REVIEW

The influence of diet quality and dietary behavior on health-related quality of life in the general population of children and adolescents: a systematic review and meta-analysis

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Abstract

Objective The association between diet quality, dietary behavior and health-related quality of life has been mostly examined in children and adolescents with specific chronic diseases. No systematic review has synthesized the influence of diet quality and dietary behavior on health-related quality of life in the general population of children and adolescents. The purpose of this study was to systematically review the primary studies that evaluated the association between diet quality, dietary behavior and health-related quality of life in the general population of children and adolescents and to synthesize the findings for the association.

Methods A computer search in the databases of MEDLINE, EMBASE and PSYCINFO was performed to retrieve English language studies that were published from 1946 up to April 8, 2018. We also screened the PubMed-related articles and the reference lists of the existing relevant literature to identify other eligible studies. We synthesized the association between diet quality, dietary behavior and health-related quality of life using both a qualitative method and meta-analysis. We reported the review following up the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guideline.

Results Seventeen studies were included in the synthesis including twelve cross-sectional studies and five longitudinal studies. We found that diet quality and dietary behavior were associated with health-related quality of life in children and adolescents. The positive effect of healthy diets on health-related quality of life was observed for multiple domains of health-related quality of life, including physical, school and emotional functioning, and psychosocial quality of life. We observed a dose–response relationship between the diet exposure and health-related quality of life, where an unhealthy dietary behavior or lower diet quality was associated with decreased health-related quality of life among children and adolescents.

Conclusion The findings of the systematic review suggest the importance of promoting healthy diets and nutrition for good health-related quality of life among children and adolescents. Future research is needed to strengthen the evidence for prospective relationships and for the dose–response effect between diet quality, dietary behavior and health-related quality of life among children and adolescents.

Keywords Children · Adolescents · Diet quality · Dietary behavior · Health-related quality of life · Systematic review · Meta-analysis

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Introduction

It is widely acknowledged that poor diet quality, or an unhealthy dietary behavior, is a key risk factor for various chronic diseases in children and adolescents, such as obesity, diabetes and cardiovascular diseases [1–4]. A healthy diet or better diet quality was defined as a higher intake of fruits, vegetables, fish, whole grains and other foods which are acknowledged to be beneficial to health [3, 5]. Diet quality is commonly measured as a summary index that represents

the overall quality of diet, as well as the quality of the underlying components [6, 7]. An unhealthy dietary behavior is characterized as a behavior or an eating habit (e.g., eating fast food, skipping breakfast or meal) that leads to a higher intake of foods with saturated fat, sugar and processed food products, and inadequate intakes of healthy food groups [3, 5]. Previous studies have also demonstrated that low diet quality and unhealthy dietary behaviors are associated with a number of mental health concerns in children and adolescents, including internalizing disorders (e.g., depression, anxiety) [5, 8–11], and externalizing disorders (e.g., attention deficit and hyperactivity disorder) [12–15]. Prospective studies that examined the longitudinal association between diet quality, dietary or nutrient patterns and mental health reported that lower diet quality, unhealthy dietary patterns were related to poor mental health later in childhood and adolescence [8–10, 15]. Moreover, children and adolescents with poor diets encountered more problems in cognitive development and academic performance of their school work [16, 17]. Food insecurity has been found to be associated with low nutrient intake and poor diet quality and had adverse effects for the physical and mental health outcomes among children and adolescents [18, 19]. Household food insecurity is defined as a lack of access to adequate and safe food due to household financial constraint [19] and is commonly measured by national household food security scales [20].

Health-related quality of life (HRQoL) is a multidimensional construct that encompasses physical and psychological health and social well-being [21]. Health-related quality of life is a subjective evaluation of an individual's total health as well as the health of underlying sub-dimensions: physical, psychological and social functioning and well-being. Assessment of HRQoL among children and adolescents is important in identifying subgroups with poor health in order to develop and implement effective intervention strategies to enhance the health status of young people. In the last two decades, we have witnessed cumulative studies on the influence of health behaviors of physical activity and sedentary behavior on HRQoL among children and youth [22]. Research evidence of systematic reviews suggests that physical activity is positively, and sedentary behavior is negatively associated with HRQoL among children and adolescents [22]. Regarding the effect of diet quality and diet behavior on HRQoL in children and adolescents, previous studies have predominantly investigated the relationship among children and adolescents with specific disease conditions (e.g., obesity, cancers) [23, 24]. These studies have well documented that better diet quality and healthy dietary behaviors are associated with significant improvements in HRQoL including physical, mental and psychological health among children and adolescents. In recent years, studies are emerging to examine the relationship between diets and

HRQoL in the general population of children and adolescents [25–28]. To the best of our knowledge, no systematic review to date has synthesized the influence of diet quality and dietary behavior on HRQoL among the healthy population of children and adolescents. Particularly, how the diet influences the total and a sub-dimension of HRQoL in children and adolescents, and whether there is a dose–response effect between different components (total diet quality, food group or dietary behavior) of the diet exposures and HRQoL remains to be thoroughly investigated and systematically synthesized.

The present study aimed to (1) systematically review and synthesize the studies that evaluated associations between diet quality, dietary behavior or pattern and health-related quality of life in the general population of children and adolescents; (2) determine whether a dose–response relationship exists between diet quality or dietary behavior and health-related quality of life; (3) provide evidence-based information for school health and community intervention programs promoting healthy eating and nutrition to enhance the health status among children and adolescents.

Methods

Literature search

We searched the electronic databases of MEDLINE (1946 to March, 2018), EMBASE (1966 to April, 2018) and PSYCINFO (1806 to March, 2018) for English language literature. The MeSH headings and keywords included 'diet or diets', 'diet quality', 'Mediterranean diet', 'food intake', 'dietary or health behavior', 'nutrition', 'food insecurity', 'quality of life', 'health status', 'children', 'adolescents', 'teen', 'youth'. We also searched PubMed with 'related articles' feature and manually examined references of the extracted full-text articles to retrieve additional eligible studies. The literature search strategy for electronic databases was provided in Supplementary Table S1 in the supplementary file.

Inclusion and exclusion criteria

We specified the inclusion criteria in accordance with the systematic review's PI(E)CO approach: Population (P), Intervention (I) or Exposure (E), Comparison (C), and Outcomes (O). Selection of the eligible studies was based on the following inclusion criteria: (1) Participants in the primary study were from the general population of children and adolescents aged between 3 years and 18 years (P). The general population of children and adolescents was defined as those children and adolescents in communities or schools in a geographic region or a country. The population-based samples of children and adolescents are relatively healthier

than those peers in clinical settings (e.g., patients with specific diseases). For longitudinal studies with a follow-up age greater than 18 years, the age of children and adolescents was restricted to 3–18 years at baseline when the diet exposure information was measured. (2) Measures of the exposure (E): diet quality, dietary behavior (e.g., frequency of breakfast or fast food), dietary pattern (e.g., Mediterranean diet), food intakes and household food insecurity. The Mediterranean diet is deemed as a healthy diet pattern, characterized by high consumption of olive oil, fruits, vegetables, whole grains, fish, moderate consumption of dairy foods (e.g., milk, yogurt), and low consumption of meat foods [28]. (3) Study design included cross-sectional, cohort and case–control studies aimed to examine the association between the exposure of interest and the outcome (C). (4) Studies used one or more multidimensional health-related quality of life measures, and the primary outcome has to be health-related quality of life or health status measured by a multidimensional HRQoL instrument (O).

The exclusion criteria were: (1) Studies that examined associations between the exposure of interests and health-related quality of life among children and adolescents with specific chronic disease conditions, or among adults. (2) Studies that assessed the association between the diet exposure and the outcome of interest using a single item of self-rated or self-perceived health as an indicator of HRQoL. (3) Studies that examined individual nutrients or supplements (e.g., Vitamin D), or eating disorders (e.g., binge eating, bulimia nervosa). (4) Reviews, meta-analyses, study protocols, comments, letters, case reports and guidelines.

Study selection and data extraction

Two reviewers (XYW, LHZH) screened the title and the abstract to identify eligible studies from the database searching according to the predefined inclusion and exclusion criteria. For those studies that the reviewer was uncertain whether a study should be included for the synthesis through the abstract review, we obtained the full text articles for a detail examination for eligibility. Subsequently, the reference lists of the extracted studies were intensively examined for additional eligible studies by the two reviewers separately. Disagreements on the eligibility of the selected studies were resolved by discussion between the two reviewers, and among all the researchers if the two reviewers did not reach a consensus on the eligibility of the studies. Data for synthesis were abstracted from the included studies by the first reviewer (XYW) and then checked for accuracy and completion by the second reviewer (LHZH).

Data synthesis

We used a standardized data synthesis form and described the following characteristics of the included studies: first author, year of publication, country, samples, assessment of the diet exposure and the HRQoL, key analytical methods and covariates in the regression analysis. The key findings were summarized for each study for the associations between diet quality, dietary behavior, food insecurity and HRQoL. We performed a meta-analysis for the association between diet quality or dietary behaviors and health-related quality of life using data from the studies that adopted similar measures of HRQoL. To account for potential heterogeneity across the studies in the meta-analysis, we used the random effects model. For continuous outcomes of HRQoL, we estimated the mean difference in the HRQoL scores between healthy diets (e.g., high diet quality) and unhealthy diets (e.g., low diet quality) groups. For categorical outcomes of HRQoL, we estimated the difference in the odds of poor HRQol comparing unhealthy eating and healthy eating habits among children. The pooled estimates were reported for the mean difference score and the odds ratio for HRQoL with their 95% confidence intervals across the studies. The Cochran Q statistic (follows a Chi-square distribution with a k-1 degree of freedom, k = number of studies) and I^2 statistic were used to test the degree of heterogeneity, with a P value less than 0.1 in the Q test, and an I^2 value greater than 50% indicating significant and substantial heterogeneity [29]. Publication bias was detected using funnel plots. An asymmetrical funnel plot suggests a presence of publication bias [30]. The funnel plot asymmetry was tested by Egger test, in which the standardized effect is regressed against its standard error (precision) [31], with a P value < 0.1 for the intercept (α) indicating a statistically significant asymmetry. The meta-analysis was conducted using statistical software of Review Manager 5.2 (The Cochrane Collaboration, Copenhagen Denmark).

We followed up the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guideline in this systematic review [32].

Assessment of the risk of bias

The Newcastle–Ottawa Scale was used to assess the risk of bias of the included studies [33]. The Newcastle–Ottawa Scale is an eight-item checklist with three quality components: selection, comparability and outcome. Each item can be scored as one or two points and summed up to a total score, ranging from 0 to 9. A higher score indicates low risk of bias or better quality [33]. Previous research categorized the risk of bias score of individual studies into high, moderate and low risk of bias [34]. We classified the summed scores into high (0–4), moderate (5–6) and low (7–9) risk

of bias. Two reviewers (XYW and LHZH) independently assessed the study quality and assigned a score for each study. Any disagreement was solved by discussion.

Results

Characteristics of the included studies

We identified 9176 relevant citations by searching the electronic databases: EMBASE ($n = 4437$), MEDLINE ($n = 4079$) and PSYCINFO ($n = 660$). After removing the duplicate records ($n = 860$) between the different databases, 8316 unique citations were screened for eligibility. We identified an additional five studies through searching PubMed for related articles and manually screening the references from the retrieved included studies. After the title and the abstract screening, 42 full text articles were retrieved for detailed examination using the predefined inclusion and exclusion criteria. Of these studies, 25 studies were excluded due to inappropriate outcomes (e.g., single-item self-rated health), ineligible exposures (e.g., parental encouragement for healthy eating), inappropriate objectives (e.g., HRQoL as a mediation factor for self-esteem outcome), or other reasons (e.g., patient or adult participants) [35–59]. As a result, a total of 17 studies fulfilled the predefined criteria and were included in the final synthesis [25–28, 60–72]. The selection process of the studies was presented in the PRISMA flow diagram (Fig. 1).

Table 1 presents the characteristics of the included studies, the assessment of the diet exposure and the measurement of HRQoL. Four studies were conducted in Australia, and three studies were conducted in Japan. One study analyzed the merged data from 12 countries. The remaining nine studies were conducted in the following countries: The USA ($n = 2$), Canada ($n = 2$), Greece ($n = 2$), Spain ($n = 1$), the UK ($n = 1$) and Switzerland ($n = 1$).

In total, 47,932 participants were available in the statistical analysis of all the primary studies with a sample size varying between 152 [67] and 7,887 [70] in the individual studies (Table 2, Table 3). The total number of the participants in the longitudinal studies ($n = 16,974$) accounted for 35.4% of the total participants. The included studies were mostly cross-sectional investigations ($n = 12$), and five were longitudinal studies.

Assessment of the diet exposure and health-related quality of life

Most of the included studies used self-report or parent-report food frequency questionnaires to collect food intake data (Table 1) [26, 28, 60–63, 65, 66]. Three of these studies assessed the level of adherence to the Mediterranean diet using the Mediterranean Diet Quality Index [28, 60, 66].

Fig. 1 PRISMA flow diagram for selection and inclusion of the eligible studies
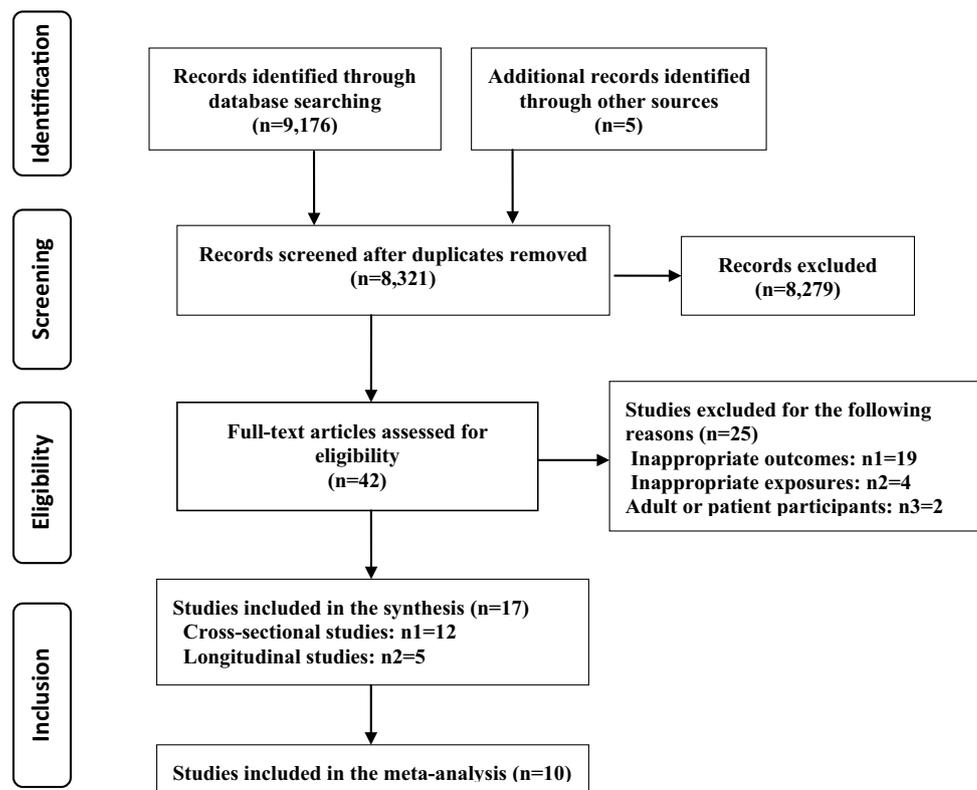
Table 1 Characteristics of the included studies, assessments of the diet quality and the health-related quality of life

Author, publication year	Country	Study design, samples	Assessment of diet quality and dietary behavior	HRQoL measure
Muros et al., 2017 [28]	Spain	Cross-sectional Adolescents n=456, 51.5% girls Age range 11–14	Self-report The Mediterranean diet (MD) quality index contains 16 dichotomous items (yes/no), giving a maximum possible total score of 12. Children's diets were classified as optimal (≥8 points), in need of improvement (4–7 points), or low quality (≤3 points)	Self-report The KIDSCREEN-27 27 items, five dimensions: physical well-being, psychological well-being, autonomy and parent's relation, social support and peers, and school environment. The scale scores were transformed into T values with mean (±SD) scores of 50±10. A higher score indicates higher HRQoL
Zervaki et al., 2017 [60]	Greece	Cross-sectional Adolescents n=400, 50.5% girls Age range 14–17	Self-report The Mediterranean diet (MD) quality index	Self-report The KIDSCREEN-27
Dumuid et al., 2017 [61]	12 countries	Cross-sectional Children n=5,759, 55% girls Age range 9–11	Self-report The Food Frequency Questionnaire (FFQ) with a total of 23 food categories. Eating pattern was derived from the food categories using principal component analysis. Two factors were identified: (1) a healthy eating pattern (vegetables, fruit, whole grains, etc.), and (2) an unhealthy eating pattern (fast food, soft drinks, sweets, etc.). Four major lifestyle behavior clusters were identified by means of cluster analysis: (1) high physical activity (actives); (2) high sedentary behavior (sitters); (3) unhealthy eating pattern/high screen time (junk-food screenies); (4) low screen time/ healthy eating pattern/ moderate PA and sedentary behavior (all-rounders)	Self-report The KIDSCREEN-10, 10 questions on a five-point scale covering physical activity, energy and fitness, moods and emotions, social and leisure participation, social and family relationships, cognitive capacity, and school experience. The item scores were summed and transformed into T values with a mean of 50 and a SD of approximately 10, with higher values representing better HRQoL
Bolton et al., 2016 [25]	Australia	Cross-sectional Adolescents n=1,144 Rural: n1=722, 54% girls; Urban: n2=422, 41% girls Age range 11.77–18.91	Self-report (1) The type and serves of foods eaten on the previous school day (Tuesday-Friday) were collected with 10 questions through a self-reported paper-based survey (2) Healthy diet score and unhealthy diet score were calculated based on the Australian nutrition-related survey data	Self-report Assessment of Quality of Life (AQoL), the AQoL-6D: 20 items on six domains: physical ability, social and family relationships, mental health, coping, pain and vision, and hearing and communication. The score ranges between 0 (worst health state) and 1(best health state)

Table 1 (continued)

Author, publication year	Country	Study design, samples	Assessment of diet quality and dietary behavior	HRQoL measure
Gopinath et al., 2016 [62]	Australia	Cohort study, 5-year follow-up Adolescents n = 858, 59.3% girls Age range 12–17 (follow-up) Mean age:17.4 (SD0.6) for boys, 17.2 (SD0.6) for girls	Self-report Dairy intake data were collected using a 120-item self-administered food frequency questionnaire. Servings of dairy foods were calculated by adding intakes of core dairy foods: milk servings (258 g or 250 ml of any type of fluid milk including plain and flavored milk), cheese servings (40 g of any type of hard or soft cheese), and yogurt servings (200 g of any type of yogurt)	Self-report The Pediatric Quality of Life Inventory (PedsQL) 4.0, administered in the follow-up study. The PedsQL contains 23 items, with 4 subscale scores: physical functioning (PF), emotional functioning (EF), social functioning (SF), and school functioning, and produces 3 summary scores: a total score, a physical health summary score and a psychosocial health summary score. The PedsQL score ranges from 0 to 100, a higher score indicating better HRQoL
Michels et al., 2016 [63]	Switzerland	Cohort study, one year follow-up Pre-school children n = 291, 53% girls Age range 3.9–6.3 (baseline);4.6–7.1 (follow-up) Mean age:5 (baseline); 5.9 (follow-up)	Parents-report Parents completed a food frequency questionnaire on their child's diet intake during the last 4 weeks. The dietary intake included the categories: (1) fruit, (2) vegetables, (3) soft drinks, (4) sweets, (5) fatty junk foods (French fries, hamburgers and pizza). Data on diet intake were collected on both time points	Parents -report The parent proxy version of the PedsQL 4.0 for children 5–7 years. Psychosocial QoL scale (Likert-scale of 5 response levels): emotional, social and school dimensions with five items in each dimension. A higher score represents better HRQoL. HRQoL data were available for both time points
Chen et al., 2014 [64]	Australia	Cross-sectional Children and adolescents n = 3,357, 51% girls Primary school students Mean age = 10.6 Age range 7.9–13.0 High school students Mean age = 15.1 Age range 13.6–16.9	Self-report Eating fast food or takeaway (including burgers, pizza, fried chicken, fish and chips) was measured as frequency and categorized as rarely/ sometimes, often/a lot	Self-report The Child Health Utility 9D, CHU9D, nine dimensions: worried, sad, pain, tired, annoyed, school work, sleep, daily routine, ability to join in activities, and five response levels in each question indicating severity
Gopinath et al., 2014 [65]	Australia	Longitudinal 5-year follow-up Adolescents n = 742 Age range 12 (baseline), 17–18 (follow-up)	Self-report Food and nutrient intakes were measured with a 120-item self-administered food frequency questionnaire. A lifestyle behavior index was generated with five obesogenic behavioral risk factors (including high soft drink intake, high snack intake, low fruit and vegetable intake, low physical activity, high screen time) with '1' for present and '0' for absent. Data on lifestyle habits were available at both time points (2004–2005 and 2009–2011)	Self-report The PedsQL 4.0, measured at follow-up. The HRQoL score ranges between 0 and 100 with higher scores representing higher QoL. The HRQoL data were collected only at the follow-up

Table 1 (continued)

Author, publication year	Country	Study design, samples	Assessment of diet quality and dietary behavior	HRQoL measure
Costarelli et al., 2013 [66]	Greece	Cross-sectional Adolescents $n = 359$ (166 boys, 193 girls), 53.8% girls Age range 13–16	Self-report The adherence to the Mediterranean diet was assessed through a Mediterranean diet quality index. The index comprises 16 yes-or-no questions, with a total score ranging from −4 to 12.The diet quality index can be categorized into 3 levels: very low (≤3); in need of improvement (4–7); optimal (8–12)	Self-report The KIDSCREEN-27
Wu et al., 2012 [26]	Canada	Cross-sectional Children in grade five $n = 3,421$ Age range 10–11	Self-report The Harvard Food Frequency Questionnaire for Youth and Adolescents (YAQ) was used to collect the data of food intakes. On the basis of these intakes, the diet quality index was calculated based on the Diet Quality Index–International (DQI-I) composite measure. The DQI-I score was divided into tertiles with a higher tertile indicating better diet quality	Self-report The EQ-5D-Y (youth), five dimensional descriptive system: walking, looking after myself, doing usual activities, having pain or discomfort, and feeling worried, sad or unhappy. A Visual Analogue Scale (VAS) ranges between 0 (worst imaginable health) and 100 (best imaginable health)
Boyle et al., 2010 [27]	UK	Cross-sectional Children $n = 1,771$, 48.3% girls Age range 11–15 Mean age:13.2 (SD1.2)	Self-report The Block food intake screener was used to assess diet and the intake of fat, fiber, fruit and vegetables. Fat and fruit intake was classified as achieving the optimal of fats (<35% of calories consumed per day) or optimal fruit and vegetable (at least 5 portions per day) or not	Self-report The PedsQL 4.0, the EQ-5D-Y, the EQ-5D index and a Visual Analogue Scale (VAS) on 0 to 100 scale
Dalton et al., 2010 [67]	USA	Cross-sectional Children in grade six $n = 152$, 54% girls Age range 11–12	Self-report Fruit and vegetable servings per day was measured by two questions: In a typical day, how many servings of fruit do you eat? In a typical day, how many servings of vegetables do you eat? Two categories: ≤ 4 servings/day, ≥ servings/day	Self-report The PedsQL 4.0

Table 1 (continued)

Author, publication year	Country	Study design, samples	Assessment of diet quality and dietary behavior	HRQoL measure
Wang et al., 2008 [68]	Japan	Longitudinal 10-year follow-up 9,674 families (response rate: 95.1%) with children of 3 years old responded to the survey (Phase I) between 1992 and 1994. 9,718 students (response rate: 93.0%) in the first grade of junior high schools responded to the Phase IV survey in 2002. Complete data for both surveys were available for 7,289 children, 49.4% girls Age nearly 13.0 years at follow-up	Parent-report Dietary habits measure included regularity of breakfast eating (every day, sometimes, almost never), regularity of meal time and snack time (regular, almost regular, irregular), and frequency of eating instant noodles (≥3/week, 1–2/week, 2–3/month, ≤1/month). Dietary habits data for children at three years old were used	Self-report The Japanese version of the Dartmouth Primary Care Cooperative Project (COOP) chart, a self-administered HRQoL questionnaire. The chart covers nine dimensions of HRQoL: physical fitness, daily activities, social activities, pain, change in health, social support, feelings, overall health, and quality of life. The chart 'Quality of life' question was: How have things been going for you during the past 4 weeks? Five response categories: very well, pretty good, good and bad parts about equal, pretty bad, very bad. HRQoL was classified as 'good QoL' by combining the 'very good' and 'good' responses into one group, and 'poor QoL' by combining the 'about equal, pretty bad, and very bad'. The HRQoL data were available only in the follow-up (Phase IV survey in 2002)
Chen et al., 2005a [69]	Japan	Longitudinal 3-year follow-up Children n=7,794 with complete baseline (1999) and follow-up (2002) data (follow-up rate: 74.7%), 50.4% girls Mean age:12.8 (follow-up)	Self-report Frequency of breakfast eating and snack eating was rated as one of four levels: everyday, often, sometimes, and almost never. Dietary habits data of both time points were used	Self-report Japanese version of the COOP charts. Subjects rated as 'very well' or 'pretty good' for the HRQoL question were considered to have 'good QoL' and the remainder (about equal, pretty bad, and very bad) was classified as having 'poor QoL'. The HRQoL data were available only in the follow-up
Chen et al., 2005b [70]	Japan	Cross-sectional Children n=7,887 in the analysis, 50.5% girls Mean age:12.75 (SD0.29)	Self-report Frequency of eating breakfast and snack food was rated as 'everyday, often, sometimes, and almost never'	Self-report Japanese version of the COOP charts. The HRQoL was recoded into two categories: good and poor HRQoL
Kirk et al., 2014 [71]	Canada	Cross-sectional Grade five students n=5,853 Age range 10–11	Household member-report Food security (FS) status was assessed using the Household Food Security Survey Module (HFSSM) in the US, which has six items. Based on the total score, the households were classified as four groups: high food security (score=0), marginal food insecurity (score=1), moderate food insecurity (score=2–4), severe food insecurity (score=5–6)	Self-report The EQ-5D-Y (youth), five dimensional descriptive system. Based on the responses to the EQ-5D-Y questions, the US EQ-5D index values were calculated and used as HRQoL scores

Table 1 (continued)

Author, publication year	Country	Study design, samples	Assessment of diet quality and dietary behavior	HRQoL measure
Casey et al., 2005 [72]	USA	Cross-sectional Children $n = 399$ in the analysis, 51.8% girls Age range 3–17	Adult-reported household food security Food security status was assessed using the US Household Food Security Scale (18-items). The food security status was classified into 3 categories: households show no or minimal evidence of food insecurity; (2) Food insecure without hunger; (3) Food insecure with hunger	Both parent- and child self-report The PedsQL 4.0

HRQoL health-related quality of life, *PedsQL* Pediatric Quality of Life Inventory, *EQ-5D-Y* European Quality of Life 5 Dimension measure for youth, *AQoL-6D* Assessment of Quality of Life (AQoL)-6D, *CHU9D* Child Health Utility 9D, *FFQ* Food Frequency Questionnaire, *SD* standard deviation, *MD* Mediterranean diet, *FI* food insecurity, *DQI-I* Diet Quality Index–International, *UK* United Kingdom

A Canadian study calculated the overall diet quality using the Diet Quality Index–International (DQI-I) composite measure that was based on responses to the Harvard Food Frequency Questionnaire for Youth and Adolescents (YAQ) [26]. Three Japanese studies measured frequency of breakfast eating and snack eating [68–70]. Two studies derived diet-related variables for analysis with a combination of health behaviors including soft drink and high snack intake, fruit and vegetable intake, physical activity and sedentary behavior [61, 65]. Two other studies in the USA and Canada, respectively, measured the experience of household food insecurity [71, 72].

With respect to the health-related quality of life measures, six studies used the Paediatric Quality of Life Inventory 4.0 (PedsQL 4.0) [27, 62, 63, 65, 67, 72], which was the most frequently used HRQoL measure among the included studies (Table 1). The KIDSCREEN-27 was used in three studies [28, 60, 66], and the KIDSCREEN-10 was used in one study [61]. Three studies utilized the EQ-5D-Y [26, 27, 71]. Other HRQoL measures included the Japanese COOP charts ($n = 3$), the Child Health Utility 9D (CHU9D) ($n = 1$), the EQ-5D index ($n = 2$) and the Assessment of Quality of Life-6D ($n = 1$).

Risk of bias assessment

The risk of bias score ranged between 4 and 7 for the individual studies with an average score of 5.76 and a standard deviation of 0.97. Eleven studies were rated as moderate risk of bias (score: 5–6), and two studies was scored as high risk of bias (score = 4). Only four studies were rated as low risk of bias (Table 2). The main reasons for the low quality (moderate or high risk of bias) included small sample size, inadequate report of descriptive data or a lack of control for important confounders in statistical analyses.

Associations between diet quality, dietary behavior and health-related quality of life

Table 2 shows the findings of the individual studies for the association between diet quality, dietary behavior or pattern, food insecurity and HRQoL among children and adolescents. Table 3 displays a summary for the main findings across all studies.

Findings from the cross-sectional studies

Of the 12 total cross-sectional studies, six studies explored the relationship between dietary patterns, food items or eating habits and HRQoL [25, 27, 61, 64, 67, 70], four studies examined the relationship between the overall diet quality index level (e.g., the DQI-I, the Mediterranean diet quality index) and HRQoL [26, 28, 60, 66], and two studies

Table 2 Main findings, statistical methods and the risk of bias assessment of the included studies

Author, publication year	Outcome	Summary of the main findings	Key statistical methods	Covariates	Risk of bias score
Muros et al., 2017 [28]	The KIDSCREEN-27 score	Better adherence to the Mediterranean diet (MD) was associated with higher HRQoL scores. The mean HRQoL scores with SD between groups of adherence to the MD: Very low: 41.55 ± 11.50; Need to improve: 51.69 ± 7.87; Optimal: 54.25 ± 7.87. Regression coefficient adjusted $\beta = 0.142$, $P < 0.01$ for the total QoL score	Hierarchical linear regression	BMI, physical activity	5
Zervaki et al., 2017 [60]	The KIDSCREEN-27 score	Adherence to the Mediterranean diet significantly positively correlated with higher scores in total QoL, physical well-being, psychological well-being, parents and autonomy, peers and social support. Regression coefficient adjusted $\beta = 0.13$, $P = 0.049$ for the total QoL score	Spearman rank correlation, multiple linear regression	Age, obesity, BMI, parental education level	4
Dumuid et al., 2017 [61]	The KIDSCREEN-10 score	Health-related quality of life was greatest in the all-rounders (healthy eating pattern/low screen/moderate PA and sedentary behavior) at all 11-country sides except the US, suggesting that healthy diet and low screen time were related to better HRQoL	Analysis of covariance (ANCOVA)	BMI, sex, parental education and family structure	5
Bolton et al., 2016 [25]	The AQoL-6D score	(a) A unit increase in healthy diet score was associated with an increase in HRQoL. Unstandardized coefficient $\beta \pm SE$: 0.02 ± 0.01, $P < 0.02$. (b) A unit increase in unhealthy diet scores was associated with a decrease in HRQoL. Unstandardized coefficient $\beta \pm SE$: −0.01 ± 0.00, $P < 0.05$	Multiple linear regression	Gender, age, socioeconomic status, BMI	6

Table 2 (continued)

Author, publication year	Outcome	Summary of the main findings	Key statistical methods	Covariates	Risk of bias score
Gopinath et al., 2016 [62]	The PedsQL total and subscale scores	Temporal associations: Boys who were in the highest tertile of yogurt intake relative to the lowest tertile over the 5 years had 7.4 points higher psychosocial health summary scores (P trend = 0.04), and 12.4 points higher school functioning scores (P trend = 0.02). Boys who remained in the same tertile of yogurt consumption during the 5 years had 10.4 units higher school functioning scores (P = 0.01) than those peers who decreased the yogurt consumption Cross-sectional associations: HRQoL by yogurt consumption among 17-18-year-old boys (n = 349): Psychosocial health summary scores: First tertile: 74.3 (SE2.1); Second tertile: 77.3 (SE2.1); Third tertile: 80.2 (SE1.9). School functioning scores: First tertile: 59.1 (SE3.2); Second tertile: 61.4 (SE3.2); Third tertile: 68.2 (SE2.9)	Mixed linear regression models	Age, sex, ethnicity, BMI, parental education, total physical activity and screen time	7
Michels et al., 2016 [63]	The PedsQL total score, emotional, social and school functioning scores	Cross-sectional associations: Sweet intake was associated with lower social functioning $\beta = -0.109$, and lower school functioning $\beta = -0.164$; Fat intake was associated with lower emotional functioning $\beta = -0.198$ Longitudinal associations: Lower total psychosocial QoL predicted a decrease of fruit intake. Lower emotional QoL predicted an increase in fat intake in girls	Multilevel linear regressions	Children' gender, age, migration, physical activity and parents' education level	6

Table 2 (continued)

Author, publication year	Outcome	Summary of the main findings	Key statistical methods	Covariates	Risk of bias score
Chen et al., 2014 [64]	The CHU9D utility score	Compared with those who never or sometimes ate fast food or took away, students often ate fast food or took away had lower mean utilities after adjustment for gender, age, region and socioeconomic position. Adjusted mean difference in utilities: Primary school students: $\beta = -0.04$ (SE 0.008); High school students: $\beta = -0.036$ (SE 0.013)	Multiple linear regression random effect model	Gender, age, region and socioeconomic position	6
Gopinath et al., 2014 [65]	The PedsQL total and subscale scores	In boys, there was a significant decrease in both total score and physical summary score with multiple unhealthy behaviors, 4.5-units (4 or 5 vs 0 or 1 lifestyle risk factors, P trend $=0.02$) and 4.2-units (4 or 5 versus 0 or 1 lifestyle risk factors, P trend $=0.01$), respectively. Girls who engaged in 4 or 5 versus 0 or 1 lifestyle risk factors at baseline experienced 4.6 points lower physical summary score (P trend $=0.04$) at the 5-year follow-up Beta coefficients: $\beta = -1.45$ (P trend $=0.001$) for physical summary in total sample ($n=742$); In boys ($n=375$), $\beta = -1.37$ (P trend $=0.02$) for total score, $\beta = -1.57$ (P trend $=0.01$) for physical summary score	General linear regression	Age, ethnicity, BMI, parental education	7
Costarelli et al., 2013 [66]	The KIDSCREEN-27 total and the subscale scores	Adherence to the MD significantly positively correlated with all the subscales and total score of HRQoL (Spearman's correlations). The regression model showed that adherence to the MD was associated with higher total HRQoL ($\beta = 0.210$, $P < 0.001$) in adolescents	Multiple linear regression	Gender, BMI, obesity, number of meals, parental education	5

Table 2 (continued)

Author, publication year	Outcome	Summary of the main findings	Key statistical methods	Covariates	Risk of bias score
Wu et al., 2012 [26]	The EQ-5D-Y dimensions; VAS score	The VAS score was significantly higher for students who were in the highest tertile of the DQI-I than students who were in the lowest tertile of the DQI-I ($\beta=2.76$, 95% CI 1.26, 4.26, $P<0.001$). Students in the middle tertile of the DQI-I were less likely to report problems in the pain or discomfort dimension of the EQ-5D-Y (OR = 0.81, 95% CI 0.68, 0.98, $P=0.026$) relative to students in the lowest tertile of the DQI-I	Multilevel logistic and linear regressions	Gender, residential area, parental education, household income	6
Boyle et al., 2010 [27]	The PedsQL total, physical and psychosocial health summary scores, subscale scores, the EQ-5D VAS, the EQ-5D utility	In terms of fat intake, adolescents in the optimal fat intake (<35% of daily calorie intake in fats) group reported better HRQoL than the peers in the high fat intake group only for the emotional functioning (EF) dimension (3.9 points difference, $P=0.021$) of the PedsQL in the winter survey after adjustment for covariates. Regarding fruit and vegetable consumption, statistically significant differences were observed between the optimal (5 or more portions of fruit and vegetables per day) and not optimal consumption groups for the EF (mean difference = 3.7, $P=0.01$), Social functioning (mean difference = 2.7, $P=0.028$), Psychosocial health summary score (mean difference = 2.5, $P=0.03$) and Total score (mean difference = 2.4, $P=0.02$) of the PedsQL in the winter survey. Adolescents who achieved the optimal consumption reported better HRQoL. Similar pattern was observed in the summer survey, though the magnitude of the difference in HRQoL between the two fruit and vegetable consumption groups was largely smaller	Linear regression	Age, gender, ethnicity, free school meals, season, area	6

Table 2 (continued)

Author, publication year	Outcome	Summary of the main findings	Key statistical methods	Covariates	Risk of bias score
Dalton et al., 2010 [67]	The PedsQL total and subscale scores	Statistically significant correlations were observed between fruit and vegetable servings per day and PedsQL total score ($r=0.20$), psychosocial summary score ($r=0.22$), and social functioning ($r=0.24$). Linear regression analysis showed a marginal significant association between fruit and vegetable consumption and social functioning of the PedsQL (beta coefficient $=0.17$, $P=0.046$)	Correlation (Pearson's correlation) and linear regression	Physical activity, actual weight, screen time	4
Wang et al., 2008 [68]	Dichotomous QoL outcome	Children who ate breakfast 'sometimes' or 'almost never' at 3 years of age were more likely to have poor HRQoL ($OR=1.16$ and 1.59, $P=0.012$ and 0.002, respectively) than those who had breakfast eating 'everyday', showing a dose–response pattern. Frequent instant noodle consumption (≥ 3/week, versus ≤ 1/month) was related to an increased risk of having a poor HRQoL ($OR=1.50$, $P=0.007$). Children who had irregular meals or snacks at 3 years of age experienced an increased risk of having a poor HRQoL than those of having meals or snacks at regular times	Multiple logistic regression	Age, gender, BMI and family factors (e.g., parents' occupation), other lifestyles (bedtime, walking time, sleep duration, PA)	7
Chen et al., 2005a [69]	Dichotomous QoL outcome	Relative to those who maintained their breakfast eating 'often' during the follow-up, children who changed from 'often' to 'seldom', or maintained eating breakfast as 'seldom' were more likely to have poor HRQoL at three years later ($OR=1.61$, 95% CI 1.24, 2.07; $OR=2.05$, 95% CI 1.03, 4.09) after adjustment for sex, age, and BMI at baseline, suggesting a dose–response relationship	Multiple logistic regression	Age, sex, BMI, PA, television viewing, sleep habits at baseline	7

Table 2 (continued)

Author, publication year	Outcome	Summary of the main findings	Key statistical methods	Covariates	Risk of bias score
Chen et al., 2005b [70]	Dichotomous QoL outcome	Skipping breakfast was associated with poor HRQoL in all domains of the COOP charts. Frequent snack eating was associated with poor HRQoL in the domains of physical fitness, feelings, daily activities, pain, overall health, social support, and quality of life	Univariate and multivariable logistic regression	Age, sex, BMI, social background, and somatic symptoms	6
Kirk et al., 2014 [71]	The EQ-5D index score	Both univariate and multivariable linear regressions showed a significant association between food insecurity and lower health-related quality of life (the EQ-5D index score). Regression coefficients in the univariate model (reference group: high food security): $\beta = -0.02$, $P = 0.05$ for marginal food insecurity (FI); $\beta = -0.02$, $P < 0.05$ for moderate FI; $\beta = -0.03$, $P < 0.05$ for severe FI. The association appears to be in a dose–response manner across the severity of FI	Univariate and multivariable linear regressions	Gender, residential area, parental education	6
Casey et al., 2005 [72]	The PedsQL total, physical and psychosocial health summary scores	Household food insecurity was significantly associated with lower total HRQoL (mean difference = 4.1, 95% CI 1.29, 6.99, $P = 0.005$), lower physical functioning (mean difference = 4.0, 95% CI 1.17, 6.79, $P = 0.006$), and lower psychosocial functioning (mean difference = 4.1, 95% CI 0.78, 7.56, $P = 0.017$)	Linear regression	Child's age, race, gender, and family income	5

BMI body mass index, *OR* odds ratio, *CI* confidence interval, *EF* emotional functioning, *PA* physical activity, *ANCOVA* analysis of covariance, *SD* standard deviation, *SE* standard error, *MD* Mediterranean diet, *FI* food insecurity

Table 3 Summary of the results for the relationship between diet quality, dietary behavior and health-related quality of life

Study design, number of studies	Total sample	The exposure of diets	HRQoL measure	Summary of the main findings	Level of quality assessment
Cross-sectional study, n = 12	30,958	(1) Diet quality index The Mediterranean Diet (MD) Quality Index; the Diet Quality Index-International (DQI-I) (2) Dietary patterns Healthy eating pattern (vegetables, fruit, whole grains, etc.); unhealthy eating pattern (fast food, soft drinks, sweets, etc.) (3) Frequency of dietary behavior Servings of dairy foods (yogurt, milk, cheese); eating fast food; breakfast eating; snack eating (4) Dietary intakes of food groups Fruits; vegetables; soft drinks; sweets; fatty junk foods; fat (5) Food insecurity	(1) Generic profile measure The KIDSCREEN-27; the KIDSCREEN-10; The Pediatric Quality of Life Inventory (PedsQL) 4.0; the EQ-5D-Y; VAS; the COOP chart (2) Utility measure The AQoL-6D; the CHU9D utility; the EQ-5D index	Higher diet quality and healthy dietary behaviors are associated with better health-related quality of life in children and adolescents. Diet quality, dietary behaviors have significant effects on multiple domains of HRQoL. A dose–response relationship was observed in several studies, showing that healthy dietary behavior and diet quality were positively associated with HRQoL	Moderate risk of bias (score: 5–6): n = 10 studies High risk of bias (score: 0–4): n = 2 studies
Longitudinal study, n = 5	16,974	(1) Dietary patterns Cluster of dietary behavior (high soft drink intake, high snack intake, low fruit and vegetable intake, low physical activity, high screen time) (2) Frequency of dietary behavior Servings of dairy foods (yogurt, milk, cheese); eating fast food; breakfast eating; snack eating (3) Dietary intakes of food groups Fruit; vegetables; soft drinks; sweets; fatty junk foods	Generic profile measure The PedsQL 4.0; the EQ-5D-Y; the COOP chart	Higher diet quality and healthy dietary behaviors predict better HRQoL later in children and adolescents. A dose–response relationship was observed between the frequency of unhealthy diet behaviors and poor HRQoL	Low risk of bias (score: ≥7): n = 4 studies Moderate risk of bias (score: 5–6): n = one study
Total (n = 17)	47,932				

explored the influence of food insecurity on HRQoL [71, 72] (Table 2). Of those studies that explored the relationship between the dietary pattern or behavior, the majority examined the importance of food intakes of fruits, vegetables, fat, fast foods and dairy food for HRQoL.

All of the cross-sectional studies revealed a significant relationship between diet quality, diet behavior, nutrient patterns or food insecurity and HRQoL. Only one study by Dalton et al. observed a marginal statistically significant association between fruit and vegetable consumption and social functioning of the PedsQL (Beta coefficient = 0.17, $P = 0.046$) [67]. This study used a small sample of school children ($n = 152$), which may compromise the statistical power for identifying the true association. Muros et al., Zervaki et al. and Costarelli et al. reported in their studies that adolescents who had better adherence to the Mediterranean diet experienced higher HRQoL than the adolescents who had low adherence to the Mediterranean diet [28, 60, 66]. Wu et al. (2012) observed in a large representative sample of grade five students ($n = 3,421$) in Canada that higher diet quality was associated with higher HRQoL [26]. The Japanese study by Chen et al. (2005b) found that skipping breakfast and frequent snack eating in childhood were associated with poor HRQoL [70]. The two studies that examined the effect of household food insecurity on HRQoL consistently reported that household food insecurity was related to lower HRQoL among children [71, 72].

Lower diet quality or poor dietary behaviors were linked to decreased HRQoL in multiple domains among children and adolescents. Wu et al. observed that children with better diet quality relative to children with lowest diet quality were less likely to report adverse health problems (OR = 0.81, $P = 0.026$) in the pain or discomfort dimension of the EQ-5D-Y [26]. Boyle et al. reported that excessive consumption of fat was associated with worse emotional functioning of the PedsQL [27]. Casey et al. found that household food insecurity was significantly associated with lower total HRQoL, lower physical and psychosocial functioning among children [72].

Several cross-sectional studies found a dose–response relationship between diet quality or diet behaviors and HRQoL [26, 28, 62, 70, 71]. Muros et al. (2017) observed that health-related quality of life scores as assessed by the KIDSCREEN-27 among adolescents increased with the elevated level of adherence to the Mediterranean diet [28]. Gopinath et al. [62] reported that higher consumption of yogurt was associated with higher total PedsQL scores (mea $n = 80.5, 83.3, 85.2$ for the first, second and third tertiles of yogurt intake, $P = 0.03$), better psychosocial health summary scores (mea $n = 74.3, 77.3, 80.2$ for the first, second and third tertiles, $P = 0.02$), and higher school functioning scores (mea $n = 59.1, 61.4, 68.2$ for the first, second and third tertiles, $P = 0.01$) among 17–18 year old boys [62]. A

Canadian study found that the overall diet quality index was associated with the Visual Analogue Scale (VAS) score in a dose–response manner (mean difference of VAS = 1.47, 2.76 points for second and third tertiles versus first tertile of the DQI-I score) among grade five students [26]. Chen et al. reported that children who ate breakfast seldom or almost never had a higher odds of experiencing poor HRQoL than children who ate breakfast every day or often [70], suggesting a dose–response relationship between frequency of breakfast skipping and HRQoL in Japanese children. Additionally, the association between household food insecurity and health-related quality of life of children tended to be in a dose–response trend as reported in a Canadian study (mean difference in the EQ-5D index = 0.03 between severe food insecurity group and food security group) [71].

Findings from the longitudinal studies

All five longitudinal studies that examined longitudinal or temporal associations between the diet intake exposures and HRQoL found a significant effect of the diets on health-related quality of life among children and adolescents (Table 2) [62, 63, 65, 68, 69]. These studies were conducted in Australia ($n = 2$), Japan ($n = 2$) and Switzerland ($n = 1$). Gopinath et al. [62] observed that boys in Sydney of Australia who were in the highest tertile of yogurt intake relative to the lowest tertile over the 5-year follow-up had 7.4 points (P trend = 0.04), 12.4 points (P trend = 0.02) higher psychosocial health summary and school functioning scores at the follow-up, respectively [62]. Wang et al. documented that children who ate breakfast 'sometimes' or 'almost never' at 3 years of age had an increased risk of having poor HRQoL at the 10-year follow-up in first-year junior high school study (OR = 1.16 and 1.59, $P = 0.012$ and 0.002, respectively) than those children who ate breakfast 'everyday' [68]. Children who had irregular meals or snacks at 3 years of age experienced a higher risk of developing poor HRQoL later in first-year junior high school study than those of having meals or snacks at regular times [68].

A dose–response relationship between level of unhealthy dietary behaviors and poor HRQoL can also be seen in the few longitudinal studies in children and adolescents. Gopinath et al. [65] reported in a cohort study that exposure to unhealthy diet behaviors (e.g., high consumption of soft drink and salty snack foods, low fruit and vegetable intake) had a dose–response relationship with the PedsQL scores of adolescents [65]. Adolescents who engaged in an unhealthy diet behavior at baseline had decreased HRQoL scores in both total and physical health summary scales of the PedsQL at the 5-year follow-up [65]. Chen et al. examined temporal relations between changes of diet habits over 3 years and HRQoL in Japanese children and found that relative to those who maintained their breakfast eating 'often'
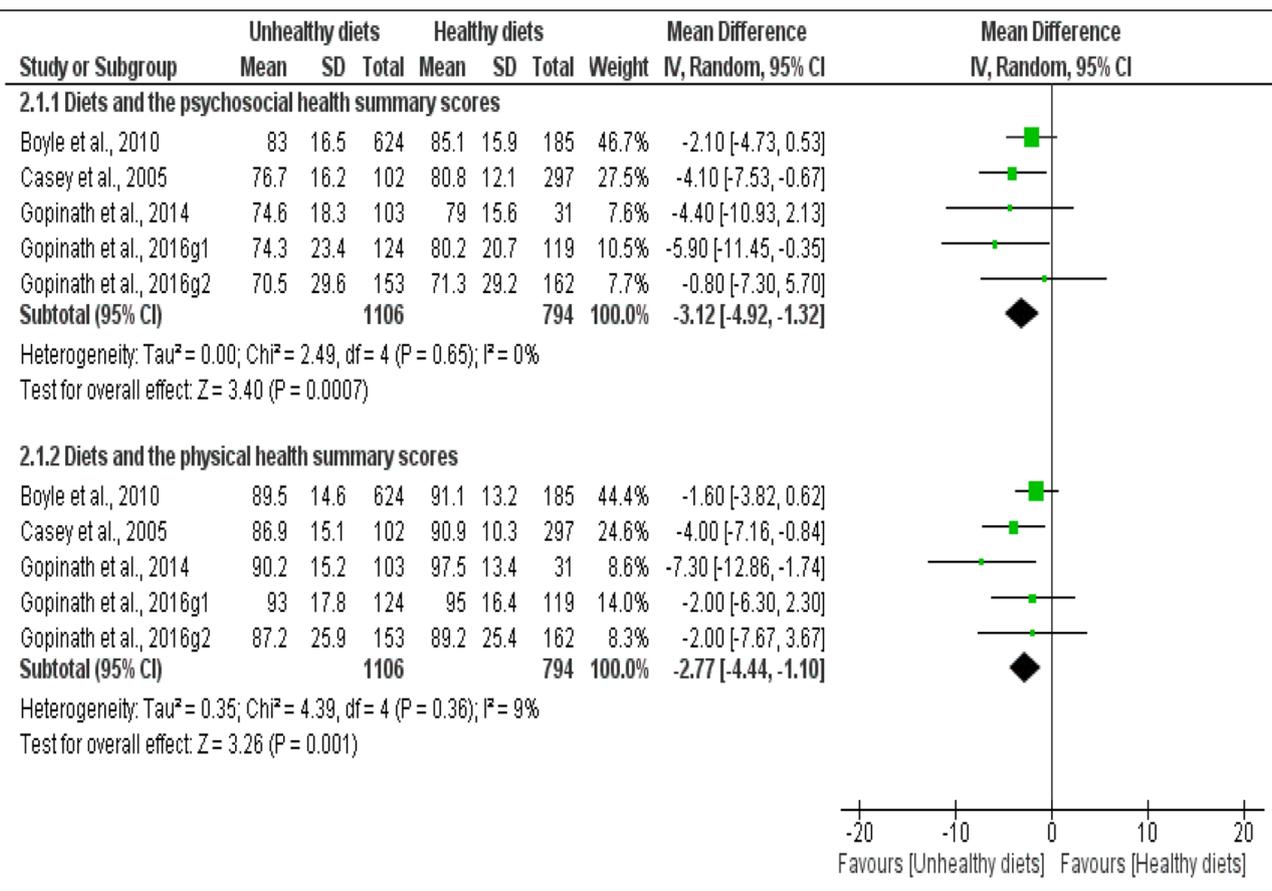
The diet exposure and the levels in the study:
Boyle et al., 2010: Fat intake too high (>35% of calorie intake) vs. Optimal fat intake (≤35% of calorie intake);
Gopinath et al., 2014: Having one or more diet risk factors (unhealthy diets) vs. no diet risk factors (healthy diets);
Gopinath et al., 2016g1-g2: Yogurt consumption First tertile (unhealthy diets) vs. Third tertile (healthy diets);
Casey et al., 2005: Food insecure vs. Food secure.
Gopinath et al., 2016 has two groups: Gopinath et al., 2016g1 for boys; Gopinath et al., 2016g2 for girls.
The HRQoL measure: The PedsQL 4.0.

Fig. 2 Meta-analyses of the mean difference in the psychosocial health summary and the physical health summary scores of the PedsQL 4.0 between healthy diet and unhealthy diet groups

during the follow-up, children who changed breakfast eating from 'often' to 'seldom', or maintained as 'seldom', had a higher risk of poor HRQoL at follow-up (OR = 1.61, 95% CI 1.24, 2.07; OR = 2.05, 95% CI 1.03, 4.09, respectively) after adjusting for the effect of sex, age and BMI at baseline in the regression model [69], suggesting a presence of dose–response relationship between breakfast skipping and HRQoL of children.

Results of the meta-analysis

The data for meta-analysis were extracted from ten studies. Forest plots were generated for five studies that used similar generic HRQoL measures, four studies that analyzed utility values of preference-based HRQoL measures (e.g., the ED-5D index, the CHU9D), and for three studies that used

the Japanese COOP charts [26, 27, 62, 64, 65, 68–72]. Figures 2 and 3 present the difference in the HRQoL total score, the physical health and psychosocial health summary scores between healthy and unhealthy diet groups among children and adolescents. The data were based on five cross-sectional studies and one prospective study [65]. Children and adolescents with healthy diet had significantly a higher total HRQoL score measured by the PedsQL and the EQ-5D-Y VAS (pooled mean difference = 3.45, 95% CI 2.40, 4.50, P < 0.0001) than children and adolescents with unhealthy diet. The EQ-5D-Y VAS and the PedsQL 4.0 total scores ranged between zero (worst health) to 100 (best health). Likewise, there was a significant difference in the physical health summary and psychosocial health summary scores of the PedsQL measure between the two diet groups (total mean difference of healthy diet group versus unhealthy diet
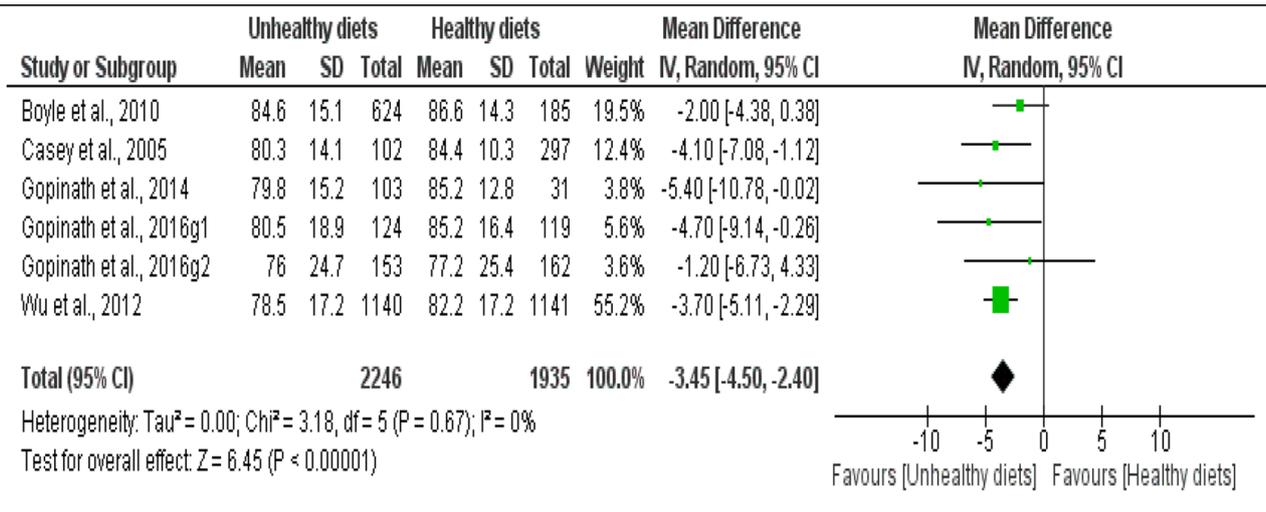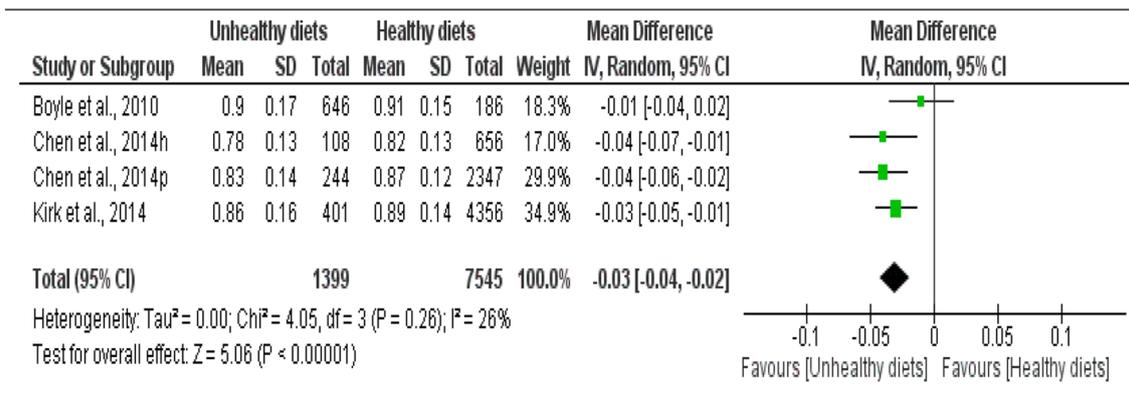
The diet exposure and the levels in the study:
Boyle et al., 2010: Fat intake too high (>35% of calorie intake) vs. Optimal fat intake (≤35% of calorie intake);
Gopinath et al., 2014: Having one or more diet risk factors (unhealthy diets) vs. no diet risk factors (healthy diets);
Gopinath et al., 2016g1-g2: Yogurt consumption First tertile (unhealthy diets) vs. Third tertile (healthy diets); 2016g1
for boys; Gopinath et al., 2016g2 for girls; Casey et al., 2005: Food insecure vs. Food secure; Wu et al., 2012: The
DQI-I Lowest tertile (unhealthy diets) vs. Highest tertile (healthy diets).
The HRQoL measure: The EQ-5D-Y VAS in Wu et al., 2012; The PedsQL 4.0 for other studies.

Fig. 3 Meta-analysis of the mean difference in total HRQoL scores between healthy diet and unhealthy diet groups

The diet exposure and the levels in the study:
Boyle et al., 2010: Fat intake too high (>35% of calorie intake) vs. Optimal fat intake (≤35% of calorie intake);
Chen et al., 2014h: Eat fast food or takeaway 'Often or a lot' vs. 'Never or sometimes'; Chen et al., 2014h represents
high school sample, and Chen et al., 2014p represents primary school sample; Kirk et al., 2014: Severe food insecurity
vs. Food security.
The HRQoL measure:
The ED-5D index: Boyle et al., 2010; Kirk et al., 2014; The CHU9D utility: Chen et al., 2014h; Chen et al., 2014p.

Fig. 4 Meta-analysis of the mean difference in the utility scores of preference-based HRQoL measures between healthy diet and unhealthy diet groups

group 3.12, 95% CI 1.32, 4.92, $P < 0.001$ for psychosocial health; total mean difference = 2.77, 95% CI 1.10, 4.44, $P < 0.01$ for physical health). There was not a significant heterogeneity between these studies ($I^2 = 0\%$ and 9%, $P = 0.36$ and 0.67, respectively).

Figure 4 presents the pooled estimate for the mean difference in the utility score comparing healthy diets to unhealthy diets groups of four cross-sectional studies. A significant difference in the mean utility value was observed between children and adolescents with healthy diets and those with
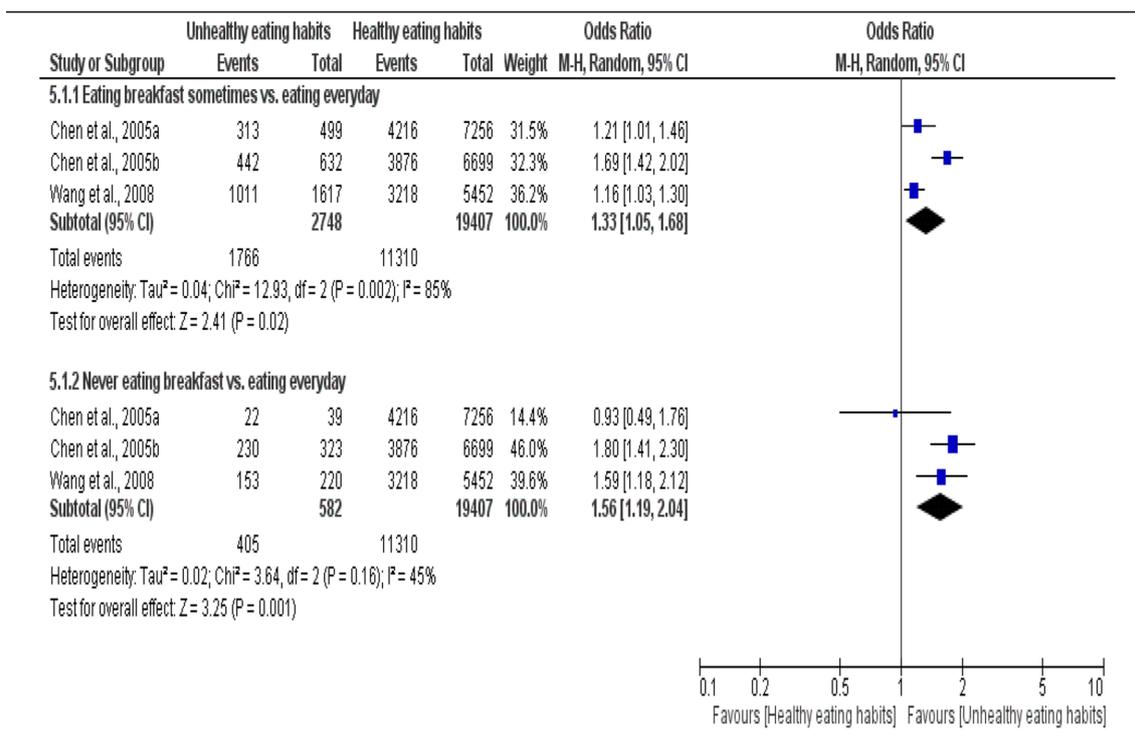
The HRQoL measure used in the study: The Japanese COOP charts.
5.1.1 compared HRQoL between the breakfast eating 'sometimes' with the breakfast eating 'everyday'; 5.1.2 compared HRQoL between the breakfast eating 'never' with the breakfast eating 'everyday'.

Fig. 5 Meta-analyses of the odds ratio for poor HRQoL by the frequency of breakfast eating

unhealthy diets (pooled mean difference = 0.03, 95% CI 0.02, 0.04, $P < 0.0001$), with a low and nonsignificant heterogeneity ($I^2 = 26\%$, $P = 0.26$) across the studies.

Figure 5 shows the forest plot for the difference in the odds of poor HRQoL between unhealthy and healthy eating groups across two cohort studies [68, 69] and one cross-sectional study (70). Children who ate breakfast 'sometimes' or 'never' had a higher odds of having poor HRQoL than the children who ate breakfast 'everyday' (OR = 1.33, 95% CI 1.05, 1.68, $P < 0.05$ for 'sometimes' group; OR = 1.56, 95% CI 1.19, 2.04, $P < 0.01$ for 'never' group), indicating a dose–response effect of the frequency of breakfast eating on HRQoL. The studies showed a high heterogeneity ($I^2 = 85\%$, $P = 0.002$) between breakfast eating 'sometimes' and 'everyday'. The high heterogeneity may be explained by the differences in characteristics of the samples and in the design across the studies.

The funnel plot for the studies included in Figs. 2 and 3 is presented in Fig. 6. The funnel plot of the mean difference (MD) in total HRQoL score plotted against the standard error (SE) of the MD across six studies appeared symmetrical (Fig. 6a), suggesting no presence of publication bias (intercept $\alpha = -0.03$, $t = -0.05$, $P = 0.966$ in Egger test). The funnel plot for physical and psychosocial HRQoL,

respectively, appeared slightly asymmetrical (Fig. 6b), and the Egger test showed no significant risk of publication bias ($\alpha = -1.46$, $t = -1.15$, $P = 0.334$ for physical QoL, $\alpha = -0.70$, $t = -0.66$, $P = 0.554$ for psychosocial QoL).

Discussion

The present systematic review is the first to synthesize how diet quality and dietary behavior influence health-related quality of life in the healthy population of children and adolescents. We have found evidence that higher diet quality and healthy dietary patterns or behaviors are associated with better health-related quality of life in children and adolescents. Diet quality and dietary behaviors have significant effects on multiple domains of HRQoL including physical functioning, school functioning, emotional functioning, physical and psychosocial quality of life. We have found a dose–response relationship with respect to the effect of diet quality and dietary behaviors on HRQoL among children and adolescents.

We observed the evidence for consistent cross-sectional and temporal associations between the diet exposures and health-related quality of life. The association was demonstrated for HRQoL outcomes measured by both

Fig. 6 Funnel plots of comparisons of the mean difference in HRQoL by diets among children and adolescents
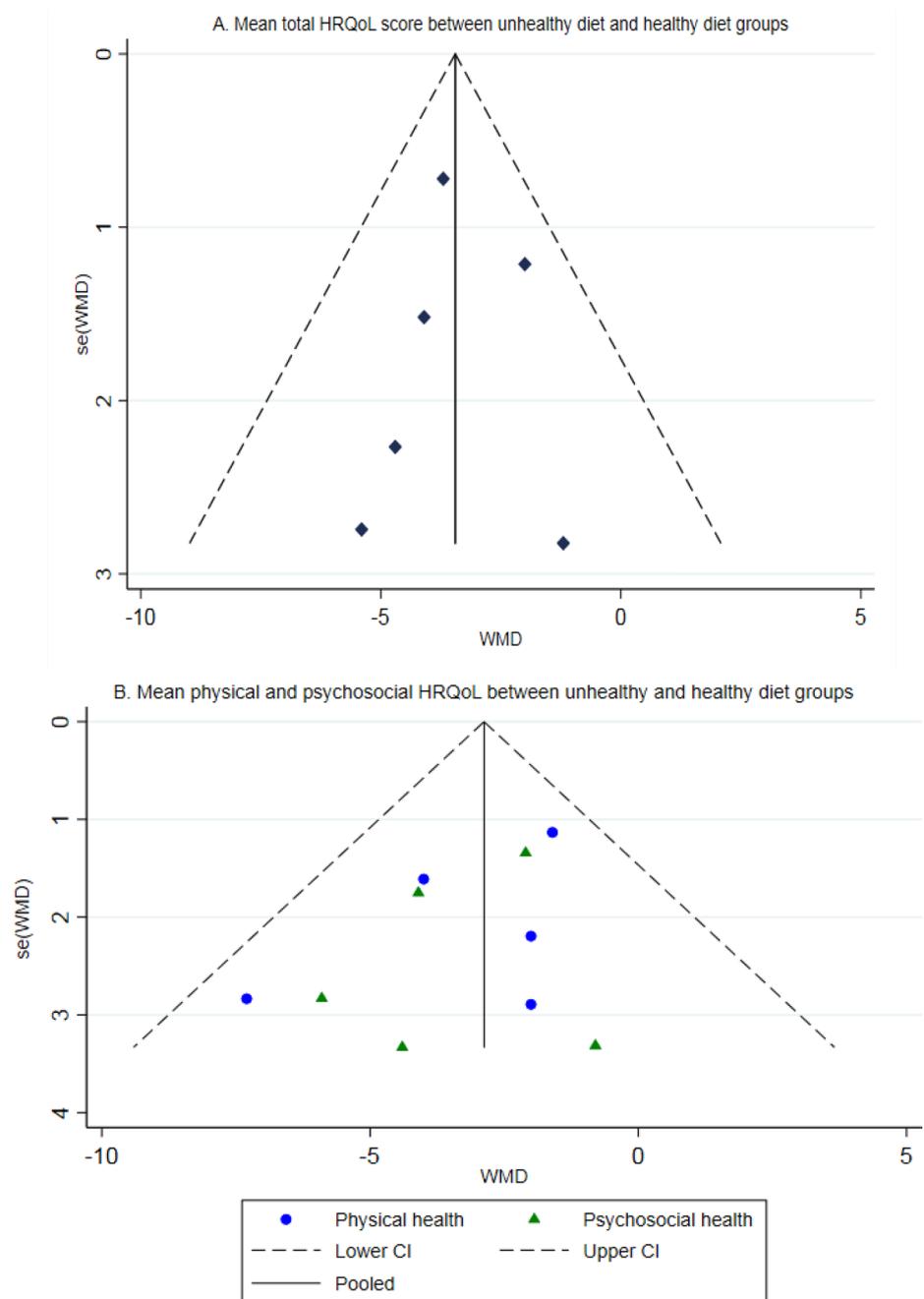
multidimensional generic pediatric HRQoL profiles (e.g., PedsQL) and utility measures (e.g., the CHU9D, the AQoL-6D). The associations between diets and HRQoL were reported to be independent of weight status, age, gender and socioeconomic characteristics of children and adolescents. These findings add to the existing literature that has investigated the relationship between diet quality and HRQoL in children and adolescents with a variety of chronic diseases [23, 24] and are consistent with the previous research that has addressed the relationship between diet quality, nutrient patterns and HRQoL in adult populations [48, 73–76].

The relationship between diet quality or dietary behavior and multidimensional health-related quality of life in children and adolescents has not been extensively examined in the published literature as previous studies in this field often evaluated health status using a single item health indicator variable such as self-rated health [36, 40, 42–44, 55]. Relative to multidimensional HRQoL measures, use of single-item self-perceived health is limited in evaluations of the impact of diets on individual components or domains of HRQoL. The present review filled the gap by revealing positive influence of diet quality predictors on

different aspects of the health status assessed with multidimensional of HRQoL instruments among children and youth through a systematic synthesis of the primary research in this field. For example, Boyle's and Michels's studies found that children and adolescents who ate more fat in their diets reported a significantly lower emotional functioning than the peers who ate healthy foods [27, 63]. Several studies observed that children and adolescents who consumed more fruits and vegetables (versus low consumption of fruits and vegetables) experienced higher HRQoL in social functioning, physical functioning and psychosocial health summary scores in the PedsQL [63, 65, 67]. The present finding is consistent with the previous studies showing that poor diet quality and unhealthy dietary patterns are related to poor physical health, mental health and low psychosocial health in children and adolescents [4, 5, 8–11, 77].

The present systematic review contributes to the literature on the relationship between diets and HRQoL for revealing a dose–response effect between poor diet quality or an unhealthy dietary behavior and impaired health-related quality of life in children and adolescents. The association appears to be in a linear trend between the dose of the diet exposure and the level of HRQoL, and this result was reported for a variety of the diet-related predictors including total diet quality scores [26, 28], yogurt consumption [62], dietary pattern [65], frequency of breakfast eating [68, 69] and food insecurity [71]. However, the finding is mainly based on cross-sectional studies, and prospective studies are sparse. In the future research, more longitudinal studies are needed to confirm the dose–response effect to strengthen the inference for a causal relationship between diet quality, dietary behavior and HRQoL during childhood and adolescence.

In terms of the effect of different food groups or components of diets on health-related quality of life, some studies observed that unhealthy diets of fatty foods, sweet intake and salty snack food consumption were related to poor HRQoL [27, 63, 64, 68–70], while higher intakes of fruits and vegetables, yogurt and fish were related to better HRQoL childhood and adolescence [62, 63, 67]. While the observation by Gopinath et al. that yogurt was associated with better HRQoL of adolescent boys added evidence that yogurt can be beneficial to adolescents' health [62], the effect of yogurt on children and adolescents' health is debatable. Studies have shown that yogurts with high sugar content may had an adverse effect on health status among children and youth [78]. Research that expands cohort studies and randomized controlled trials and that evaluates different nutrient contents of yogurts is needed to confirm the relationship and direction between yogurt consumption and health status among children and adolescents The observation that a good adherence to Mediterranean dietary pattern among children and adolescents is associated with better HRQoL is in accordance with

previous studies in adults showing that adherence to healthy diets is related to significant improvements in multiple subscales of quality of life [73–75]. These findings suggest that either the overall dietary pattern or some food groups are sensitive predictors for HRQoL with healthier diets associated with elevated HRQoL.

The mechanism for the associations between diet quality, some food groups and HRQoL has yet to be studied. Several studies in the present review provided possible explanations for the biological mechanism [25, 63, 65]. Healthy foods like fruits and vegetables, whole grains and fish are rich in essential nutrients such as folate, B-group vitamins, zinc, magnesium and fiber. These nutrients could help modulate immune system functioning, improve metabolic processes and positively influence neurotransmitters and cortisol activity among children and youth [25, 63, 65]. Previous studies have also documented possible pathways through which the diet quality may influence mental health disorders in children and adolescents such as depression and anxiety [5]. Future investigations in this regard should confirm the mechanism for the protective effect of healthy dietary factors on HRQoL among children and adolescents.

When interpreting the difference in HRQoL values between comparison groups by diet quality or a diet behavior, it is also necessary to consider whether the magnitude of the difference in HRQoL is clinically important or significant, that is to say to identify the minimum clinically important difference (MCID), or the minimally important difference (MID) of HRQoL values [79]. The MID represents a meaningful difference in the HRQoL value that has clinical or practical importance for public health and health interventions. The MID criterion varies with HRQoL instruments as their scaling methods and the range of scores are different. For example, a 4.5-point difference in HRQoL across groups was considered as the MID value for the PedsQL instrument [80]. In the present review, several primary studies discussed the use of MID [26, 27, 64]. We observed that the difference in HRQoL scores was greater than the MID value for some group comparisons. For example, Gopinath et al. [62] indicated that adolescent boys who were in the highest tertile of yogurt intake relative to the lowest tertile over the 5-year follow-up had 7.4-units higher psychosocial health summary scores, 12.4-units higher school functioning scores, which exceeded the MID value of 4.5 unit for the PedsQL 4.0 [62].

Due to a large heterogeneity in the measurement of the diet exposures and the health-related quality of life, we performed meta-analyses for a small number of studies comparing the HRQoL in children and adolescents with healthy diets to those child and adolescent peers with poor diets. We applied random effect model to account for the heterogeneity across studies in the meta-analysis. The meta-analysis showed a significant positive effect of diet quality and healthy dietary behaviors for HRQoL assessed by both

HRQoL profile measures and utility measures. Several other studies [25, 63, 67] used similar HRQoL measures (e.g., the PedsQL, the AQoL-6D) to the studies in the meta-analysis. Since these studies did not report the mean HRQoL score with the standard deviation by the diet exposure groups, they were not included in the meta-analysis. In addition, we were not able to perform subgroup analysis by different study designs in the meta-analysis due to sparse data from prospective studies. Future research is recommended to extend studies that utilize similar measures for HRQoL, diet quality and dietary behavior, and increase prospective studies to facilitate comparisons across studies by different types of HRQoL outcomes and design methods using meta-analysis. The Egger test for funnel plots showed no significant indication of publication bias across the studies in the meta-analysis. However, the number of studies assessed in the funnel plot was relatively small, the power of funnel plots for detection of publication bias may be limited as previous studies suggest that funnel plot asymmetry tends to be greater in meta-analysis with smaller number of studies [30]. Future research is needed to add more studies to facilitate assessment of publication bias using funnel plots.

HRQoL in children and adolescents is a multidimensional construct that includes physical, emotional, social and school functioning [80] and is considered to be a sub-set of overall quality of life [81]. The HRQoL measures in the present review are heterogeneous with respect to the underlying construct coverage. Some instruments (e.g., the EQ-5D) include questions that measure the multidimensional construct of physical and mental health pertaining only to disease and disorder impact. Other HRQoL instruments (e.g., the PedsQL, the CHU9D) contain a number of questions that cover broader constructs of health and health impacts, including some dimensions measuring other aspects of QoL that are less or not health related, such as school work and coping. Given the heterogeneity in the subscales between the HRQoL measures, we mainly focused on qualitative data synthesis of the results from the primary studies (Tables 2, 3). The comparison of scores between different HRQoL measures in the meta-analysis may be influenced by the heterogeneity in the dimension coverage. Future research needs to expand studies that use more homogeneous HRQoL measures to facilitate subgroup synthesis by the HRQoL instrument and by the underlying dimension.

There are several strengths of the present review. We performed a comprehensive literature search with a rigorous selection process for the identification of eligible studies using predefined inclusion and exclusion criteria. The health-related quality of life was measured by a variety of generic multidimensional HRQoL measures and preference-based measures, allowing for analysis of the effect of the diet exposure on both total HRQoL and a specific domain of HRQoL, and on both generic HRQoL profiles and utility measures. We included a range of diet exposures (e.g., diet quality, dietary behavior pattern, food insecurity), which granted an opportunity to assess the effect of diverse diet exposures on HRQoL among children and adolescents. Since the majority of the included studies used large population-based samples of children and adolescents, the influence of important confounders such as socio-demographic characteristics, body weight status, physical activity of children and adolescents can be simultaneously accounted for in multivariable regression analyses. Hence, the effect of diets on HRQoL observed in the present review can be considered being independent of socio-demographic characteristics, body weight status and physical activity of children and adolescents.

Limitations in the present study should also be clarified when interpreting the results. Most of the included studies were cross-sectional studies and very few prospective studies were available for the evaluation. The results of this review should be interpreted with caution with respect to a causal relationship between the diet exposure and HRQoL in children and adolescents. Despite most primary studies used validated and reliable food frequency questionnaires or dietary intake questions, the assessment of dietary intake was based on self- or parent-report, which was prone to measurement error and thus may have influenced the results. Studies have reported that self-reported food frequency questionnaires tend to underestimate energy and fat intake due to social desirability bias [82, 83]. Finally, although most included studies have taken account of the effect of important confounding predictors in the analysis, results in some studies may have been affected by residual confounding due to a presence of unmeasured potential confounding variables.

Conclusion

We have shown in the present study that high diet quality and healthy dietary behaviors are associated with increased health-related quality of life in children and adolescents. More prospective studies are needed to ascertain the positive impact of the diet quality on future health-related quality of life among healthy populations of children and adolescents. The findings of this review may help justify the primary prevention and public health policy for broader investments in school or community health programs targeting at promoting healthy eating and nutrition among children and adolescents to enhance their health-related quality of life.

Author contributions Conceptualization: XYW; Literature searching: XYW; Study selection, data extraction and quality assessment:

Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interests.

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