrition knowledge among Australian children of similar age group (de Vlieger et al. 2022). Another study showed equivalent test–retest correlation values for the individual domains of a nutrition knowledge questionnaire in primary school children of a slightly younger age (Gower et al. 2010). It is noteworthy that Pearson's correlation coefficient values have been interpreted differently across studies in the literature. For instance, values between 0.50 and 0.80 were regarded as moderately correlated in a study by de Vlieger et al. (2022). In contrast, cut-off values of 0.50 to 0.69 were deemed moderately correlated in a study by Gower et al. (2010). Parmenter and Wardle (2000) suggested a minimum value of 0.70 to indicate test–retest reliability.

The test–retest reliability of each individual item using kappa statistics showed moderate agreement for most items. However, eight items had only fair to slight agreements. Of these, one item (q21) had a high difficulty index (answered correctly by 94% of the students) and low discrimination indices. This item, which asks children about the association between eating sweets and the development of tooth decay, could be improved or eliminated from the questionnaire.

The overall item difficulty and discrimination indices were determined for each individual item. Most items were in the acceptable range of difficulty and discrimination levels. This indicates that the questionnaire has an appropriate level of difficulty for its target audience and can discriminate between students with correct answers in the higher quartile and those in the

lower quartile. As anticipated, the sixth-grade students had the highest difficulty index, followed by the fifth- and fourth-grade students, respectively. The discrimination indices between the various grades, however, showed no trend.

4.2.2 Categorization of nutrition knowledge scores

The third objective of this thesis was to assess the level of nutrition knowledge among upper primary school children in Jeddah, the second largest city in Saudi Arabia. According to the findings of the study, 45% of the sample scored below the mean, achieving a score of less than 67%, and thus was found to have poor nutrition knowledge. A higher level of poor nutrition was reported in another study that assessed nutrition knowledge among upper primary school children in Sharjah, United Arab Emirates, in which more than 83% of the students had knowledge scores below 50% (Al-Yateem and Rossiter 2017). In Fayoum, Egypt, 45% of primary school students included in a study were found to have fair nutrition knowledge (scores between 50%–70%), while 21% were reported to have poor knowledge (scores < 50%) (Abd El-Kader et al. 2019). Despite the difficulty of the comparison, as each study used a different questionnaire with potentially different difficulty levels, the results reflect a lack of nutrition knowledge in the region.

In this study, the level of nutrition knowledge was further analyzed for the individual domains. Poor nutrition knowledge was observed in the first domain, which asked about the food groups and their recommended intake. Two questions in this domain were relatively difficult and were answered correctly by only one-third of the sample. The majority of students chose two servings of fruits and vegetables as the recommended daily intake. The students' answers may reflect their daily consumption of fruits and vegetables. A cross-sectional study of 725 school students from Saudi Arabia reported that more than two-thirds of the sample did not consume fruits and vegetables daily (Alsubaie 2018). Another cross-sectional study assessed the

adherence of Saudi adults to the recommendations of the Healthy Food Palm and found that 98% and 88% of the sample reported inadequate consumption of vegetables and fruits, respectively (Halawani et al. 2019). The other question in this domain that was relatively difficult asked students to identify the correct statement regarding carbohydrate, with most students choosing the "I am not sure" option.

For the second domain, it was found that 51% of the students were categorized as having poor knowledge regarding the food sources of nutrients, and the majority of students were not able to identify food items that contain a high amount of fiber. In a recent cross-sectional study, inadequate intake of fiber was observed among children in Saudi Arabia (Kutbi 2021).

For the third domain, 42% of the sample was identified as having poor knowledge regarding the effect of food on health and diseases. As for the first domain, a question about carbohydrates was answered incorrectly by the majority of students. This may indicate that students are not aware of the functions of carbohydrates, or even of the term "carbohydrate".

4.2.3 Comparison of nutrition knowledge scores between different groups categories

Grades

The mean level of knowledge was significantly higher among sixth graders, followed by fifth and fourth graders, respectively. This can be explained by the differences in cognitive development between students in different grades. Additionally, this difference in knowledge levels may reflect the nutrition knowledge that children gain from school, as students receive some nutrition-related lessons as part of the family and life skills curriculum. In fact, there is some evidence supporting the idea that integrating nutrition education with the school curriculum may improve the nutrition knowledge of school children (Carraway-Stage et al. 2015). However, the findings of the present study indicate that upper primary students still lack

nutrition knowledge and that the few nutrition lessons provided in schools might not be enough for students.

School types

Although children in both public and private schools receive the same main curriculum, the level of nutrition knowledge among children attending private schools was found to be significantly higher than that of their peers attending public schools. One possible explanation for this difference in knowledge scores could be the differences in socioeconomic status between students attending public and private schools, as it is suggested that students attending private schools are more likely to have families with higher socioeconomic status (Jabri et al. 2021). These findings are in line with those of another study, which reported that female students attending private schools in Jeddah had better fruit and vegetable consumption than students attending public schools (Obaid Musaiger and Zagzoog 2013). The school food environment could be another possible explanation for this difference in nutrition knowledge. Although the Ministry of Education in Saudi Arabia sets clear regulations for the type of food allowed to be provided or sold in schools, adherence to these regulations varies among schools. For example, one study measured the level of school compliance with these requirements in the city of Riyadh, found that the level of compliance was moderate in most schools (Aldubayan and Murimi 2019). No study has assessed the difference in compliance between private and public schools. However, one study reported that parents of children attending private primary schools were more satisfied with the food options offered at schools than parents of children attending public schools (Bookari 2022).

Nationality and educational region

No significant differences were found in the knowledge scores between students of different nationalities and students attending schools of different educational regions. However, after controlling for other confounding factors, nationality and educational regions appeared to have an influential impacts on the nutrition knowledge of school children.

4.2.4 Strengths and limitations

This study provides a valid and reliable tool to assess nutrition knowledge among female primary school students in Saudi Arabia. With its appropriate length and relatively short completion time, this questionnaire can be easily administered to a large sample. Furthermore, the present study is the first to assess the level of nutrition knowledge among female primary school children in Saudi Arabia.

In addition to the aforementioned strengths, this study has several limitations. The first limitation is the low response rate. However, this low response rate was expected for several reasons. First, the data collection took place during the COVID-19 pandemic, which influenced students' attendance rates. Another reason is that students at this age may tend to forget to return their parents signed informed consent forms. Thus, the sample size was increased to account for the low response rate.

Another limitation is that the study included only female students. Thus, the results might not be generalizable to male students. It is recommended that future research assess the validity and reliability of the questionnaire for male students to assess their level of nutrition knowledge. Furthermore, the study included students from one city only (i.e., Jeddah). However, the sample size was large and involved students from all educational regions in the city. Additionally, the questionnaire was validated for its content validity by a panel of experts, which included five dietitians. As the questionnaire is targeted at school children, it would have

been advantageous to involve schoolteachers to ensure that all questions were suitable for the age of the target audience. Another limitation is that the internal consistency reliability and test–retest reliability of the questionnaire's individual domains showed suboptimal values. Thus, it is recommended that the questionnaire be used as a whole rather than using each domain separately. Finally, data on the parents' socioeconomic status were not collected. However, school type (i.e., public or private) may indicate the socioeconomic status of the parents.

4.2.5 Conclusion

Although there is potential for further improvement, the developed questionnaire can be used as a valid and reliable tool to assess nutrition knowledge among primary school children in Saudi Arabia. The findings of the cross-sectional study demonstrated that a large proportion of female upper primary school students in Jeddah have insufficient nutrition knowledge, specifically those related to the daily recommended intake of fruits and vegetables, sources of fiber, and the function of carbohydrates. The level of nutrition knowledge was significantly higher for sixth graders, followed by fifth and fourth graders, respectively. Students attending private schools showed significantly higher levels of nutrition knowledge than their peers attending public schools. After controlling for school types and grades, nationality and educational regions were found to have an influence on the nutrition knowledge of school children.

4.3 Implications for future research

The findings of this thesis place particular emphasis on the possibility of school-based nutrition interventions to improve specific parental and family outcomes, such as parental nutrition knowledge. These findings also indicate that there is a lack of available evidence on the effects of school-based nutrition interventions beyond children. Moreover, they point to the need for future research to investigate the important intervention characteristics (e.g., intervention duration and intensity, parental involvement, and intervention components) that could strengthen the effects of interventions on children and their parents. This information may help maximize the benefits of school-based nutrition interventions and assist health promotion efforts to reach broader segments of the community through the school setting. Furthermore, there is a tendency to underreport the long-term impacts of the interventions. It is important for future research to assess the long-term impacts of school-based nutrition interventions to identify whether these impacts are sustainable over time.

In the context of Saudi Arabia and in light of the urgent need to find solutions to reduce the prevalence of risk factors for NCDs, the findings of this thesis highlight the lack of nutrition knowledge among upper primary school children and emphasize the need for interventions to improve the nutrition knowledge of school children. This study also provides information on the areas of nutrition knowledge that must be addressed in future nutrition interventions.

The developed nutrition knowledge questionnaire for children in Saudi Arabia could contribute to the future development of nutrition interventions, as it can be used to capture changes in nutrition knowledge after the implementation of school-based nutrition education interventions. However, although the overall questionnaire displayed acceptable psychometric properties, some items in the questionnaire showed a high difficulty index and might need to be improved or replaced in the future use of the questionnaire.

5. SUMMARY

Non-communicable diseases represent a significant global challenge for public health, and efforts to combat these diseases are therefore constantly increasing. Schools are one of the key settings for the delivery of nutrition and other health interventions, and considerable evidence supports the potential impact of school-based interventions on children's nutrition and health outcomes. However, studies on the broader effects of these interventions on the parents and other family members are limited. The status of non-communicable diseases in Saudi Arabia is comparable to the global picture in that they account for approximately 73% of all deaths and constitute a great burden on the country's health system and economy.

The first objective of the thesis was to systematically review the available literature on the potential influence of school-based nutrition interventions targeted at school children on the nutrition knowledge, dietary intake, and health outcomes of their parents and other family members. The systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis.

The second part of the thesis shifts the focus to Saudi Arabia in particular. As there is currently no instrument available to evaluate the state of nutrition knowledge in Saudi Arabia, the second objective was therefore to develop and determine the validity and reliability of a nutrition knowledge questionnaire for primary school children in the country. The third objective was to assess the current state of nutrition knowledge among female students of the upper primary schools in Jeddah, the second largest city in Saudi Arabia, by employing the validated questionnaire. This information serves as a cornerstone for designing and evaluating school-based nutrition interventions.

The findings of the systematic review support the positive impact of school-based nutrition interventions on parental nutrition knowledge. It also found promising but limited evidence suggesting a positive impact on parental health outcomes, and evidence on outcomes relating

to dietary intake was equivocal. Furthermore, the findings highlighted the lack of studies evaluating the impact of school-based interventions on family members other than parents and pointed to the need for more systematic assessment to identify intervention characteristics that may strengthen their impact.

For the Saudi Arabian context, the questionnaire developed and used for this thesis demonstrated acceptable validity and reliability. The results show that nearly 46% of the participating students have poor levels of nutrition knowledge (scoring below the mean), and three areas were found specifically lacking among the study participants: i. daily recommended intake of fruits and vegetables; ii. sources of fiber; and iii. carbohydrates. The level of nutrition knowledge was higher among sixth graders, followed by the fifth and fourth graders. Additionally, students attending private schools had significantly higher levels of nutrition knowledge than their peers attending public schools. After controlling for school type and grade of participants, school's educational region and nationality appeared to influence the nutrition knowledge of school children.

To conclude, this thesis provides the first steps for developing and assessing school-based nutrition interventions for female upper primary school children in Saudi Arabia. These interventions are found to have positive effects beyond the children themselves (i.e., among their parents) and could help deliver health promotion efforts to a large segment of the population.

6. ZUSAMMENFASSUNG

Nichtübertragbare Krankheiten stellen eine große globale Herausforderung für die öffentliche Gesundheit dar, weshalb die Anstrengungen zu deren Bekämpfung ständig zu nehmen. Schulen gelten als einer der wichtigsten Orte für die Bereitstellung von Ernährungs- und anderen Gesundheitsinterventionen bei Kindern und zahlreiche Studien belegen die Wirksamkeit schulbasierter Interventionen. Es gibt jedoch nur eine begrenzte Zahl von Studien zu den möglichen Auswirkungen auf die Eltern und andere Familienmitglieder. In Saudi-Arabien ist die Situation bei nichtübertragbaren Krankheiten nicht anders als weltweit. Sie sind für etwa 73 % aller Todesfälle verantwortlich und stellen eine große Belastung für das Gesundheitssystem und die Wirtschaft des Landes dar.

Das erste Ziel der Arbeit bestand in einer systematischen Literaturrecherche zum möglichen Einfluss schulbasierter Ernährungsinterventionen für Schulkinder auf das Ernährungswissen, die Nahrungsaufnahme und die Gesundheit ihrer Eltern und anderer Familienmitglieder. Der zweite Teil konzentrierte sich auf Saudi-Arabien. Da es dort noch kein Instrument zur Bewertung des Ernährungswissens gab, war die Entwicklung und Validierung eines Fragebogens zum Ernährungswissen für Kinder der Primarstufe das zweite Ziel der Arbeit.

Das dritte Ziel bestand darin, den aktuellen Stand des Ernährungswissens von Schülerinnen der oberen Primarstufe in Jeddah, der zweitgrößten Stadt Saudi-Arabiens, unter Verwendung des entwickelten Fragebogens zu ermitteln. Diese Informationen dienen als Eckpfeiler für die Entwicklung und Evaluierung schulischer Ernährungsinterventionen.

Die Ergebnisse der systematischen Review zeigten positive Auswirkungen schulischer Ernährungsinterventionen auf das Ernährungswissen der Eltern. Es wurde auch vielversprechende, aber begrenzte Evidenz für die positiven Auswirkungen auf die Gesundheit der Eltern gefunden. Die Ergebnisse in Bezug auf die Nahrungsaufnahme waren nicht eindeutig. Darüber hinaus wurde festgestellt, dass es an Studien mangelt, die die Auswirkungen

schulischer Interventionen auf andere Familienmitglieder als die Eltern bewerten, und dass eine systematischere Erfassung der Ergebnisse erforderlich ist, um die relevanten Merkmale der Interventionen zu ermitteln. Der entwickelte Fragebogen wies eine akzeptable Validität und Reliabilität auf und die Ergebnisse zu Ernährungswissen zeigen, dass fast 46 % der teilnehmenden Schülerinnen über ein geringes Ernährungswissen verfügen (unter dem Mittelwert liegende Werte), wobei drei Bereiche bei den Studienteilnehmerinnen als besonders mangelhaft eingestuft wurden: i. die täglich empfohlene Aufnahme von Obst und Gemüse, ii. die Ballaststoffquellen und iii. die Kohlenhydrate. Außerdem wiesen Schülerinnen, die eine Privatschule besuchten, ein signifikant höheres Ernährungswissen auf als ihre Altersgenossinnen an öffentlichen Schulen. Nach Kontrolle der Schulform und der Klassenstufe der Teilnehmerinnen schienen die Bildungsregion und die Nationalität einen Einfluss auf das Ernährungswissen zu haben.

Die vorliegende Arbeit war ein erster Schritt für die Entwicklung und Evaluierung von schulbasierten Ernährungsinterventionen bei Kindern der oberen Primarstufe in Saudi-Arabien darstellt. Es wurde gezeigt, dass diese Interventionen positive Auswirkungen über die Kinder hinaus haben und dazu beitragen könnten, Gesundheitsförderungsmaßnahmen für einen großen Teil der Bevölkerung durchzuführen.

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8. LIST OF PUBLICATIONS

Peer-Reviewed Publications related to this thesis (first authorship)

Abderbwih, E., Mahanani, M. R., Deckert, A., Antia, K., Agbaria, N., Dambach, P., Kohler, S., Horstick, |O., Winkler, V. and Wendt, A. S. (2022). **The Impact of School-Based Nutrition Interventions on Parents and Other Family Members: A Systematic Literature Review.** Nutrients 14 (12), doi: 10.3390/nu14122399.

Under Peer Review

Abderbwih, E., Kutbi, H. A. and Winkler, V. (2023). **Validity and reliability of a nutrition knowledge questionnaire for fourth-, fifth-, and sixth-grade students in Saudi Arabia** Manuscript submitted for publication.

Other Peer-Reviewed Publications (co-authorship)

Mahanani, M. R., Abderbwih, E., Wendt, A. S., Deckert, A., Antia, K., Horstick, O., Dambach, P., Kohler, S. and Winkler, V. (2021). **Long-Term Outcomes of in Utero Ramadan Exposure: A Systematic Literature Review.** Nutrients 13 (12), doi: 10.3390/nu13124511.

APPENDICES

Appendix I

استبانة لقياس المعرفة الغذائية لدى طالبات المرحلة الابتدائية

المعلومات الشخصية

رمز المشارِكة: _____ **، العمر:** _____

اسم المدرسة: _____

المرحلة الدراسية: _____

الجنسية: _____

اختاري الإجابة الصحيحة لكل من الاسئلة التالية (اختاري إجابة واحدة فقط من كل سؤال)

المجموعات الغذائية والكميات/الحصص اليومية الموصي بها

١. أي من العبارات التالية حول مجموعات الطعام صحيحة؟

١) الغذاء الصحي يجب ان يحتوي على مجموعة متنوعة من الأطعمة من جميع المجموعات الغذائية

٢) الغذاء الصحي يجب ان يحتوي على الفواكه والخضروات فقط

٣) لست متأكدة

٢. كم عدد حصص الفواكه والخضروات التي يجب أن نتناولها كل يوم؟

١) حصتين فقط

٢) ٥ على الاقل

٣) ١٠ على الاقل

٤) لست متأكدة

٣. أي من العبارات التالية حول النشويات صحيحة؟

١) تعتبر النشويات المصدر الرئيسي للطاقة في جسمنا

٢) يجب علينا تجنب الأطعمة الغنية بالنشويات لأنها مضرة بالصحة

٣) لست متأكدة

٤. الي أي مجموعة غذائية ينتمي البيض؟

١) مجموعة الحبوب (الأطعمة الغنية بالنشويات)

٢) مجموعة البروتين

٣) مجموعة الحلويات والدهون والزيوت

٤) لست متأكدة

٥. الي أي مجموعة غذائية ينتمي الخس والسبانخ؟

١) مجموعة الحبوب (الأطعمة الغنية بالنشويات)

٢) مجموعة البروتين

٣) مجموعة الخضروات

٤) لست متأكدة

٦. أي من الاطعمة التالية تنتمي الي مجموعة الحبوب؟

١) الحليب

٢) الأرز

٣) العنب

٤) لست متأكدة

٧. أفضل سائل/مشروب لأجسامنا؟

١) الماء

٢) الحليب

٣) العصير

٤) لست متأكدة

٨. من أي نوع من الأطعمة يجب أن نأكل أقل كميات؟

١) الحلويات والدهون والزيوت

٢) اللحم والدجاج والبيض

٣) الخبز والأرز

٤) لست متأكدة

٩. اختاري المجموعة الغذائية التي تستخدمها أجسامنا لبناء العضلات

١) مجموعة الفواكه والخضروات

٢) مجموعة البروتين

٣) مجموعة الحبوب (الأطعمة الغنية بالنشويات)

٤) لست متأكدة

١٠. اختاري المجموعة الغذائية التي تحتوي على أطعمة بها الكثير من الفيتامينات

١) مجموعة الفواكه والخضروات

٢) مجموعة الحلويات والدهون والزيوت

٣) مجموعة البروتين

٤) لست متأكدة

١١. أي العبارات التالية عن الدهون صحيحة؟

١) من المهم ان نتناول كميات صغيرة من الدهون الصحية في نظامنا الغذائي

٢) يجب علينا الامتناع عن تناول الدهون تماما

٣) لست متأكدة

العناصر الغذائية في الطعام

١٢. أي من الأطعمة التالية تحتوي على كميات دهون <u>اقل</u>؟

١) البطاطس المسلوقة

٢) البطاطس المقلية

٣) لست متأكدة

١٣. أي من الأطعمة التالية تحتوي على دهون <u>أكثر</u>؟

١) الخبز

٢) الدونات، والكيك

٣) لست متأكدة

١٤. أي من الأطعمة التالية يحتوي ألياف <u>أكثر</u>؟

١) الفواكه مثل التفاح والكمثرى

٢) السمك

٣) لست متأكدة

١٥. أي من الأطعمة التالية تحتوي على سكر <u>أكثر</u>؟

١) الحليب

٢) عصير البرتقال

٣) لست متأكدة

١٦. أي من الأطعمة التالية تحتوي على ملح <u>أكثر</u>؟

١) المكرونة سريعة التحضير (على سبيل المثال، إندومي)

٢) اللبن زبادي

٣) لست متأكدة

١٧. أي من الأطعمة التالية يجب أن نتناولها عندما نحتاج إلى فيتامين ج (فيتامين سي)؟

١) الكيوي، الفلفل الحلو، البرتقال

٢) الاجبان، الحليب، اللبن

٣) الخبز، الأرز، المكرونة

٤) لست متأكدة

١٨. أي من الأطعمة التالية يجب أن نتناولها عندما نحتاج إلى الكالسيوم؟

١) الاجبان، الحليب، اللبن

٢) الجزر، الطماطم، التفاح

٣) زيت الزيتون، الزبدة

٤) لست متأكدة

١٩. أي من الأطعمة التالية يجب أن نتناولها عندما نحتاج إلى البروتين؟

١) الخبز، الأرز، المكرونة

٢) الحليب، الدجاج، البقوليات

٣) لست متأكدة

تأثير الغذاء على الصحة / وظائف الغذاء

٢٠. يساعد تناول وجبة الافطار على تحسين الأداء في المدرسة

١) نعم

٢) لا

٣) لست متأكدة

٢١. الإكثار من تناول الحلويات والمشروبات المحلاة بالسكر ممكن ان يتسبب في تسوس الأسنان

١) نعم

٢) لا

٣) لست متأكدة

٢٢. ما نأكله يؤثر على صحتنا

١) نعم

٢) لا

٣) لست متأكدة

٢٣. فيتامين أ ضروري لصحة النظر

١) نعم

٢) لا

٣) لست متأكدة

٢٤. تناول الطعام أكثر من الحاجة ممكن ان يسبب مشاكل صحية للأطفال

١) نعم

٢) لا

٣) لست متأكدة

٢٥. يعد تناول الفواكه والخضروات يوميًا أمرًا مهمًا لأنها تساعد أجسامنا على محاربة الأمراض مثل نزلات البرد والإنفلونزا

١) نعم

٢) لا

٣) لست متأكدة

٢٦. الأشخاص الذين يعانون من النحافة أو السمنة الزائدة يمرضون بسهولة أكبر

١) نعم

٢) لا

٣) لست متأكدة

٢٧. من اهم وظائف النشويات بناء العضلات

١) نعم

٢) لا

٣) لست متأكدة

٢٨. الألياف الموجودة في الطعام مهمة لأنها تجعلنا نشعر بالشبع وتحافظ على صحة الجهاز الهضمي

١) نعم

٢) لا

٣) لست متأكدة

٢٩. يمكن أن يتسبب نقص الكالسيوم في كسر العظام، وخاصة عند تقدم الانسان في العمر

١) نعم

٢) لا

٣) لست متأكدة

شكرا ☺

Appendix II

The main characteristics of participating schools

School type/educational region	**Number of schools**	**Number of invited students**	**Number of participants (%)**	**Response rate**	**Mean age (SD)**
School type					
Public	7	1274	502 (78.9%)	39.4%	11.0 (1.03)
Private	4	489	134 (21.1%)	27.4%	10.8 (1.02)
Regions					
North	3	436	171 (26.9%)	39.2%	11.0 (1.10)
South	2	371	85 (13.4%)	22.9%	11.0 (1.14)
East	3	482	218 (34.3%)	45.2%	11.0 (0.94)
Middle	3	474	162 (25.5%)	34.2%	10.7 (1.00)

Appendix III

Item analysis of each individual item by grades and test re-test reliability results

Domain Item number	**Item difficulty** (% correct answers) (n= 636)				**Item discrimination** (n= 636)				**Test-retest reliability** (n= 69)
	4th grade	**5th grade**	**6th grade**	**All grades**	**4th grade**	**5th grade**	**6th grade**	**All grades**	
Food groups and their recommended intake									
Q1	0.55	0.72	0.83	0.71	0.20	0.42	0.36	0.45	0.55
Q2	0.34	0.35	0.31	0.34	0.18	0.18	0.23	0.11	0.56
Q3	0.22	0.33	0.43	0.33	0.09	0.39	0.43	0.35	0.54
Q4	0.69	0.82	0.90	0.80	0.42	0.33	0.28	0.39	0.49
Q5	0.82	0.90	0.92	0.88	0.31	0.21	0.11	0.23	0.17
Q6	0.70	0.79	0.87	0.79	0.36	0.33	0.28	0.38	0.48[a]
Q7	0.65	0.71	0.76	0.71	0.20	0.36	0.30	0.35	0.61[a]
Q8	0.85	0.85	0.93	0.87	0.11	0.31	0.23	0.26	0.35
Q9	0.36	0.55	0.59	0.51	0.31	0.33	0.60	0.48	0.38
Q10	0.70	0.79	0.83	0.78	0.51	0.31	0.34	0.42	0.23
Q11	0.58	0.70	0.83	0.70	0.33	0.54	0.40	0.51	0.57[c]
Overall	0.58	0.68	0.74	0.67	0.27	0.38	0.32	0.35	0.60[d]*
Food sources of nutrients									
Q12	0.73	0.81	0.92	0.82	0.56	0.36	0.30	0.41	0.36
Q13	0.89	0.88	0.96	0.91	0.16	0.24	0.15	0.23	0.35[a]
Q14	0.22	0.34	0.36	0.31	0.24	0.37	0.13	0.26	0.51[b]
Q15	0.87	0.74	0.83	0.80	0.09	0.27	0.15	0.19	0.57
Q16	0.79	0.85	0.87	0.84	0.42	0.27	0.23	0.30	0.53

Q17	0.39	0.55	0.62	0.53	0.40	0.49	0.68	0.58	0.63
Q18	0.42	0.54	0.59	0.52	0.49	0.66	0.47	0.56	0.55
Q19	0.53	0.59	0.67	0.59	0.36	0.48	0.43	0.47	0.46[a]
Overall	0.60	0.66	0.73	0.66	0.34	0.39	0.32	0.37	0.59[d]*
Effect of food on health and disease									
Q20	0.91	0.92	0.97	0.93	0.24	0.24	0.06	0.19	0.58
Q21	0.94	0.95	0.94	0.94	0.09	0.13	0.13	0.14	0.31
Q22	0.41	0.55	0.53	0.50	0.27	0.52	0.45	0.47	0.56
Q23	0.45	0.50	0.53	0.49	0.62	0.34	0.38	0.39	0.45
Q24	0.70	0.72	0.79	0.74	0.49	0.45	0.47	0.47	0.41
Q25	0.85	0.85	0.85	0.85	0.24	0.27	0.28	0.26	0.22
Q26	0.55	0.61	0.61	0.59	0.60	0.43	0.53	0.52	0.45
Q27	0.29	0.31	0.31	0.31	0.07	0.24	0.28	0.20	0.47[a]
Q28	0.51	0.61	0.80	0.64	0.71	0.61	0.36	0.60	0.51
Q29	0.54	0.63	0.75	0.64	0.71	0.68	0.47	0.68	0.60
Overall	0.61	0.66	0.71	0.63	0.40	0.39	0.34	0.39	0.58[a]*
Pearson correlation									**0.75[e]***

Kappa statistic was used to assess test re-test reliability of each item

* Pearson correlation of the total scores; all p values < 0.001

[a] = 1 missing value; [b]= 2 missing values; [c]= 3 missing values; [d]= 4 missing values; [e]= 9 missing value

CURRICULUM VITAE

PERSONAL INFORMATION

Name	Eman Abderbwih
Date of Birth	26.05.1988
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EDUCATION – SCHOOL

2019-present	Doctorate at Heidelberg Institute of **Global Health**, University Hospital Heidelberg. 2019-2023 *Topic of dissertation: The impact of school-based nutrition interventions on the nutrition knowledge of children and their parents*
2014-2015	MSc in **International Health** Heidelberg Institute of Global Health, Heidelberg, Germany *Master thesis: The Prevalence and Risk Factors of Vitamin D Deficiency in Saudi Arabia: A Systematic Review and Meta-Analysis*
2005-2009	Bachelor's degree in **Clinical Nutrition** King Abdul-Aziz University (Applied Medical Science), Jeddah, Saudi Arabia
1993-2005	Full general school education

EMPLOYMENT

2010-2011	**Clinical Dietitian -** King Abdulaziz Medical City - Jeddah, Saudi Arabia
2009-2010	**Intern Clinical Dietitian** in three different public and private hospitals- Jeddah, Saudi Arabia

AWARDS

2012-2015	**MSc scholarship** awarded by The Custodian of the Two Holy Mosques Scholarship Program, Ministry of Education, Saudi Arabia
2019-present	**PhD scholarship** awarded by The Custodian of the Two Holy Mosques Scholarship Program, Ministry of Education, Saudi Arabia

PROFFESSIONAL TRAINING AND COURSES

22-26 August 2022	Summer School 'Trends in Nutrition Epidemiology'
17-20 August 2021	Web-based training 'Using Stata Effectively: Data Management, Analysis, and Graphics Fundamentals'
May–August 2019	Advanced Epidemiology and Biostatistics for Doctoral Students
April- July 2019	Research Methods in Global Health

ADDITIONAL SKILLS

Programming skills

MS Office (Word, Excel, PPT, Outlook)	Good knowledge
STATA	Good knowledge
EpiData	Good knowledge

Language skills

Arabic	Native language
English	Proficient
German	Conversant

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AFFIDAVIT

1. Bei der eingereichten Dissertation zu dem Thema **"The impact of school-based nutrition interventions on the nutrition knowledge of children and their parents"** handelt es sich um meine eigenständig erbrachte Leistung.

2. Ich habe nur die angegebenen Quellen und Hilfsmittel benutzt und mich keiner unzulässigen Hilfe Dritter bedient. Insbesondere habe ich wörtlich oder sinngemäß aus anderen Werken übernommene Inhalte als solche kenntlich gemacht.

3. Die Arbeit oder Teile davon habe ich bislang nicht an einer Hochschule des In- oder Auslands als Bestandteil einer Prüfungs- oder Qualifikationsleistung vorgelegt.

4. Die Richtigkeit der vorstehenden Erklärungen bestätige ich.

5. Die Bedeutung der eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unrichtigen oder unvollständigen eidesstattlichen Versicherung sind mir bekannt. Ich versichere an Eides statt, dass ich nach bestem Wissen die reine Wahrheit erklärt und nichts verschwiegen habe.

Place, Date *doctoral candidate's signature*