British Journal of Nutrition (2017), **117**, 1055–1065
doi:10.1017/S0007114517000915

A systematic review of diet quality indices in relation to obesity

Golaleh Asghari[1,2], Parvin Mirmiran[1,2]*, Emad Yuzbashian[1] and Fereidoun Azizi[3]

[1]*Nutrition and Endocrine Research Center, Research Institute for Endocrine Science, Shahid Beheshti University of Medical Sciences, Tehran 19395-4763, Iran*

[2]*Department of Clinical Nutrition and Dietetics, Faculty of Nutrition Sciences and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran 19395-4741, Iran*

[3]*Endocrine Research Center, Research Institute for Endocrine Science, Shahid Beheshti University of Medical Sciences, Tehran 19395-4763, Iran*

(Submitted 26 October 2016 – Final revision received 12 March 2017 – Accepted 16 March 2017 – First published online 8 May 2017)

Abstract

Tools, called 'diet/dietary quality indices', evaluate the level of adherence to a specified pattern or a set of recommendations in populations. Yet, there are no review studies providing unanimous comprehensive results of dietary indices on obesity. We reviewed observational studies, focusing on the association of diet quality indices with general obesity or abdominal obesity in adults. We systematically conducted a search in all English language publications available on MEDLINE, ISI Web of Science and Embase between January 1990 and January 2016. Among the wide variety of indices and weight-derived variables, studies with dietary-guideline-based indices and mean changes for weight gain or OR for general obesity and abdominal obesity were selected. From a total of 479 articles, thirty-four studies were selected for the current review, ten of which had prospective designs and twenty-six had cross-sectional designs. Associations of weight status with the original Healthy Eating Index (HEI) and other versions of the HEI including alternative HEI, HEI-2005 and HEI-05 were examined in thirteen studies, with ten studies revealing significant associations. The HEI was a better general obesity predictor in men than in women. Diet scores lacked efficacy in assessing overall diet quality and demonstrated no significant findings in developing countries, in comparison with US populations. In addition, indices based on dietary diversity scores were directly associated with weight gain. Despite the insufficient evidence to draw definitive conclusions about the relation between dietary indices and obesity, HEI was found to be inversely associated with obesity and diversity-based indices were positively associated with obesity.

Key words: Dietary indices: Diet quality indices: Obesity

Obesity is associated with an increased risk for non-communicable diseases (NCD) such as CVD, type 2 diabetes, certain types of cancers and premature death. The most important variables that contribute to obesity include over-eating, sedentary lifestyle, genetic, environmental, neurological, physiological, biochemical, socio-cultural and psychological factors[1].

Diet is a major modifiable determinant of obesity, and diet quality has been defined as the degree to which a diet reduces the risk for NCD[1–3]. To assess diet quality in a population, the *a priori* dietary pattern was introduced as a tool known as 'diet quality/dietary quality indices', which evaluates the level of adherence to a specified pattern or a set of recommendations[4] or reflects the risk gradient for major diet-related chronic diseases[5]. Assessing diet quality can provide information on dietary behaviours. Behaviours, as a holistic view, include several components that work synergistically on health and disease[3,5]. Thus, in recent years, diet quality indices have been developed to meet the requirement of this field of nutrition research[6]. To the best of our knowledge, there are no published comprehensive systematic reviews clarifying which of the developed indices for adherence to dietary recommendations can predict the risk for obesity among healthy populations.

The aim of the current review was to systematically summarise all available literature regarding the association of dietary indices with general obesity/abdominal obesity in observational studies.

Methods

Eligibility criteria

Study designs. Prospective (cohort), cross-sectional and nested case–control studies were included, whereas reviews, meta-analyses, commentaries, clinical trials, editorials or duplicate publications were excluded.

Participants. Studies were included if their participants had been healthy adult individuals (aged ≥18 years) of both sexes, and

Abbreviations: DDS, Dietary Diversity Score; DGAI, Dietary Guidelines for Americans Index; DGI, Dietary Guideline Index; DQI, Diet Quality Index; FNRS, Framingham Nutritional Risk Score; HEI, Healthy Eating Index; WC, waist circumference.

* **Corresponding author:** P. Mirmiran, fax +98 21 2236 0657, email mirmiran@endocrine.ac.ir; parvin.mirmiran@gmail.com

were excluded if they had been conducted on infants, children, adolescents, pregnant or lactating women, and patients.

Exposure. We included studies that investigated the Healthy Eating Index (HEI), the Diet Quality Index (DQI), the Dietary Guidelines for Americans Index (DGAI), the Dietary Guideline Index (DGI), the Framingham Nutritional Risk Score (FNRS), the Recommended Food Score (RFS), the Not Recommended Food Score (NRFS), the French Program National Nutrition Santé-Guideline Score (PNNS-GS), the Dietary Quality Score (DQS), the Food Variety Score (FVS), the Elderly Dietary Index (EDI), the Australian Recommended Food Score (ARFS) and the Dietary Diversity Score (DDS) as exposures (Appendix). These studies included the DQI to score dietary guideline recommendations and the food guide pyramid. Studies were excluded if they had investigated dietary patterns or specific diets that were not based on dietary guidelines such as the Mediterranean dietary pattern or the Dietary Approaches to Stop Hypertension (DASH) diet.

Outcomes. The main outcomes in the studies reviewed were overweight, general obesity, overweight and/or obesity, and abdominal obesity. Weight status as defined by BMI (normal weight: 18·5–24·9 kg/m^2; overweight: 25–29·9 kg/m^2; obese: ≥30 kg/m^2; overweight/obesity: ≥25 kg/m^2) was based on World Health Organization classification[7]. Abdominal obesity was defined according to author-specified criteria such as the National Cholesterol Education Program Adult Treatment Panel III (waist circumference (WC) >88 cm for women and WC > 102 cm for men)[8], World Health Organization (WC ≥ 94 cm for men and WC ≥ 80 cm for women)[7] or national cutoff points. Results of studies were reported using means for WC and BMI, weight or BMI changes, and OR or relative risk for overweight and obesity.

Search strategy

A search was performed of literature published between January 1990 and January 2016 using MEDLINE (http://www.nlm.nih.gov/bds/pmresources/html) and Embase (http://www.embase.com) by using diet(ary) quality, diet(ary) patterns, diet score, diet (quality) index, or diet indices in combination with BMI, WC, (general) obesity, or abdominal (central) obesity. Search results were downloaded and imported directly into EndNote (version X5).

Study selection

Study selection was a three-step process; first, we removed exact duplicate articles using EndNote tools. Second, to detect irrelevant studies, two authors (E. Y. and G. A.) screened all titles identified through the electronic database search. Third, E. Y. and G. A. read all abstracts and full texts and based on inclusion criteria, selected studies from the remaining articles. If the results of a study were reported in more than one publication, only the publication with the most complete results was retained. To avoid double-counting data from multiple publications, we juxtaposed author names, sample sizes and outcomes. Lastly, to identify other potentially relevant articles, G. A. examined the reference lists of selected articles; disagreements between E. Y. and G. A. were resolved by consensus, and when consensus could not be reached, a third author (P. M.) made the final decision.

Results

Using the above-mentioned search engines, 479 papers were identified, which described original English-language research studies conducted on humans. After reviewing titles, abstracts and full texts, 445 articles were excluded because they did not include *a priori* dietary patterns. Articles that assessed specific diets, for example, the Mediterranean or DASH diet scores were also excluded. In the final step, full texts were reviewed for cited references and one more article was included. Finally, thirty-four studies were selected for the current review (Fig. 1). Characteristics of the studies included are illustrated in Tables 1 and 2.

For HEI, updated or modified versions such as alternative HEI (AHEI)[20], HEI-05[35] and HEI-2005[17] have been reported; however, the original HEI had the highest frequency in articles (*n* 13), followed by DQI (*n* 7), DGAI (*n* 5), RFS (*n* 4), DDS (*n* 3), and FNRS, DGI and FVS (*n* 2 each). However, EDI, DQS, ARFS and PNNS-GS scores, along with some of the scores mentioned above, were investigated in single studies only. Only one article had targeted a population of the elderly (≥65 years) and EDI was used as the DQI in this population[34].

In all, ten studies had a prospective design, with only one of them focusing solely on women[36] and the remaining on both sexes. Out of ten published articles, five had >10-year follow-ups, of which the study by Zamora *et al.*[37] had a 20-year follow-up. A total of five prospective studies were performed on the North American population[24,35–38] and the remaining were conducted in Iran[18], Australia[39], France[40], Canada[22] and Spain[41]. However, among cross-sectional studies, thirteen had been performed on North American[11–13,15–17,19,20,24,25,27,28,34], three on Iranian[18,31,32] and one each on Brazilian[9], French[10], Guatemalan[23], Sri Lankan[30], Danish[33], Spanish[14] and Australian[29] populations.

Eight studies had <1000[9,11,18,30–32,34,36]; fifteen had between 1000 and 10 000[12,14,23–29,35,37–42] and six studies had >10 000[12,13,17,20,33,43] participants. FFQ (*n* 19) and 24-h recalls (*n* 9) were the most common dietary methods; however, some studies used multiple dietary methods. A total of seven studies investigated BMI, not as the main outcome, rather, as the

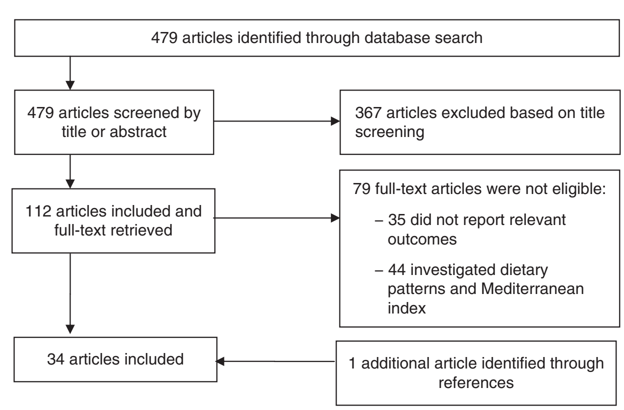

Fig. 1. Review flow chart for the association of diet quality indices with obesity.

Table 1. Summary of the findings for diet quality and obesity in cross-sectional studies

First author (reference)	Index	Participants (*n*)	Population	Outcome	Adjusted variables	Food measurements	Findings
Tardivo[9]	HEI	173	Brazilian postmenopausal women	BMI, WC, WHR, BF%	Age and menopause	A 24-h recall	No relation between values of HEI with BMI, WC, WHR, and BF% was seen; however, HEI was associated with categories of BF%
Drewnowski[10]	HEI	F: 2881 M: 2200	SU.VI.MAX Study	BMI	Age, energy intake, tobacco use, and alcohol consumption	A 24-h recall	M: higher HEI scores were weakly associated with lower BMI (β –0·08) F: HEI score was unrelated to BMI
Fung[11]	HEI AHEI DQI-R RFS	690	Nurses' Health Study	BMI, WC		FFQ	HEI, AHEI, and DQI were inversely associated with BMI, and RFS did not relate to BMI
Tande[12]	HEI	F: 8188 M: 7470	Third National Health and Nutrition Examination Survey	Abdominal obesity	Age, ethnicity, residence location, income, marital status, smoking, education, energy intake, alcohol intake	24-h recall	M: each one-point increase of HEI was associated with ↓ 1·4% risk for abdominal obesity F: each one-point increase of HEI was associated with ↓ 0·8% risk for abdominal obesity
Guo[13]	HEI	F: 5571 M: 5359	Third National Health and Nutrition Examination Survey	Overweight, general obesity	Age, sex, race, physical activity, smoking, alcohol, income, education	24-h recall	M: lower scores of HEI increased risk for general obesity and overweight 90 % and 50 %, respectively F: lower scores of HEI increased only risk for general obesity by 70 %
Schröder[14]	HEI	3179	Free-living Spanish men and women adult	General obesity	Sex, energy intake, smoking, age, physical activity	FFQ	Highest quartile of HEI was associated with 40 % lower risk for general obesity
McCullough[15]	HEI-f	38 622	Health professional follow-up study	BMI	–	FFQ	BMI was slightly ↓ in higher HEI quintiles
McCullough[16]	HEI-f	67 272	Nurses' Health Study	BMI	–	FFQ	BMI was slightly ↓ in higher HEI quintiles
Nicklas[17]	HEI-2005	18 989	National Health and Nutrition Examination Survey	Overweight/obese, abdominal obesity	Age, sex, ethnicity, energy intake:energy requirement ratio, poverty:income ratio, physical activity, smoking, and alcohol	A 24-h recall	Highest HEI-2005 quartile were related to approximately 35 % lower risk for overweight/obese and abdominal obesity
Asghari[18]	DQI-I, HEI-2005	467	Tehran Lipid and Glucose Study	BMI, WC	Age, sex, and energy intake	Three 24-h recall	None of the indices was significantly associated with BMI and WC
de Koning[19]	HEI-2005 AHEI RFS	51 529	Health Professionals Follow-Up Study	BMI	Age	FFQ	Higher scores of all indices were associated with a ↓ BMI
McCullough[20]	AHEI RFS	F: 38 615 M: 67 271	Health professional follow-up study and Nurses' Health Study	BMI	Age	FFQ	F: AHEI score was associated with 1·3 unit ↓ and RFS with 0·3 unit ↑ in BMI M: AHEI and RFS score was associated with 1·1 and 0·2 unit ↓ in BMI, respectively
Drenowatz[21]	HEI-2010	Total: 407 M: 197 F: 210	USA young adults	Overweight/general obesity	Age, education, race/ethnicity and spent time in moderate-to-vigorous physical activity	Two 24-h recall	F: higher score was not related to overweight/general obesity. M: higher score was associated with lower risk for overweigh/general obesity Total: higher score was associated with lower risk for overweigh/general obesity
Sundararajan[22]	HEI-2005 DQI	13 536	Canadian Community Health Survey	BMI	Age, sex, marital status, immigration status, length of immigration, educational status, employment status, household income, energy intake, leisure-time physical activity, percentage of energy consumed, self-perceived stress, smoking, rural/urban location and province of residence	A 24-h dietary recall	One-unit ↑in DQI score is associated with a 0·053 kg/m^2 ↓ in BMI and a one-unit ↑ in HEI score is associated with a 0·095 kg/m^2 ↓ in BMI

Table 1. *Continued*

First author (reference)	Index	Participants (*n*)	Population	Outcome	Adjusted variables	Food measurements	Findings
Gregory[23]	RFS NRFS FVS DQI-I	1220	Guatemalan young adults	BMI, WC	Age, smoking, physical activity, rural or urban residence	FFQ	DQI was positively associated with BMI and WC. None of the other scores was associated with the WC and BMI.
Quatromoni[24]	DQI	F: 1845 M: 1433	Framingham Offspring cohort	BMI, overweight, general obesity	Age, smoking cessation, alcohol intake, physical activity, intentional changes in eating behaviour and menopausal status (women only)	Three 24-h recalls	M: higher scores was not related to BMI, and prevalence of overweight and general obesity F: higher scores was associated with lower BMI and prevalence of overweight
Fogli-Cawley[25]	DGAI	3323	Framingham Heart Study Offspring Cohort	BMI, WC	Sex, age	FFQ	Highest quintile of DGAI was associated with ↓ in approximately 2 units of BMI and 6 cm of WC
Hosseini-Esfahani[26]	DGAI	2504	Tehran Lipid and Glucose Study	BMI, WC	Sex, age, energy intake, smoking status and physical activity	FFQ	No relation was observed between DGAI and WC and BMI
Fogli-Cawley[27]	DGAI	3177	Framingham Heart Study Offspring Cohort	WC	Age, sex, energy intake, physical activity, multivitamin use and smoking status	FFQ	Higher DGAI score was associated with 50 % reduction in enlarged WC
Fogli-Cawley[28]	DGAI	3082	Framingham Heart Study Offspring Cohort	BMI, WC	Age and sex	FFQ	Highest quintile of DGAI was associated with ↓ in approximately 2 unit of BMI and 6 cm of WC
McNaughton[29]	DGI	F: 3996 M: 3300	Australian Diabetes, Obesity and Lifestyle study	BMI, abdominal obesity	Age, education, energy intake, smoking, physical activity, TV viewing time	FFQ	M: DGI was associated with 30 % ↓ risk for abdominal obesity F: DGI score was unrelated to change in any measurement
Jayawardena[30]	DDS, DDSP, FVS	481	Sri Lanka Diabetes and Cardiovascular Study	Overweight, general obesity, abdominal obesity	–	24-h recall	Overweight, general obesity, and abdominal obesity was positively associated with DDS, DDSP and FVS
Azadbakht[31]	DDS	581	Tehran Lipid and Glucose Study	General obesity, WC, WHR	Age, sex, smoking, physical activity, BMI, WHR, energy intake, % energy of fat, use of oestrogen, anti-blood pressure drug	FFQ	No significant difference regarding WC and WHR across DDS quartiles; however, the risk for general obesity increased 39 % with higher DDS scores
Azadbakht[32]	DDS	289	Healthy female from Isfahan University of Medical Sciences	General obesity, abdominal obesity	Age, physical activity, total energy intake, For WC adjusted BMI	FFQ	Highest quartile of DDS was associated with 80 % ↓ risk for general obesity and abdominal obesity
Toft[33]	DQS	12 934	Danish Population-Based Inter99 study	BMI, WC	Age, sex, physical activity, smoking, education	FFQ	None of the indices was associated with BMI and WC
Kourlaba[34]	EDI	668	Elderly subjects from the MEDIS Study	General obesity	Sex, age, physical activity, smoking, education, living alone	FFQ	Higher EDI score was associated with 60 % ↓ risk for general obesity

HEI, Healthy Eating Index; WC, waist circumference; WHR, waist:hip ratio; BF, body fat; F, female; M, male; SU.VI.MAX, SUpplementation en VItamines et Minéraux AntioXydants; AHEI, alternative HEI; DQI-R, Diet Quality Index Revised; RFS, Recommended Food Score; HEI-f, healthy eating index-food-frequency questionnaires; NRFS, Not Recommended Food Score; FVS, Food Variety Score; DQI-I, Diet Quality Index-International; DQS, Dietary Quality Score; DQI, Diet Quality Index; DGAI, Dietary Guidelines for Americans Index; DGI, Dietary Guideline Index; DDS, Dietary Diversity Score; DDSP, Dietary Diversity Score with Portions; EDI, Elderly Dietary Index; MEDIS, Mediterranean Islands Study.

https://doi.org/10.1017/S0007114517000915 Published online by Cambridge University Press

Table 2. Summary of findings for diet quality and obesity in prospective studies

First author (reference)	Follow-up	Index	Participants (*n*)	Population	Outcome	Adjusted variables	Food measurements	Findings
Zamora[37]	20 years	DQI	4913	Coronary Artery Risk Development in Young Adults Study	10 kg weight gain	Age, sex, race, education, baseline BMI, clinic of recruitment, physical activity, energy intake and smoking	Diet history	A ten-point ↑ in DQI score was associated with a 10 % risk ↓ in whites (particularly if normal weight) and 15 % risk ↑ in blacks (particularly if obese)
Wolongevicz[36]	16 years	FNRS	590	Healthy women from the Framingham Offspring and Spouse Study	Overweight/ general obesity	Age, smoking status, physical activity	Three dietary records	Higher FNRS tertile was associated with 76 % ↑ in risk for overweight/general obesity
Kimokoti[38]	16 years	FNRS	F: 825 M: 690	Framingham offspring/spouse overweight and obese adult	Weight	Age, baseline weight, physical activity, smoking	Three dietary records	M: no association was found F: Higher FNRS was associated with additional 5·2 kg weight gain compared with lower FNRS
Arabshahi[39]	15 years	DGI	M: 532 F: 699	Australian population-based Nambour Skin Cancer Study	BMI, WC	Age, education, smoking, alcohol and physical activity For women additional occupation, HRT use, parity	FFQ	M: higher DGI Score were less likely to gain BMI and WC over time F: DGI score was unrelated to change in any measurement
Lassale[40]	13 years	PNNS-GS DGAI DQI-I	F: 1471 M: 1680	SU.VI.MAX study	Weight change	Age, energy intake, smoking, education, supplementation, baseline weight and height, physical activity, and menopause for women	Three 24-h recalls	M: higher scores of PNNS-GS, DGAI and DQI were associated with 30–40 % ↓ risk for weight change. F: not any score was associated with general obesity
Funtikova[41]	10 years	DQI	2181	Population-based survey conducted in Girona	BMI, WC	Age, sex, smoking, education, physical activity	FFQ	Higher DQI score was inversely associated with WC; whereas it was not related to BMI
Quatromoni[24]	8 years	DQI	M: 990 F: 1255	Framingham Offspring cohort	Weight gain	Age, smoking cessation, alcohol intake, physical activity, intentional changes in eating behaviour and menopausal status (women only)	Three 24-h recalls	M: highest scores had 2·7 pounds weight gain, compared with lowest scores 5·1 pounds weight gain F: highest scores had 3·3 pounds weight gain, compared with lowest scores 8 pounds weight gain
Asghari[18]	6·7 years	DQI-I, HEI-2005	708	Tehran Lipid and Glucose Study	BMI, WC	Age, sex and energy intake	Three 24-h recall	None of the indices was associated with BMI and WC dietary
Aljadani[57]	6 years	ARFS	1104	Australian Longitudinal Study of Women's Health	Overweight, obesity	Education, area of residence, baseline weight (in kilogram), physical activity, smoking status, menopause and total energy intake	FFQ	No association was found
Gao[35]	18 months	HEI-05, HEI	6236	Multi-Ethnic Study of Atherosclerosis	BMI, WC	–	FFQ	HEI-05 and HEI were associated with decrement in approximately 1 unit of BMI and 3–4 cm of WC

DQI, Diet Quality Index; FNRS, Framingham Nutritional Risk Score; F, female; M, male; DGI, Dietary Guideline Index; HRT, hormone replacement therapy; WC, waist circumference; PNNS-GS, Program National Nutrition Sante´-Guideline Score; SU.VI.MAX, SUpplementation en VItamines et Minéraux AntioXydants; DGAI, Dietary Guidelines for Americans Index; DQI-I, Diet Quality Index-International; HEI, Healthy Eating Index; ARFS, Australian Recommended Food Score.

baseline characteristic in an unadjusted or in age- and sex-adjusted models[15,16,19,20,30,35,43].

The relation of the Healthy Eating Index and its modified versions with obesity-related outcomes

Associations of weight status with the original HEI were examined in eight cross-sectional studies, seven of which reported a significant relation[10–16,18]; two studies found no correlation in women[9,10], whereas one of them found a correlation in men[10]. Other versions of the HEI include AHEI, HEI-2005, HEI-2010 and HEI-05, which were assessed in six cross-sectional and two prospective studies. Significant inverse associations with BMI and WC was observed in all cross-sectional studies[11,17,19–22] and one prospective study[35]; however, one study of HEI-2005 documented no significant association[18].

The average mean score of the original HEI was 63 in French[10], 67·8 in Spanish[14], 64·9 in Iranian[44], 56·6 in Brazilian[9] and 63·8 in American[6] studies.

All studies, whether conducted on population-based subjects or on specific groups such as nurses or health professionals, showed an inverse relation between HEI and its modified versions and obesity status. It needs to be mentioned that in non-significant association studies[9,10,18], the 24-h recall was used for dietary assessment, indicating that one or two 24-h recalls cannot extract the dietary patterns and usual food intakes. The sample populations of the above-mentioned studies were small, and the studies were conducted outside the USA – namely, in Brazil, Iran and France.

Studies in males and females revealed different correlations. Tande *et al.*[12] showed that the correlation between the HEI score and abdominal obesity was stronger in men than in women (1·4 *v.* 0·8 % risk reduction), and Drewnowski *et al.*[10] found a significant correlation between higher the HEI score and lower BMI (β-coefficient = –0·08) in males but not in females. Moreover, Drenowatz *et al.*[21] revealed that a higher HEI-2010 score was correlated with a decreased risk for general obesity and overweight among men but not among women. In addition, Guo *et al.*[13] showed that, in men, lower scores of HEI increased the risk for general obesity and overweight by 90 and 50 %, respectively; however, in women, lower scores of HEI increased the risk for general obesity by 70 % but not of overweight. A general overview may imply that the HEI score showed a better correlation with general obesity or abdominal obesity in males and a weak correlation in females.

The relation of the Diet Quality Index and its modified versions with obesity-related outcomes

Associations of weight status with the original DQI, Diet Quality Index-International (DQI-I), and the Diet Quality Index Revised (DQI-R) were observed in four[22,24,37,41], three[18,23,40] and one[11] study, respectively; of these, three had prospective[37,40,41] and three had cross-sectional designs[11,22,23], whereas two had both cross-sectional and longitudinal designs[18,24]. Of three studies investigating the original DQI, one study had significant findings on WC but not on BMI[41]; the second revealed ethnicity-specific findings, with an inverse association among whites and a direct one among blacks[37]; and the third study, with a cross-sectional design, found correlations in both sexes. However, no significant prediction was found in its prospective design for men[24]. Of the studies conducted on DQI-I, conflicting results were found for both sexes: Gregory *et al.*[23] found a positive correlation, whereas one study found an inverse prediction in men and no prediction in women[40] and Asghari *et al.*[18] observed no significant associations. In the only study on DQI-R that revealed a significant inverse correlation[11], mean scores of the DQI-I were 63, 67 and 59 in Iran, Guatemala and USA, respectively.

The sample size was relatively low, ranging from 467 to 4913, compared with studies on HEI. The DQI was evaluated in various countries including France[40], USA[11,24,37], Iran[18], Guatemala[23] and Spain[41]. FFQ and 24-h recalls were the most common dietary methods[18,23,24,40,41]. Four studies reported BMI[11,18,23,41] and two studies measured weight gain during follow-up[37,40], and in one study, the combination of weight gain and BMI was calculated[24].

Funtikova *et al.*[41] found that after adjustment for confounders, a ten-point increment in the DQI predicted a 3·2 cm reduction in WC, but there was no significant prediction of BMI on the basis of DQI over a 10-year follow-up period among Spanish men and women. Zamora *et al.*[37] observed that a ten-point increment in the DQI score predicted 15 % more weight gain in blacks (particularly obese ones), and 10 % less weight gain in whites, after adjustment for confounders. In addition, Quatromoni *et al.*[24] found an inverse, linear association between better adherence to DQI and lower weight gain over an 8-year follow up in the Framingham Offspring Study. Fung *et al.*[11] showed that higher adherence to the DQI-R was inversely correlated with BMI in the Nurses' Health Study. Lassale *et al.*[40] observed a 32 % increment in the risk for general obesity after 13 years of follow up in French men with higher adherence to the DQI; these predictions were not statistically significant in women. In a cross-sectional study from Guatemala, DQI-I was positively correlated with BMI and WC in both men and women[23]. Asghari *et al.*[18] reported no significant association in the Tehran Lipid and Glucose Study for both longitudinal and cross-sectional analyses. Overall, studies regarding DQI or its modified versions indicate controversial and sex-specific findings.

The relation of variety scores with obesity-related outcomes

Among four cross-sectional studies, all in developing countries (two in Iran[31,32], one in Sri Lanka[30] and one in Guatemala[23]), DDS had the highest frequency (*n* 3). In the Tehran Lipid and Glucose Study, the highest quartile of DDS, compared with the lowest, increased the risk for general obesity by 39 %[31]; in contrast, healthy females with higher DDS had an approximately 80 % decrement in the risk for general obesity and abdominal obesity[32]. In Sri Lanka, using a 24-h dietary recall, it was found that BMI and WC in the lowest category compared with the highest category of DDS were 22·16 *v.* 23·82 kg/m^2 and 77 *v.* 80 cm, respectively[30]. Regarding FVS, Jayawardena *et al.*[30] observed a positive correlation and Gregory *et al.*[23] reported a non-significant correlation with general obesity risk. Also, the Dietary Diversity Score with Portions score was positively correlated with general obesity[30]. Considering different effects of higher scores of food variety on general obesity, two pathways were determined: First, greater food variety is associated with higher energy intake, and therefore may be associated with general obesity; second, greater variety can be increased by consumption of a diversity of healthy and low-energy-dense food groups (vegetables, whole grains and fruits), with a simultaneous decrease in the risk for general obesity.

The relation of the Dietary Guidelines for Americans Index with obesity-related outcomes

Only one prospective and four cross-sectional studies provided data on adherence to DGAI scores and obesity[25–28,40]; of these five studies, three studies conducted in US populations indicated that a higher DGAI score could imply a 50 % reduction in enlarged WC and two units of BMI[25,27,28]. Hosseini-Esfahani *et al.*[26] reported no correlation between enlarged WC and BMI and DGAI in the Tehran Lipid and Glucose Study population. However, in a prospective study conducted by Lassale *et al.*[40] on French participants, higher scores of DGAI after adjustment for confounding variables predicted a 40 % decreased risk for general obesity in men, but not in women, after 13 years of follow-up. It seems that DGAI has a good correlation with central and abdominal obesity.

The relation of the Dietary Guideline Index with obesity-related outcomes

In Australian populations, two prospective and cross-sectional studies provided evidence for DGI scores and anthropometric status[29,39]. In a cross-sectional study by McNaughton *et al.*[29], a significant decrease in the risk for enlarged WC with increasing compliance with DGI, and insignificant findings for women, was reported. Also, in the Nambour Skin Cancer Study, men in the highest quartile had the lowest gain in BMI (0·05 *v.* 0·11 kg/m^2 per year), and those in the third quartile had the smallest increase in WC (0·04 *v.* 0·26 cm/year) during a 15-year follow-up. However, in women, the DGI score was not associated with change in any of the anthropometric measures[39]. In addition, a study of Australian women indicated no relation of dietary scores with general obesity, probably because overweight individuals adhered to healthier diets to manage their weight and dieting issues were more popular in women than in men[39].

Other dietary indices with obesity-related outcomes

Two longitudinal studies investigated the FNRS and the risk for general obesity after a 16-year follow-up in the Framingham study offspring and spouses and found a positive association[36,38]. Wolongevicz *et al.*[36] found that weight gain was about 1·4 kg for those with higher quality diets compared with 2·3–3·6 kg for those with poorer quality diets. In addition, Kimokoti *et al.*[38] showed that women with a lower diet quality gained an additional 5·2 kg, compared with those with higher diet quality[38].

All of the studies on RFS used FFQ for dietary intakes collection[11,19,20,23]; two had significant findings[19,20], whereas others had unrelated findings[11,23]. Three studies were conducted in USA and one in Guatemala[23]. McCullough *et al.*[20] indicated that a higher RFS score was correlated with a 0·2 unit decrement and a 0·3 unit increment of BMI in men and women, respectively.

Toft *et al.*[33], in a Danish population, found no correlation of DQS with general obesity. A cross-sectional study from the Greek islands, conducted by Kourlaba *et al.*[34] showed that a higher EDI was correlated with a 60 % lower risk for general obesity in the elderly. A study conducted on 1220 Guatemalan young adults by Gregory *et al.*[23] showed no significant prediction of NRFS with BMI and abdominal obesity. Other dietary indices have been investigated on sporadic studies. The PNNS-GS predicted lower risk for general obesity after a 13-year follow-up in men, but not in women[40].

Discussion

The current systematic review provides a comprehensive summary of the diet quality indices that have been developed to assess the overall healthfulness of dietary intakes and overweight, obesity, and weight gain in adults. Among thirteen studies on HEI, ten had inverse and three had no associations; however, of seven studies on DQI, only two reported inverse associations and others had conflicting associations based on race, sex and design of the study. Furthermore, studies on variety scores mostly had significant positive associations with general obesity. Of five studies providing data on adherence to DGAI, three were inversely associated with a lower risk for general obesity. Diet quality assessed by two population-specified indices in Australia and Framingham, DGI and FNRS, had consistent inverse associations with general obesity in a sex-specified manner.

The use of diet quality indices is increasing worldwide in various populations. Several diet quality scores reflect a common dietary pattern characterised by high intakes of plant-based foods such as whole grains, and moderate intakes of alcohol, and low intakes of red and processed meat, Na, sweetened beverages and *trans*-fatty acids.

An in-depth investigation of diet quality studies indicated that, in most cases, subjects who adhered to diet quality indices had favourable health behaviours associated with being older, married, higher education levels, higher physical activity levels and lower smoking[37,45–47].

Controversial findings on both men and women may be explained by some factors. It is particularly challenging for men to adhere to the cholesterol and Na recommendation because they consume more total energy content[48]; despite this apparent sex difference in diet quality, menopausal women tend to gain more weight over time than men, resulting from the potentially confounding effect of hormonal changes[40]. Despite the fact that people can meet the recommendations for fruits by eating either fresh–raw or processed fruits, the differences in nutritional quality and glycaemic effects can be huge. Hence, people may achieve higher scores by choosing many different food options.

Several studies have found dietary diversity to be directly associated with overweight and general obesity at the individual level[30,31,33]. Dietary variety and diversity may reflect consumption of both high- and low-quality foods[31]. Data shows dietary diversity to be directly associated with energy availability[30,31].

One of the explanations for the conflicting findings on the association between general obesity and diet quality indices is that the range of higher categories, compared with lower categories was relatively narrow, indicating that subjects in the higher and lower categories could not clearly distinguish differences in dietary patterns, and could attenuate the association of diet with obesity. In addition, some of the scores do not show the extent to which a person deviates from the recommended values because persons consuming over the recommended amounts for food groups receive full points. Furthermore, diet scores assessed the adherence to dietary guidelines (e.g. HEI, DQI and DGAI), most of which were designed for US populations; however, populations may be incapable of assessing overall diet quality until more is known about patterns of consumption. The major issues in developing countries are both under- and over-nutrition. Measures of diet quality in developing countries are more complex to design and interpret; it is also complex in such countries to assess diet quality in terms of both micronutrient adequacy and prevention of overweight, indicating the need for better measures of diet quality specifically for these populations. In addition, there are differences in the scoring models of indices, based on dietary guidelines, for example, the HEI-2005 was designed to differentiate diet quality from diet quantity; however, the original HEI considered only quantity[6,49]. Another point to consider is the critical role of energy intakes, which determines what kinds of dietary indices lead to loss or gain of weight. Adherence to dietary guidelines has a favourable effect on weight status when the proportion of energy requirements of individuals is taken into account. It is important that the energy density (e.g. intakes per 4184 kJ (1000 kcal)) be applied in the scoring systems. Moreover, in nutritional epidemiology, by considering energy intake as a confounder in the multivariable-adjusted models, the role of nutrients or foods is determined independent of body size and physical activity in terms of energy intake. However, studies evaluated the association of dietary indices with obesity both before and after energy adjustment. Interestingly, findings revealed that energy-adjusted-OR or energy-adjusted means were not markedly different from unadjusted OR or unadjusted-means in baseline models. Indeed, adjustment of energy did not change the results of the studies. Conflicting results may also be due to the fact that overweight individuals adopt a healthier diet to manage their weight, and the effect of a healthy diet as assessed by scores on their obesity status hence could not be detected. In addition, the population that the index is developed for is important; for example, FNRS and DGI were developed for the Framingham and Australian populations, respectively; hence, it is clear that specific indices can be evaluated only in specific populations.

There was no single study investigating the differences of abdominal obesity definitions in relation to the dietary indices; therefore, we were unable to determine the effect/impact of different definitions of abdominal obesity on results.

Nutritional behaviour and food choice, as well as economic and cultural factors and ethnicity, play major roles[14,35]. In a Spanish population, diet cost increases with higher adherence to the HEI and higher scores of the HEI were inversely associated with general obesity; subjects who strongly adhere to HEI had to pay 42€ (52·5$) more per month than those with low adherence to this dietary score[14]. Ethnicity, as a culturally relevant factor, is proposed to influence the HEI adherence and its relation to general obesity[35]. Adherence to HEI scores for white populations was better than the other ethnicities. HEI predictability for outcome of obesity was different among ethnicities, efficient in whites, only fair in Chinese and Hispanic, and poor in African-Americans. Lack of understanding of nutrition guidelines and misconceptions about 'good' *v.* 'bad' foods are two of the major obstacles to a healthy diet, particularly in whites and African-Americans. Dietary habits are changing in the Chinese and Hispanics, and they are adopting new dietary behaviours. In addition, people who have migrated recently were less able to adapt their traditional foods to US nutritional guidelines[35].

Some limitations of this review need to be mentioned. First, it is possible that this review did not identify all relevant publications; although using wide search terms, repeating our search in numerous relevant databases, and hand-searching reference lists were attempted to minimise this possibility. Second, there are several factors that may have introduced bias in our findings; specifically, the selection of English-language publications. The third limitation is that twenty-four of the identified articles had a cross-sectional design. These studies cannot show causal effects of adhering to dietary indices on weight status, and only explained an association. The fourth limitation of the literature is that most of the studies were conducted in developed countries. This is important because other populations may differ with respect to weight reduction and acceptability of food items from dietary guidelines.

In conclusion, the review findings suggest that overall diet quality seems to be an important component of the diet–obesity relationship, and also provides potential new insights for use in future research on developing preventive nutrition strategies. Diet quality indices provide important information on updating food guidelines. We found that diet quality indices based on dietary guidelines were inversely associated with parameters of weight status in most studies. However, the difference in scores observed in different populations indicated that future dietary guidelines should be developed and updated to address the dietary needs of different specific population groups. Scoring on the basis of dietary diversity was directly associated with weight gain. Further research using longitudinal studies and field trials to confirm these findings are recommended.

Acknowledgements

The authors would like to acknowledge Ms Niloofar Shiva for critical edition of English grammar and syntax of the manuscript.

This work was funded by a grant from the Research Institute for Endocrine Sciences, Shadid Beheshti University of Medical Sciences, Tehran, Iran.

G. A. and E. Y. Conceptualised and designed the study, and drafted the initial manuscript. F. A. and P. M. supervised the project and revised the final version of the manuscript. All authors read and approved the final manuscript.

None of the authors has any conflicts of interest to declare.

References

1. Hruby A, Manson JE, Qi L, *et al.* (2016) Determinants and consequences of obesity. *Am J Public Health* **106**, 1656–1662.
2. Balter K, Moller E & Fondell E (2012) The effect of dietary guidelines on cancer risk and mortality. *Curr Opin Oncol* **24**, 90–102.
3. Kant AK (2004) Dietary patterns and health outcomes. *J Am Diet Assoc* **104**, 615–635.
4. Wirt A & Collins CE (2009) Diet quality – what is it and does it matter? *Public Health Nutr* **12**, 2473–2492.
5. Kant AK (2010) Dietary patterns: biomarkers and chronic disease risk. *Appl Physiol Nutr Metab* **35**, 199–206.
6. Kennedy ET, Ohls J, Carlson S, *et al.* (1995) The Healthy Eating Index: design and applications. *J Am Diet Assoc* **95**, 1103–1108.
7. World Health Organization (2000) *Obesity: Preventing and Managing the Global Epidemic*. Geneva: WHO.
8. Grundy SM, Cleeman JI, Daniels SR, *et al.* (2005) Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation* **112**, 2735–2752.
9. Tardivo AP, Nahas-Neto J, Nahas EA, *et al.* (2010) Associations between healthy eating patterns and indicators of metabolic risk in postmenopausal women. *Nutr J* **9**, 64.
10. Drewnowski A, Fiddler EC, Dauchet L, *et al.* (2009) Diet quality measures and cardiovascular risk factors in France: applying the Healthy Eating Index to the SU.VI.MAX study. *J Am Coll Nutr* **28**, 22–29.
11. Fung TT, McCullough ML, Newby PK, *et al.* (2005) Diet-quality scores and plasma concentrations of markers of inflammation and endothelial dysfunction. *Am J Clin Nutr* **82**, 163–173.
12. Tande DL, Magel R & Strand BN (2010) Healthy Eating Index and abdominal obesity. *Public Health Nutr* **13**, 208–214.
13. Guo X, Warden B, Paeratakul S, *et al.* (2004) Healthy eating index and obesity. *Eur J Clin Nutr* **58**, 1580–1586.
14. Schröder H, Marrugat J & Covas M (2006) High monetary costs of dietary patterns associated with lower body mass index: a population-based study. *Int J Obes (Lond)* **30**, 1574–1579.
15. McCullough ML, Feskanich D, Rimm EB, *et al.* (2000) Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in men. *Am J Clin Nutr* **72**, 1223–1231.
16. McCullough ML, Feskanich D, Stampfer MJ, *et al.* (2000) Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in women. *Am J Clin Nutr* **72**, 1214–1222.
17. Nicklas TA, O'Neil CE & Fulgoni VL 3rd (2012) Diet quality is inversely related to cardiovascular risk factors in adults. *J Nutr* **142**, 2112–2118.
18. Asghari G, Mirmiran P, Rashidkhani B, *et al.* (2012) The association between diet quality indices and obesity: Tehran Lipid and Glucose Study. *Arch Iran Med* **15**, 599–605.
19. de Koning L, Chiuve SE, Fung TT, *et al.* (2011) Diet-quality scores and the risk of type 2 diabetes in men. *Diabetes Care* **34**, 1150–1156.
20. McCullough ML, Feskanich D, Stampfer MJ, *et al.* (2002) Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *Am J Clin Nutr* **76**, 1261–1271.
21. Drenowatz C, Shook RP, Hand GA, *et al.* (2014) The independent association between diet quality and body composition. *Sci Rep* **4**, 4928.
22. Sundararajan K, Campbell MK, Choi YH, *et al.* (2014) The relationship between diet quality and adult obesity: evidence from Canada. *J Am Coll Nutr* **33**, 1–17.
23. Gregory CO, McCullough ML, Ramirez-Zea M, *et al.* (2009) Diet scores and cardio-metabolic risk factors among Guatemalan young adults. *Br J Nutr* **101**, 1805–1811.
24. Quatromoni PA, Pencina M, Cobain MR, *et al.* (2006) Dietary quality predicts adult weight gain: findings from the Framingham Offspring Study. *Obesity (Silver Spring)* **14**, 1383–1391.
25. Fogli-Cawley JJ, Dwyer JT, Saltzman E, *et al.* (2006) The 2005 Dietary Guidelines for Americans Adherence Index: development and application. *J Nutr* **136**, 2908–2915.
26. Hosseini-Esfahani F, Jessri M, Mirmiran P, *et al.* (2010) Adherence to dietary recommendations and risk of metabolic syndrome: Tehran Lipid and Glucose Study. *Metabolism* **59**, 1833–1842.
27. Fogli-Cawley JJ, Dwyer JT, Saltzman E, *et al.* (2007) The 2005 Dietary Guidelines for Americans and risk of the metabolic syndrome. *Am J Clin Nutr* **86**, 1193–1201.
28. Fogli-Cawley JJ, Dwyer JT, Saltzman E, *et al.* (2007) The 2005 Dietary Guidelines for Americans and insulin resistance in the Framingham Offspring Cohort. *Diabetes Care* **30**, 817–822.
29. McNaughton SA, Dunstan DW, Ball K, *et al.* (2009) Dietary quality is associated with diabetes and cardio-metabolic risk factors. *J Nutr* **139**, 734–742.
30. Jayawardena R, Byrne NM, Soares MJ, *et al.* (2013) High dietary diversity is associated with obesity in Sri Lankan adults: an evaluation of three dietary scores. *BMC Public Health* **13**, 314.
31. Azadbakht L, Mirmiran P, Esmaillzadeh A, *et al.* (2006) Dietary diversity score and cardiovascular risk factors in Tehranian adults. *Public Health Nutr* **9**, 728–736.
32. Azadbakht L & Esmaillzadeh A (2011) Dietary diversity score is related to obesity and abdominal adiposity among Iranian female youth. *Public Health Nutr* **14**, 62–69.
33. Toft U, Kristoffersen LH, Lau C, *et al.* (2007) The Dietary Quality Score: validation and association with cardiovascular risk factors: the Inter99 study. *Eur J Clin Nutr* **61**, 270–278.
34. Kourlaba G, Polychronopoulos E, Zampelas A, *et al.* (2009) Development of a diet index for older adults and its relation to cardiovascular disease risk factors: the Elderly Dietary Index. *J Am Diet Assoc* **109**, 1022–1030.
35. Gao SK, Beresford SA, Frank LL, *et al.* (2008) Modifications to the Healthy Eating Index and its ability to predict obesity: the Multi-Ethnic Study of Atherosclerosis. *Am J Clin Nutr* **88**, 64–69.
36. Wolongevicz DM, Zhu L, Pencina MJ, *et al.* (2010) Diet quality and obesity in women: the Framingham Nutrition Studies. *Br J Nutr* **103**, 1223–1229.
37. Zamora D, Gordon-Larsen P, Jacobs DR Jr, *et al.* (2010) Diet quality and weight gain among black and white young adults: the Coronary Artery Risk Development in Young Adults (CARDIA) Study (1985–2005). *Am J Clin Nutr* **92**, 784–793.
38. Kimokoti RW, Newby P, Gona P, *et al.* (2010) Diet quality, physical activity, smoking status, and weight fluctuation are associated with weight change in women and men. *J Nutr* **140**, 1287–1293.

British Journal of Nutrition

39. Arabshahi S, van der Pols JC, Williams GM, *et al.* (2011) Diet quality and change in anthropometric measures: 15-year longitudinal study in Australian adults. *Br J Nutr* **107**, 1376–1385.
40. Lassale C, Fezeu L, Andreeva VA, *et al.* (2012) Association between dietary scores and 13-year weight change and obesity risk in a French prospective cohort. *Int J Obes (Lond)* **36**, 1455–1462.
41. Funtikova A, Baena-Diez JM, Koebnick C, *et al.* (2012) Validity of a short diet-quality index to predict changes in anthropometric and cardiovascular risk factors: a simulation study. *Eur J Clin Nutr* **66**, 1369–1371.
42. Drewnowski A, Henderson SA, Driscoll A, *et al.* (1997) The Dietary Variety Score: assessing diet quality in healthy young and older adults. *J Am Diet Assoc* **97**, 266–271.
43. Cade J, Upmeier H, Calvert C, *et al.* (1999) Costs of a healthy diet: analysis from the UK Women's Cohort Study. *Public Health Nutr* **2**, 505–512.
44. Mirmiran P, Azadbakht L & Azizi F (2005) Dietary quality-adherence to the dietary guidelines in Tehranian adolescents: Tehran Lipid and Glucose Study. *Int J Vitam Nutr Res* **75**, 195–200.
45. Parveen Z, Ali A, Ali TM, *et al.* (2016) Association of dietary patterns with anthropometric, lifestyle and socio-economic factors among women of selected communities from Karachi, Pakistan. *J Pak Med Assoc* **66**, 1249–1257.
46. Paradis AM, Perusse L & Vohl MC (2006) Dietary patterns and associated lifestyles in individuals with and without familial history of obesity: a cross-sectional study. *Int J Behav Nutr Phys Act* **3**, 38.
47. Zamora D, Gordon-Larsen P, He K, *et al.* (2011) Are the 2005 Dietary Guidelines for Americans Associated With reduced risk of type 2 diabetes and cardiometabolic risk factors? Twenty-year findings from the CARDIA study. *Diabetes Care* **34**, 1183–1185.
48. Morreale SJ & Schwartz NE (1995) Helping Americans eat right: developing practical and actionable public nutrition education messages based on the ADA Survey of American Dietary Habits. *J Am Diet Assoc* **95**, 305–308.
49. Guenther PM, Reedy J & Krebs-Smith SM (2008) Development of the Healthy Eating Index-2005. *J Am Diet Assoc* **108**, 1896–1901.
50. Patterson RE, Haines PS & Popkin BM (1994) Diet quality index: capturing a multidimensional behavior. *J Am Diet Assoc* **94**, 57–64.
51. Kim S, Haines PS, Siega-Riz AM, *et al.* (2003) The Diet Quality Index-International (DQI-I) provides an effective tool for cross-national comparison of diet quality as illustrated by China and the United States. *J Nutr* **133**, 3476–3484.
52. Newby PK, Hu FB, Rimm EB, *et al.* (2003) Reproducibility and validity of the Diet Quality Index Revised as assessed by use of a food-frequency questionnaire. *Am J Clin Nutr* **78**, 941–949.
53. McNaughton SA, Ball K, Crawford D, *et al.* (2008) An index of diet and eating patterns is a valid measure of diet quality in an Australian population. *J Nutr* **138**, 86–93.
54. Kant AK, Schatzkin A & Ziegler RG (1995) Dietary diversity and subsequent cause-specific mortality in the NHANES I epidemiologic follow-up study. *J Am Coll Nutr* **14**, 233–238.
55. Millen BE, Quatromoni PA, Copenhafer DL, *et al.* (2001) Validation of a dietary pattern approach for evaluating nutritional risk: the Framingham Nutrition Studies. *J Am Diet Assoc* **101**, 187–194.
56. Kant AK, Schatzkin A, Graubard BI, *et al.* (2000) A prospective study of diet quality and mortality in women. *JAMA* **283**, 2109–2115.
57. Aljadani HM, Patterson AJ, Sibbritt D, *et al.* (2015) Diet quality and six-year risk of overweight and obesity among mid-age Australian women who were initially in the healthy weight range. *Health Promot J Austr* **27**, 29–35.

Appendix. Description for diet quality indices

Scores	Description
Healthy Eating Index (HEI)[6]	Score range: 0–100. The HEI assesses adequacy, moderation and variety, and is based on the three energy levels in the Food Guide Pyramid and dietary guidelines. It has ten components including servings of grains, vegetables, fruit, milk, and meat/beans for adequacy, total fat, SFA, cholesterol, Na for moderation, and the tenth component is variety. Each component contributes 0–10 points
Healthy Eating Index-2005 (HEI-2005)[49]	Score range: 0–100. The HEI-2005 is based on twelve energy levels in My Pyramid and assesses the food groups in per 4184 kJ (1000 kcal) manner. It has nine adequacy components including total fruit (5 points), whole fruit (5 points), total vegetables (5 points), dark-green and orange vegetables and legumes (5 points), total grains (5 points), whole grains (5 points), milk (10 points), meat and beans (10 points), and oils (10 points), and three moderation components including SFA (10 points), Na (10 points), and energy from solid fats, alcoholic beverages, and added sugars (20 points)
Healthy Eating Index-05 (HEI-05)[35]	Score range: 0–100. It is calculated using the same components, weighting and scoring rules as for the HEI; however, it is adjusted for twelve energetic levels specified in the 2005 dietary guidelines for Americans
Alternate Healthy Eating Index (AHEI)[20]	Score range: 2·5–87·5. The components included vegetables, fruits, nuts and soya protein, white:red meat ratio, cereal fibre, *trans*-fatty acids, PUFA:SFA ratio and alcohol intake, and each contributes 0–10 points. The ninth component is multivitamin intake duration, and a score of 2·5 or 7·5 was given for intake of <5 or >5 years, respectively
Diet Quality Index (DQI)[50]	Range: 0 (high quality) –16 (poor quality). The DQI is based on the dietary guidelines for Americans. It has eight components including total fat, SFA, protein, cholesterol, Na, Ca, fruits and vegetables grains and legumes
Diet Quality Index-International (DQI-I)[51]	Range: 0–100. The DQI-I assesses following components: variety: overall food group variety (0–15 points); within-group variety for protein source (0–5 points); adequacy: vegetables, fruits, cereals, fibre, protein, Fe, Ca, vitamin C (0–5 points each); moderation: total fat, SFA, cholesterol, Na, empty-energy foods (0–6 points each); overall balance: macronutrient ratio (carbohydrate: protein: fat, 0–6 points); fatty acid ratio (PUFA:MUFA:SFA, 0–4 points)
The Diet Quality Index Revised (DQI-R)[52]	Range: 0–100. The DQI-R consists of ten components including grains, vegetables, fruit, total fat, SFA, cholesterol, iron, Ca, diet diversity, and moderation in added fat and sugar. Each component contributes 0–10 points
Elderly Dietary Index (EDI)[34]	Range: 10–40. The EDI is based on the Modified MyPyramid for Older Adults, and assessed the following components: fruits, vegetables, cereals, olive oil, meat, fish or seafood, legumes, bread, alcohol and dairy products. Each component contributes 1–4 points

Continued

Scores	Description
Dietary Guideline Index (DGI)[53]	Range: 0–150. The DGI is based on the dietary guidelines for Australians, and consists of fifteen components including variety, vegetables, fruit, cereals, whole-grain cereals, meat and alternatives, lean protein sources, total dairy products, low-fat/reduced-fat dairy products, fluids, SFA, salt, alcoholic beverages, added sugars and extra foods. Each contributes 0–10 points
Dietary Guidelines for Americans Index (DGAI)[25]	Score range: 0–20 points. The DGAI recommendations are based on energy needs calculated with BMR and physical activity level for each subject. It consists of eleven items for foods (0–1 point each): dark-green vegetables, orange vegetables, legumes, other vegetables, starchy vegetables, fruits, variety, meat and beans, dairy products, all grains, discretionary energy; and nine items for healthy choices/nutrient intake whole grains (0–1 point), fibre intake (0–1 point), total fat (0–1 point), SFA (0–1 point), *trans*-fat (0–1 point), cholesterol (0–1 point), low-fat dairy products (0–0·5 points), low-fat meat products (0–0·5 point), Na (0–1 point), and alcohol (0–1 point)
Dietary Diversity Score (DDS) – Jayawardena[30]	Score range: 0–12. The DDS by Jayawardena is defined as the total count of different food groups irrespective of the amount consumed by individuals over the 24 h period. All food items were categorised into twelve food groups including starch, vegetables, green leafy vegetables, fruits, fish, meat (including poultry, egg), legumes (including nuts and seeds except coconut), dairy products, beverages (tea, coffee and fizzy drinks), oils and fats (coconut products were included), sweets and miscellaneous (e.g. alcohol)
Dietary Diversity Score (DDS)[54]	Score range: 0–10. The DDS is based on adherence to five food groups (grains, vegetables, fruits, meats and dairy products) of the Food Guide Pyramid. These main groups were divided into twenty-three subgroups: seven subgroups for (refined bread, biscuits, macaroni, whole bread, maize flakes, rice, refined meal), two subgroups for fruits (fruit and fruit juice, berries and citrus), seven subgroups for vegetables (vegetables, potatoes, tomatoes, starchy vegetables, legumes, yellow vegetables, green vegetables), four subgroups of meat (red meat, poultry, fish, egg), and three subgroups for dairy products (milk, yogurt, cheese). A participant was considered a consumer of a food group if he/she consumed at least one-half of the serving of any subgroup. Diversity score receives 0–2 points for each food group
Dietary Diversity Score with Portions (DDSP)[30]	Range score: 0–8. The DDSP is defined according to major food groups in the Sri Lankan food pyramid which included starch, vegetables, green leafy vegetables, meat (meat/poultry/egg), fish (fish/dry fish/ sea foods), dairy products, pulses and fruits. A participant was considered as consumer if he/she consumed a minimum of one portion for the respective food group
The Framingham Nutritional Risk Score (FNRS)[55]	Range score: depends on sample size. Ranks are assigned so that desirable nutrient intake level receives a lower rank, whereas undesirable nutrient intake level receives a higher rank. Energy, protein, alcohol, total, SFA, and MUFA, dietary cholesterol, and Na intakes were ranked from low to high, whereas PUFA, carbohydrate, fibre, Ca, Se, vitamins C, B_6, B_{12}, and E, folate and carotene intakes were ranked from high to low. An overall composite nutritional risk rank was computed using the mean of the ranks of nineteen individual nutrients
Recommended Food Score (RFS)[56]	Range score: 0–23. The RFS is calculated as the sum of the following twenty-three food items if subjects consumed them at least once a week. The food items included apples or pears; oranges; cantaloupe; orange or grapefruit juice; grapefruit; other fruit juices; dried beans; tomatoes; broccoli; spinach; mustard, turnip or collard greens; carrots or mixed vegetables with carrots; green salad; sweet potatoes, yams; other potatoes; baked or stewed chicken or turkey; baked or broiled fish; dark breads like whole wheat, rye or pumpernickel; maize bread, tortillas and grits; high-fibre cereals, such as bran, granola or shredded wheat; cooked cereals; 2% milk and beverages with 2% milk; and 1% or skimmed milk
Food Variety Score (FVS)[42]	The FVS refers to the number of different dietary items consumed in a day (different food items eaten during last 24 h). The total number of foods included irrespective of quantity consumed. There is no maximum value here
Dietary Quality Score (DQS)[33]	Score range: 1–12. The calculations were based on DQI[3] and the Danish dietary guidelines. The DQS included fish (1–3 points), fruits (1–3 points), vegetables (1–3 points), and fats (1–3 points)