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Systematic Review

Associations between dietary variety and measures of body adiposity: a systematic review of epidemiological studies

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Abstract

Dietary variety is positively correlated with energy intake in most studies. However, the associations between dietary variety and measures of body adiposity are inconsistent in the literature, which limits the development of clear national nutrition recommendations regarding dietary variety. In the present systematic review, we critically evaluate the associations between dietary variety and measures of body adiposity among healthy adults within the existing literature. We conducted a systematic search of the MEDLINE and Web of Science databases in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement to examine these associations. We identified twenty-six studies in total that investigated the associations between dietary variety and body adiposity measures. Total variety was non-significantly associated with body adiposity in most studies, while variety in recommended foods was either inversely associated (six out of ten studies) or non-significantly associated (three out of ten studies) with body adiposity. Conversely, variety in non-recommended foods (i.e. sources of added sugars and solid fats) increased the likelihood of excess adiposity in most studies (six out of nine studies). Definitions and measurement of dietary variety were inconsistent across studies and contributed to some of the discrepancies noted in the literature. In conclusion, among the studies that met the inclusion criteria for the present review, dietary variety was inconsistently associated with body adiposity in diverse populations. Using consistent and specific definitions of dietary variety may help provide further insight into the associations between dietary variety and excess adiposity before definitive public health messages are made.

Key words: Dietary variety: Obesity: Adiposity

Dietary variety has historically been a component of national and international dietary guidelines because of its association with improved nutritional quality[1,2]. Dietary patterns characterised by the consumption of a diverse selection of nutritionally distinct and wholesome foods encourage nutrient adequacy and improved health outcomes[3]. However, more recently, with increasing globalisation and greater availability of highly processed foods, emerging evidence suggests that individuals who consume varied diets are at greater risk of being overweight[3]. Dietary variety improves the palatability of the overall diet, which may enhance total energy consumption and be a contributing factor to the present global obesity epidemic[3]. Although most studies suggest that dietary variety increases energy intake[4], it is not possible to infer whether dietary variety also has an adverse impact on body weight and other measures of adiposity based on these findings. Physically active individuals must consume more energy, and plausibly, a greater variety of foods to maintain energy balance. Consequently, greater dietary variety may merely be a marker for a more physically active or healthful lifestyle[5].

Most evidence addressing dietary variety and the risk of overweight comes from controlled, short-term feeding studies conducted in both animals and human subjects[6]. These studies consistently demonstrated that the presence of multiple food items is associated with approximately 25% greater energy intake[6]. Additionally, across animal studies, rats consuming

Abbreviations: WC, waist circumference; WHR, waist:hip ratio.

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a varied diet consistently gain more weight and accrue more fat mass compared with rats consuming a standard diet[7].

In epidemiological studies, the association between dietary variety and excess adiposity is inconsistent, and varies based on the study design, the definition and measurement of variety, and the study population[2,7]. Further research investigation into the associations between dietary variety and excess adiposity began after a seminal study revealed a positive correlation between dietary variety in some food groups and body fatness[8]. This finding generated concern about US national recommendations encouraging dietary variety because of uncertainty whether promoting dietary variety could unintentionally support overconsumption[9].

Despite ambiguity surrounding the relationship between dietary variety and excess adiposity, many dieters choose to restrict broad categories of food when trying to lose weight[10]. Diets restricting specific food groups produce initial success because dieters unconsciously reduce energy intake as variety in their diet decreases and eating becomes less pleasurable[11]. However, over time, this monotony can encourage food cravings, which may partly explain the high rate of attrition associated with restrictive diets[10]. The potential risks of restricting or limiting dietary variety should be comprehensively evaluated, particularly in the context of renewed scientific interest in manipulating dietary variety for weight loss and weight maintenance[12,13].

At present, it is unclear whether diets comprising a variety of lower-energy, nutrient-dense options can increase the likelihood of initiating and maintaining a reduced-energy lifestyle. Given the inconsistencies in the epidemiological literature and the potential negative consequences of limiting variety from both an overall health and a weight maintenance perspective, the purpose of the present systematic review is to examine the evidence examining the associations between dietary variety and measures of adiposity and its consistency across epidemiological studies.

Methods

Protocol

In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement, we systematically searched for cross-sectional, case–control, cohort and experimental studies examining the associations between any measure of dietary variety and measures of body adiposity. The population, intervention, comparator and outcomes method was used to narrow the focus of the research question[14]. The present review focused on healthy adults aged 18 years and older. The interventions and comparators that were examined were exposure to a high- *v.* low-variety diet. Outcome measures were measures of body adiposity including BMI, waist circumference (WC), waist:hip ratio (WHR) and percentage of body fat. MEDLINE and Thomson Reuters' Web of Science databases were searched for the following key terms: ('dietary variety' OR 'dietary diversity') AND ('obesity' OR 'body mass index' OR 'body fat' OR 'waist circumference' OR 'body adiposity' OR 'body weight' OR 'overweight'). No exclusion criteria were used in the search strategy to prevent potential misclassification of relevant articles. This review includes all studies published from January 1999 to June 2012.

Inclusion and exclusion criteria

Studies eligible to be included in the present review were published in English and evaluated the associations between dietary variety and at least one of the following outcomes: (1) body weight or BMI or (2) measures of body adiposity (WC, WHR and percentage of body fat). These markers were selected based on their clinical and epidemiological relevance. Studies were conducted in human subjects and utilised quantitative methods to examine the associations between dietary variety and the aforementioned outcome measures. Because the relationship between dietary variety is highly associated with overall health in developing countries with greater food insecurity, only studies conducted in medium-to-very-high Human Development Index countries were included in the present review. The Human Development Index is a newer and more comprehensive measure of the development status of a country and includes factors such as life expectancy, educational attainment and income[15]. Additionally, only studies published from 1999 onwards were included in the present review as a concern regarding the associations between dietary variety and excess energy consumption became a greater research focus after McCrory *et al.* (1999)[8] noted positive correlations between dietary variety in some food groups, energy intake and measures of body adiposity. Observational studies were excluded if they were insufficiently powered ($n < 200$) and if the measurement of dietary variety was not selected *a priori* (i.e. cluster analyses were excluded). Finally, studies were excluded if they were conducted in unhealthy populations or among adults younger than 18 years of age.

Database searches generated a total of 2229 abstract titles of which 1681 were eliminated from the title alone because they did not pertain to dietary patterns, dietary variety or body weight. The review of the remaining 548 abstracts resulted in eighty-three unique references requiring full-text review. Of the remaining eighty-three articles, sixty were excluded after full-text review because they did not measure the exposure or outcome(s) of interest or they were conducted among unhealthy populations or within countries ranked as 'Low Human Development' by means of the Human Development Index. A total of twenty-three articles met the eligibility criteria described above and were included in the present review. A further three articles were added from the bibliographies of the review articles, resulting in twenty-six eligible studies, which examined BMI or other measures of body adiposity (Fig. 1). Each included study was evaluated for quality using a component approach based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses recommendations[16]. The selection of the components was based on the criteria published by Sanderson *et al.* in the *International Journal of Epidemiology*[17]. The key components examined for assessing study quality included

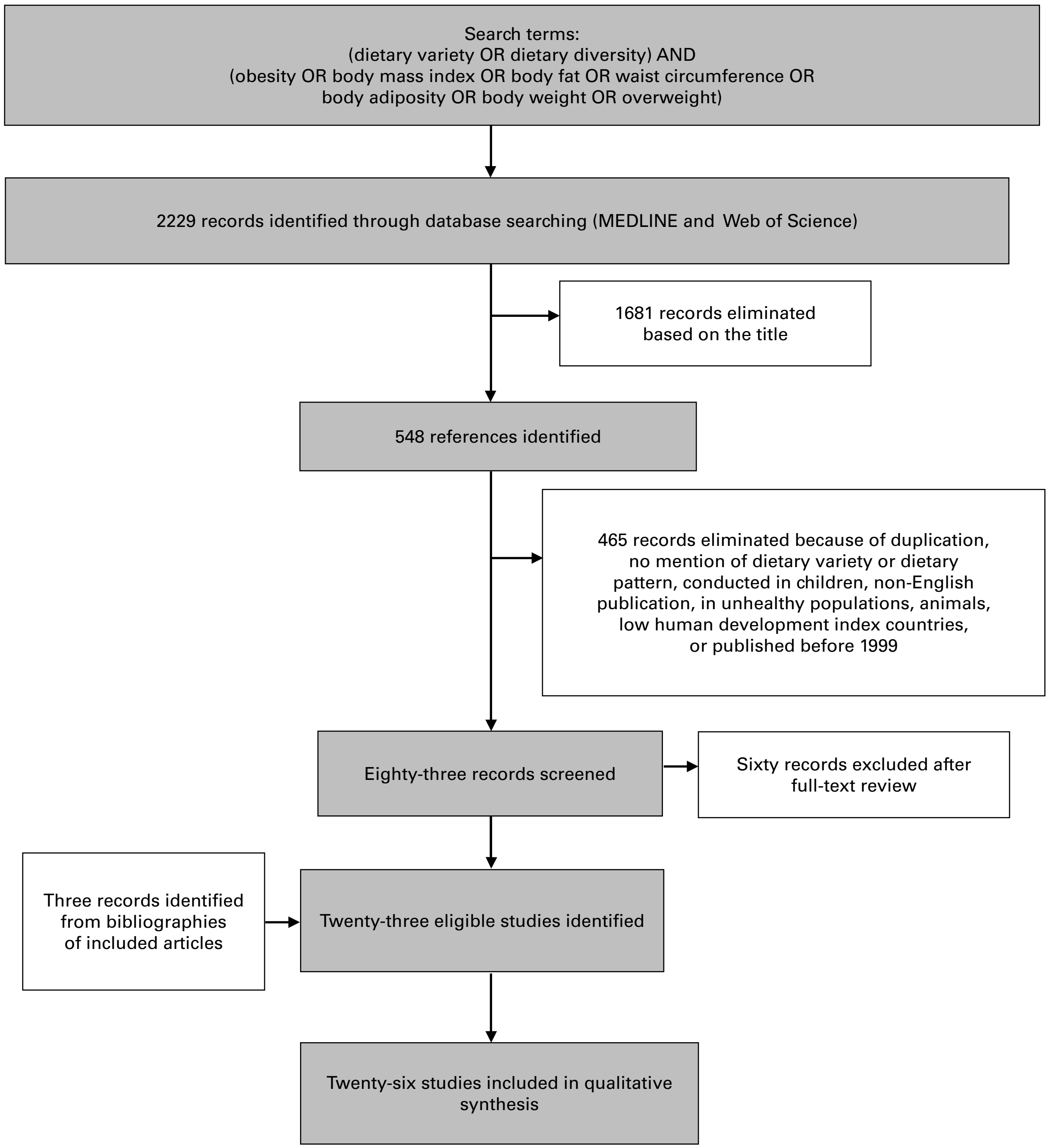

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses study selection process, describing the systematic search and selection process for this study. A comprehensive search of the MEDLINE and Web of Science databases resulted in a total of 2229 records for review. Of these records, 75 % (*n* 1681) were eliminated from the title alone, as they did not pertain to dietary variety and energy intake or measures of body adiposity. From the remaining 548 studies, eighty-three were reviewed after duplicates from the two databases and studies that did not meet the *a priori* exclusion criteria were removed. A total of twenty-three studies from the original search were used in the final review. Three additional studies were identified from bibliographies, generating a final total of twenty-six studies.

participant selection, measurement of exposure and outcome variables, study design-related bias, confounding and appropriateness of statistical methods. Studies with minimal bias, appropriate measurement of exposure and outcome variables, and adjustment for confounders were considered to be of high quality.

Results

Dietary variety and measures of body adiposity

In the present qualitative synthesis, twenty-six studies were included that examined the associations between various dietary variety indices and measures of body adiposity including

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BMI, waist and hip circumference and percentage of body fat. The majority of the studies were cross-sectional (77 %) and the results varied among populations, dietary variety assessment methods and outcome measures. For ease of comparison, the results of the studies have been organised by the dietary variety assessment method utilised, which have been divided into the following categories: (1) overall variety (Table 1); (2) variety in recommended foods (Table 2); (3) variety in non-recommended foods (Table 3). When multiple dietary variety assessments were used in a single study, each result from that study was reported in the appropriate table.

The decision to organise the results based on the type of dietary variety assessment method utilised is informed by the landmark study conducted in 1999 by McCrory *et al.*[8]. This analysis examined seventy-one healthy men and women to evaluate the associations between dietary variety within ten food groups and obesity. Greater variety within snack foods, carbohydrates, sweets and entrées was positively correlated with the percentage of body fat (r 0·38, P=0·001), while variety within vegetables was inversely correlated with the percentage of body fat (r −0·31, P=0·008). A variety ratio that measured the ratio of vegetable variety:variety within snack foods, carbohydrates, sweets and entrées was also negatively correlated with the percentage of body fat (r −0·27, P=0·02). Following the McCrory study, the role of dietary variety in body weight management became more controversial and many studies began examining the associations between dietary variety, body weight and excess adiposity.

Overall dietary variety and measures of body adiposity

There were fourteen cross-sectional studies (Table 1) that examined the associations between dietary variety within the overall diet and its associations with various body adiposity measures. Of these fourteen studies, six assessed dietary variety using diet assessment methods considered valid for the measurement of usual intake, such as a FFQ[18–23]. These studies were inconsistent in their conclusions with two studies reporting inverse associations[18,22], two with non-significant associations[21,23] and two with positive associations[19,20]. The remaining eight studies assessed dietary variety using one or two 24 h recalls, which are considered less valid estimates of usual dietary intake compared with other self-report measures that assess a longer period of time[24]. Overall, five of the eight studies reported non-significant associations between dietary variety and measures of body adiposity[25–29], one study reported a positive association[30] and two studies reported an inverse association[31,32].

Among the studies reporting positive associations, the most consistent association emerged with BMI or obesity status (determined using BMI cut-offs) as outcome measures. Among Iranian adults, greater diversity (quartile 4 *v.* quartile 1) within five main food groups and twenty-three subgroups was associated with a higher BMI and a greater percentage of obese adults[19,20]. Ponce *et al.*[30] also noted that obese and overweight Mexican adults had higher levels of dietary variety within twenty-four food groups compared with normal-weight and underweight individuals (P=0·007). However, no studies noted a positive association for other measures of adiposity such as WC or WHR[19,20].

There were four studies that reported inverse associations between dietary variety and measures of adiposity[18,22,31,32]. Young Iranian females with a higher Dietary Diversity Score had lower WC and WHR as well as a reduced percentage of obesity[18]. Greater dietary variety was inversely associated with BMI among Australian men, but no association was noted among women[22]. Using the Healthy Eating Index measure of dietary variety, male National Health and Nutrition Examination Survey III participants had a modest reduction in the odds of abdominal adiposity as dietary variety increased, while obese women had higher variety scores when compared with their normal-weight counterparts (P<0·03)[31]. Using the same measure of variety, participants from the Continuing Survey of Food Intake by Individuals had a lower BMI with greater variety if >55 % of total energy in the diet was consumed from carbohydrate (P<0·05); no difference in BMI was seen among individuals consuming a lower percentage of energy from carbohydrate[32].

There were five studies that reported no significant association between overall dietary variety and adiposity measures[25–29]. Adults in Louisiana[27] with higher Dietary Diversity Scores within five major food groups had a non-significant 11 % reduced risk of overweight and a 19 % non-significant reduced risk of obesity. In a study of Belgian adults, no significant association was detected between variety among and within food groups (data not shown)[29]. Also, two US studies[25,26] did not detect a significant association between the Healthy Eating Index measure of dietary variety and BMI among older (60+ year) US men and women. Overall, total dietary variety is inconsistently associated with measures of body adiposity and varies based on the type of dietary assessment method utilised and the population studied.

Dietary variety within recommended foods and measures of body adiposity

We identified ten studies that examined the associations between variety of recommended foods and measures of body adiposity (Table 2). Recommended food groups varied between studies, but included fruits, vegetables, low-fat dairy products and other lower-energy foods. Of these studies, seven studies reported inverse or mixed associations[28,33–38], where intake of vegetables and grains and other foods recommended by the dietary guidelines was inversely associated with BMI and body weight. Among the National Health Interview Survey participants, the proportion of adults classified as overweight by BMI standards was lower among adults with higher Recommended Foods and Behavior scores[35]. Similarly, National Health and Nutrition Examination Survey participants with greater variety in recommended foods had a lower average BMI than individuals with less variety ($\beta = -0{\cdot}18$ and $-0{\cdot}38$; P<0·00001 using the Recommended Foods Score and Dietary Diversity Score for Recommended Foods)[34]. Brunt & Rhee[33] noted that grain and vegetable variety was higher among normal *v.* obese participants. Importantly, dietary variety measured via the Recommended

Table 1. Overall dietary variety and measures of adiposity

Reference	Study design, name, location and year	Sample characteristics (*n*, age, sex)	Dietary assessment method	Dietary diversity measure	Outcome measures	Results	Overall conclusion*
Usual intake (multiple days)							
Azadbakht *et al.*[18]	Cross-sectional study of female Iranian university students, Iran, year unknown	Random sample of 289 healthy Iranian women aged 18–28 years	Dietitian-administered 168-item semi-quantitative FFQ for consumption over past 1 year	DDS with five main groups and twenty-three subgroups	Measured BMI, WHR, WC, prevalence of BMI 25–29 and $\geq$30 kg/m^2, prevalence of abdominal adiposity as WC > 88 cm	Odds of abdominal adiposity (OR 0·21, 95 % CI 0·06, 0·98 in Q4 *v.* Q1), overweight (OR 0·22, 95 % CI 0·07, 0·80 in Q4 *v.* Q1) and obesity (OR 0·21, 95 % CI 0·06, 0·96 in Q4 *v.* Q1) were lower across DDS quartiles (*P* for trend < 0·05)	–
Kent *et al.*[22]	Cross-sectional trend study from Biennial Biomedical surveys by Adventist Hospital, Sydney, Australia, 1976–2005	Ten convenience samples from approximately 280–770 adult men and women	Forty-two-item FFQ updated during the course of the study for consumption over 1-year periods	Food variety (unclear measurement)	Measured BMI	Food variety negatively associated with BMI in men ($\beta = -0{\cdot}18$; *P* = 0·01)	–
Kimura *et al.*[23]	Cross-sectional study of community-dwelling elderly adults, Qinghai, China, 2008	Convenience sample of 240 adults aged 60+ years (176 Han, sixty-four Tibetan)	Interview for food diversity over a 1-week period	Eleven-item FDSK-11 to assess variety within eleven food groups	Measured BMI	No significant difference among Han (23·4 *v.* 23·9 in high *v.* low diversity), non-significant association in Tibetan (25·8 *v.* 23·8 in high *v.* low diversity, *P* = 0·067)	NS
Gregory *et al.*[21]	Cross-sectional follow-up study of the INCAP Nutrition Cohort Study, Guatemala, 2002–4	Convenience sample of 1220 Guatemalan adults aged 25–42 years	Interviewer-administered fifty-two-item FFQ for consumption over the past 3 months	All scores based on foods consumed at least weekly including: FVS 1 point for every food, RFS with a maximum of 16, NRFS with a maximum of 15	Measured BMI and WC	FVS not significantly associated with BMI in men ($\beta = 0{\cdot}04$, 95 % CI −0·07, 0·16) or women ($\beta = -0{\cdot}03$, 95 % CI −0·1, 0·04). FVS not significantly associated with WC in men ($\beta = 0{\cdot}04$, 95 % CI −0·04, 0·1) or women ($\beta = -0{\cdot}01$, 95 % CI −0·09, 0·06)	NS
Azadbakht *et al.*[20]	Cross-sectional study part of TLGS, Iran, year unknown	Representative random sample of 581 male and female residents of Tehran 18+ years old	168-item semi-quantitative FFQ administered by dietitians for consumption over the past 1 year	DDS with five main groups and twenty-three subgroups	Measured BMI, WHR, WC and prevalence of BMI $\geq$30 kg/m^2	BMI higher in Q4 of DDS *v.* other quartiles and greater percentage of obese in Q4 (*P* < 0·05); no significant differences in WHR or WC by quartile of DDS. Odds of obesity greater in Q1 *v.* Q4 of DDS for vegetables (OR 1·39, 95 % CI 1·01, 1·51; *P* for trend < 0·03)	+ for BMI and for % obese, NS for WHR and WC
Azadbakht *et al.*[19]	Cross-sectional study part of TLGS, Iran, year unknown	Representative random sample of 581 male and female residents of Tehran aged 18–74 years	168-item validated semi-quantitative FFQ administered by dietitians for consumption over the past 1 year	DDS with five main groups and twenty-three subgroups	Measured BMI, WHR, WC, prevalence of BMI $\geq$30 kg/m^2 and WC > 88 or 102 cm in women and men	BMI significantly higher in Q4 *v.* other quartiles, no significant difference in WHR or WC. Significantly higher percentage of obese (23 %) in Q4 compared with other quartiles. NS trend for odds of abdominal adiposity (OR 0·88, 95 % CI 0·77, 1·35)	+ for BMI and for % obese, NS for WHR and WC

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Table 1. *Continued*

Reference	Study design, name, location and year	Sample characteristics (*n*, age, sex)	Dietary assessment method	Dietary diversity measure	Outcome measures	Results	Overall conclusion*
1 and 2d recalls							
Vandevijvere *et al.*[29]	Cross-sectional study from the BNFCS, Belgium, 2004–5	Nationally representative random sample of 3245 Belgian adults aged 15–75+ years	Two non-consecutive 24 h recalls using EPIC-SOFT validated software	Overall diversity: total number of food groups consumed. Within-food group diversity: total number of different foods within each food group	Self-reported BMI	No association between tertile of DDS and BMI (data not shown)	NS
Tande *et al.*[31]	Cross-sectional study from NHANES III, USA, 1988–1994	Nationally representative random sample of 15 658 US men and women aged 20–70+ years	One 24 h recall using the automated multiple-pass method	Diversity score based on the HEI measure of variety	Measured prevalence of abdominal adiposity as WC ≥88 or 102 cm in women and men	Women: HEI score 7·62 *v.* 7·37 in non-obese *v.* obese (OR 0·97, 95 % CI 0·944, 1·011; $P<0·03$). Men: HEI score 7·99 *v.* 7·90 in non-obese *v.* obese (OR 0·96, 95 % CI 0·92, 0·99; NS)	− in women NS in men
Mohindra *et al.*[27]	Cross-sectional study from the Bogalusa Heart Study, Bogalusa, USA, 1989–1991	Convenience sample of 504 young adults in Bogalusa, Louisiana aged 19–28 years	Single 24 h recall using standardised protocol and other quality controls	DDS with a range of 0–5	Measured prevalence of BMI <25, 25–29 or ≥ 30 kg/m^2	Compared with normal weight, higher DDS associated with a non-significant 11 % reduced risk of overweight (OR 0·89, 95 % CI 0·69, 1·14) and a 19 % reduced risk of obesity (OR 0·81, 95 % CI 0·62, 1·08)	NS−
Ervin *et al.*[25]	Cross-sectional study from NHANES 1999–2002, USA	Nationally representative random sample of 4976 adults aged 60+ years	One 24 h recall with the USDA multiple-pass method	Variety score based on the HEI measure of variety	Measured prevalence of BMI <25, 25–29, >30 kg/m^2	No significant difference in variety score by BMI category in either men or women ($P>0·05$)	NS
McCabe-Sellers *et al.*[26]	Cross-sectional telephone survey from the Foods of Our Delta Study (Mississippi, 2000) and data from NHANES 1999–2002, USA	Representative sample of 1699 adults from the Lower Mississippi Delta aged 18–60+ years	One 24 h recall with the USDA multiple-pass method	Variety score based on the HEI measure of variety	Self-reported and measured prevalence of BMI 19–25 or >25 kg/m^2	Variety score not associated with odds of overweight (OR 1·03, 95 % CI 0·99, 1·08)	NS
Ponce *et al.*[30]	Cross-sectional study from a larger study on nutrition transition and CVD risk, Mexico, year unknown	Random sample of 325 Mexican men aged 35–65 years	Two non-consecutive 24 h recalls administered by a trained research assistant	Variety based on the total number of twenty-four different food groups consumed over a 2 d period, DDS divided into five quartiles (maximum score of 4)	Measured prevalence of BMI <18·5, 18·5–24·9, 25–25·9, ≥30 kg/m^2	DDS scores were higher in obese (2·6 (SD 1·1)) men than normal-weight (1·9 SD (0·90)) men ($P=0·007$)	+
Roberts *et al.*[28]	Cross-sectional study of CSFII, USA, 1994–6	Nationally representative random sample of 1174 healthy white adults aged 21–90 years (adults 21–60 *v.* >61 years old)	Two interviewer-administered 24 h recalls using the multiple-pass method	Six variety scores: (1) total variety; (2) food group variety (0–5); (3) micronutrient-dense variety; (4) micronutrient-weak variety; (5) energy-dense variety; (6) energy-weak variety	Self-reported BMI and prevalence of BMI <22, 22–24·99, ≥25 kg/m^2	No significant difference in total variety or food group variety between BMI groups	NS

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Table 1. *Continued*

Reference	Study design, name, location and year	Sample characteristics (*n*, age, sex)	Dietary assessment method	Dietary diversity measure	Outcome measures	Results	Overall conclusion*
Kennedy *et al.*[32]	Cross-sectional study of CSFII, USA, 1994–6	Nationally representative random sample of 10 014 adults aged 19+ years	Two interviewer-administered non-consecutive 24 h recalls using the multiple-pass method	HEI measure of dietary variety	Measured BMI	Using linear contrast *t* tests, BMI was lower in men and women with higher variety scores if they consumed a diet with $>55\,\%$ energy from carbohydrates ($P<0·05$). There was no difference in BMI among those consuming high *v.* low variety if they consumed 30–55 % energy from carbohydrate	– for $>55\%$ carbohydrate and NS for 30–55% carbohydrate

DDS, Dietary Diversity Score; WHR, waist:hip ratio; WC, waist circumference; Q4, quartile 4; Q1, quartile 1; FDSK-11, Food Diversity Score Kyoto; INCAP, Institute of Nutrition of Central America and Panama; FVS, Food Variety Score; RFS, Recommended Foods Score; NRFS, Non-Recommended Foods Score; TLGS, Tehran Lipid and Glucose Study; BNFCS, Belgian National Food Consumption Survey; NHANES III, National Health and Nutrition Examination Survey III; HEI, Healthy Eating Index; USDA, US Department of Agriculture; CSFII, Continuing Survey of Food Intake by Individuals.

* + Denotes a positive association; – denotes an inverse association; NS denotes a non-significant association; NS– denotes a non-significant but inverse trend; NS+ denotes a non-significant but positive trend.

Foods Score was found to be protective against obesity in men over time (BMI: 25·4 *v.* 25·6 kg/m^2 in quartile 5 *v.* quartile 1; *P* for trend$<$0·001)[36]. However, the reverse was true among female nurses (BMI: 25·0 *v.* 24·7 kg/m^2 in quartile 5 *v.* quartile 1; *P* for trend$<$0·001)[36]. Similarly, Lyles *et al.*[38] found that variety in carbohydrates was inversely associated with BMI in women and positively associated with BMI in men, but it did not correlate with other measures of adiposity.

The remaining three cross-sectional studies noted no significant trends between variety in recommended foods and measures of adiposity[21,39,40]. Among Puerto Rican adults, there was no association between tertile of fruit and vegetable variety and BMI or percentage of abdominal adiposity[40]. Similarly, there was no significant relationship between Recommended Foods Score and BMI, or WC among male and female Guatemalan adults[21]. Among Brazilian adults, there was a borderline significant difference in the prevalence of obesity by tertile of healthy Dietary Diversity Score (10·6 *v.* 9·0 foods in quartile 3 *v.* quartile 1; *P*=0·05). However, it is important to note that these analyses examined approximately ten households as the average sampling unit rather than the individual. Overall, dietary variety in recommended foods is not adversely associated with body adiposity and, in some cases, may be protective.

Dietary variety among non-recommended foods and measures of body adiposity

Of the included studies, nine (four cross-sectional, one longitudinal and four intervention studies) examined the associations between the intake of non-recommended or energy-dense foods and measures of body adiposity. Of these, three of the four cross-sectional studies[28,33,38], one longitudinal study[41] and two of the four intervention studies noted positive associations[37,42], while the remaining three did not detect a significant association between dietary variety in non-recommended foods and measures of body adiposity[21,43,44].

Among the studies that detected a positive association, Woo *et al.*[41] found that variety in snack foods as well as the food variety ratio (i.e. the ratio of snack foods:grains and meats) increased the risk of overweight by 36–45 %. The food variety ratio was developed from a previous case–control study within Hong Kong Chinese adults that noted that variety within snack foods was positively correlated with the percentage of body fat, and waist and hip circumference, whereas variety in meats and grains was inversely correlated with these measures[45]. Variety among energy-dense foods, defined as carbohydrate-based foods with more than 10 % energy from fat, was associated with a higher BMI among US older adults ($\beta=0·12$; $P<0·001$)[28]. In younger adults, obese individuals reported greater variety in meats, pork, lamb, veal and other game when compared with their normal-weight counterparts ($P<0·05$)[33]. Similarly, Lyles *et al.*[38] noted that a 1-unit increase in fat and protein variety was associated with a 0·96 and a 1·98 kg/m^2 increase in BMI.

Also, two intervention studies support a relationship between dietary variety in some food categories and excess weight. In an 18-month weight-loss trial, Raynor *et al.*[37] noted that variety in high-fat foods was positively associated with body weight between 0 and 6 months ($\beta = 0{\cdot}26$; $P < 0{\cdot}01$) and between 6 and 18 months ($\beta = 0{\cdot}24$; $P < 0{\cdot}01$). Another intervention noted greater weight loss over a 7-week period among women randomised to a single cereal *v.* variety of cereal group[42].

However, three studies did not support an association between dietary variety in non-recommended foods and measures of body adiposity[21,43,44]. In one study among Guatemalan adults, the Non-recommended Foods Score was not significantly associated with BMI in men ($\beta = 0{\cdot}03$, 95 % CI $-0{\cdot}08$, $0{\cdot}14$) or women ($\beta = 0{\cdot}004$, 95 % CI $-0{\cdot}05$, $0{\cdot}06$). Additionally, the Non-recommended Foods Score was not significantly associated with WC in either sex[21]. There was no significant difference in body weight reduction (lifestyle + low variety: $-9{\cdot}9$ (SD 7·6) %); lifestyle: $-9{\cdot}6$ (SD 9·2 (%) in a recent trial where participants were randomised to standard weight-loss counselling *v.* standard counselling plus a low-variety condition, where they were asked to limit non-nutrient-dense, energy-dense variety to two foods over the 18-month follow-up period[44]. These results are consistent with a previous intervention, which did not detect a significant difference in weight loss among women choosing between a single snack *v.* a variety of snacks[43]. However, while women in the single snack condition did reduce their snack food variety, they did not limit snacks to a single food choice per the instructions. Incomplete compliance with intervention instructions may have attenuated their findings. Overall, greater variety in non-recommended food categories may adversely affect body adiposity measures. Fig. 2 summarises the key findings of the twenty-six studies included in this review.

Evaluation of study quality

There was some variation between the studies with respect to the five quality components considered (aforementioned in the Methods section). All twenty-six studies provided detailed information regarding their participant selection criteria and limited their populations to healthy adults. Target populations ranged in age from approximately 20 to 85 years and were drawn from both US and international populations, and more than 50 % of studies utilised random sampling techniques. Although measurement error exists with all self-reported dietary assessments, validated tools were used to measure dietary exposures in all but one included study[39]. Further, most studies utilised interviewer-administered assessments, tools developed for their target population and standardised protocols to enhance quality control of dietary data. The included studies incorporated techniques to minimise study design-related bias. For example, most cohort and intervention studies described rates of attrition and any observed differences between included and excluded participants. Furthermore, all intervention studies utilised appropriate randomisation techniques and blinded both researchers and participants when possible. Self-report bias was also reduced in most studies as trained

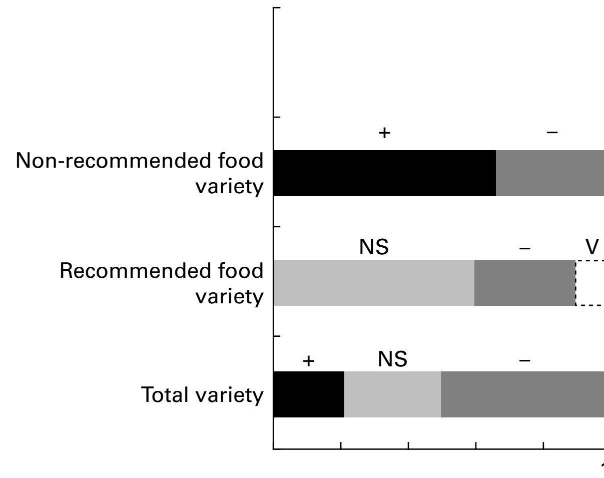

Fig. 2. Overview of results: summary of studies examining dietary variety and measures of body adiposity. +, Positive association; −, inverse association; NS, non-significant association; V, varied or mixed association. Fourteen cross-sectional studies examined the associations between total dietary variety and body adiposity measures. Seven studies reported non-significant associations ($P \geq 0{\cdot}05$)[21,23,25–29] (■), three reported positive associations[19,20,30] (■) and four reported inverse associations[18,22,31,32] (■). Ten studies examined the associations between variety in recommended foods and measures of body adiposity. Six studies reported inverse associations[28,33–37] (■). Three cross-sectional studies noted no significant trends between variety in recommended foods and measures of adiposity ($P \geq 0{\cdot}05$)[21,39,40] (■), and two studies had mixed findings that varied (V) differentially by sex [36,38] (⬚). Nine studies examined the associations between the intake of non-recommended or energy-dense foods and measures of body adiposity. Three of the four cross-sectional studies[28,33,38], one longitudinal study[41], and two of the four intervention studies noted positive associations[37,42] (■), while the remaining three did not detect a significant association between dietary variety in non-recommended foods and measures of body adiposity ($P \geq 0{\cdot}05$)[21,43,44] (■).

interviewers measured anthropometric measures that were used to define outcome variables used in the present review.

Some studies were primarily descriptive in nature, and consequently did not adjust for relevant confounding variables such as age, sex and smoking status[23,25,33]. Additionally, studies examining the associations between dietary variety and body adiposity as secondary outcomes did not sufficiently control for confounding[35,36]; however, these studies met other quality criteria. Finally, all studies utilised appropriate statistical methods such as multivariate regression.

Discussion

At present, there is no consensus in the understanding of the associations between dietary variety and measures of body adiposity. Dietary variety is hypothesised to influence body adiposity through increasing energy intake. Existing cross-sectional, longitudinal and experimental literature consistently support an association between dietary variety and energy intake[4]. Although definitions of dietary variety vary, the correlation between various measures of dietary variety and energy intake ranges from r 0·25 to 0·72, depending on the measure of dietary variety used, sex and race. Variety within recommended foods or within the broader five food groups is more weakly or non-significantly correlated with energy intake (r 0·25–0·37)[21,34,36,46,47] compared with overall variety

Table 2. Variety in recommended foods and food groups and measures of body adiposity

Reference	Study design, name, location and year	Sample characteristics (n, age, sex)	Dietary assessment method	Dietary diversity measure	Outcome measures	Results	Overall conclusion*
Cross-sectional studies							
Bezerra *et al.*[39]	Cross-sectional study using data from the 2002–3 Brazilian Household Budget Survey, Brazil	Representative sample of urban Brazilians of 35 237 households situated in 3393 urban primary sampling units aged 28–68 years	An open list of foods including amount	Healthy DDS that included the number of twenty-three healthy food groups purchased by the primary sampling units in a 7 d period	Measured BMI and prevalence of BMI ≥25 and ≥30 kg/m^2	Borderline significant difference in the prevalence of obesity by tertile of DDS (10·6 *v.* 9·0 foods in Q3 *v.* Q1; P=0·05). No significant trends for prevalence of overweight. Higher DDS associated with greater excess weight (β = 0·98; P=0·05)	NS+
Bhupathiraju *et al.*[40]	Cross-sectional study within the BPRHS, Boston, USA, 2004	1200 Puerto Rican adults aged 45–75 years	Validated semi-quantitative FFQ	Variety in FV intake = total number of unique FV consumed at least once/month	Measured BMI and abdominal adiposity (WC)	No significant difference in BMI (P=0·58) or the percentage of abdominal adiposity (P=0·89) by tertile of FV variety	NS
Gregory *et al.*[21]	Cross-sectional follow-up study of the INCAP Nutrition Cohort Study, Guatemala, 2002–4	Convenience sample of 1220 Guatemalan adults aged 25–42 years	Interviewer-administered fifty-two-item FFQ for consumption over the past 3 months	All scores based on foods consumed at least weekly including: FVS 1 point for every food, RFS with a maximum of 16, NRFS with a maximum of 15	Measured BMI and WC	RFS not significantly associated with BMI in men (β = 0·01, 95 % CI −0·09, 0·11) or women (β = −0·02, 95 % CI −0·07, 0·04). RFS not significantly associated with WC in men (β = 0·08, 95 % CI −0·01, 0·16) or women (β = 0·003, 95 % CI −0·09, 0·09)	NS
Brunt & Rhee[33]	Cross-sectional study of Canadian college students, Canada, year unknown	Convenience sample of 557 undergraduate students aged 18–56 years	Forty-two-item DVQ for consumption over past 3 d	Variety within food groups: five dairy; seven meat; three meat alternatives; five vegetables; five fruits; seven grains; seven fatty sugary snacks	Self-reported prevalence of BMI <19, 19–24·9, 25–25·9, >30 kg/m^2	Mean vegetable and grain variety was higher among normal weight *v.* obese (P= −0·01 and P=0·04, respectively)	−
Lyles *et al.*[38]	Cross-sectional study of former weight management participants, Alabama, USA, 2004–5	Convenience sample of seventy-four adults aged 22–75 years	4 d food records	Diabetic exchange-based variety score with unique foods able to count towards the carbohydrate, protein or fat variety score or multiple categories	Measured BMI, WC and body fat via DEXA	No significant correlation between BMI and Carbohydrate variety (r 0·14, P=0·55). Carbohydrate variety associated with a 0·62 kg/m^2 increased BMI in men and a 0·71 kg/m^2 decreased BMI in women (P=0·02). No significant association with other measures of adiposity	+ for BMI in men, − for BMI in women, NS for other adiposity measures

Table 2. *Continued*

Reference	Study design, name, location and year	Sample characteristics (*n*, age, sex)	Dietary assessment method	Dietary diversity measure	Outcome measures	Results	Overall conclusion*
Kant *et al.*[34]	Cross-sectional from NHANES III, USA, 1988–1994	Nationally representative random sample of 8719 healthy adults aged 20+ years	Single 24 h recall using the automated multiple-pass method	RFS (consumption of minimum amount of unique recommended food according to the Dietary Guidelines) and DDS-R score 0–5 based on five food groups and only counting foods recommended by the Dietary Guidelines	Measured BMI and prevalence of BMI <25, 25– <30, ≥30 kg/m^2	DDS-R and RFS significantly higher among normal weight *v.* obese ($P<0·01$); RFS and DDS-R inversely associated with BMI ($\beta=-0·18$ and $-0·38$, respectively; $P<0·00\,001$)	−
Roberts *et al.*[28]	Cross-sectional study of CSFII, USA, 1994–6	Nationally representative random sample of 1174 healthy white adults aged 21–90 years (adults 21–60 *v.* >61 years)	Two interviewer-administered 24 h recalls using the multiple-pass method	Six variety scores: (1) total variety; (2) food group variety (0–5); (3) micronutrient-dense variety; (4) micronutrient-weak variety; (5) energy-dense variety; (6) energy-weak variety	Self-reported BMI and prevalence of BMI <22, 22-24·99, ≥25 kg/m^2	Energy-weak variety associated with a lower BMI (2·7 (SEM 0·1) *v.* 2·4 (SEM 0·1), $P\leq0·05$ in adults with BMI <22 *v.* ≥25 kg/m^2). No association between micronutrient-dense variety and BMI was noted	−
Kant *et al.*[35]	Cross-sectional study from the National Health Interview Surveys, USA, 1987 and 1992	Nationally representative random sample of 10 084 adults aged 45+ years	Sixty-item semi-quantitative Block FFQ administered at baseline	RFBS with a maximum score of 25 for weekly consumption of twenty-three recommended foods and two positive dietary behaviours	Self-reported BMI	Higher RFBS category had a lower proportion of individuals with BMI > 25 kg/m^2 (48·1 *v.* 54·4 % in Q4 *v.* Q1; $P<0·0001$)	−
Longitudinal studies							
McCullough *et al.*[36]	Longitudinal study with 8–12 years follow-up with the sample from the Health Professionals Follow-up Study and the Nurses' Health Study beginning in 1986 and 1976, respectively, USA	Convenience sample of 38 615 male and 62 271 female health professionals	130-item semi-quantitative FFQ administered 1986 and 1990 in men; 1984, 1986 and 1990 in women	RFS: number of twenty-three recommended foods consumed at least weekly	Self-reported BMI	In men, BMI was lower in Q5 *v.* Q1 of RFS (25·4 *v.* 25·6; *P* for trend <0·001). In women, BMI was higher in Q5 *v.* Q1 of RFS (25·0 *v.* 24·7; *P* for trend <0·001)	− for men, + for women
Intervention studies							
Raynor *et al.*[37]	Randomised controlled trial with a 18-month follow-up period with subjects from Minnesota and Providence, RI, USA, year unknown	Convenience sample of 122 overweight men and women aged 25–50 years at baseline	Self-administered sixty-item semi-quantitative Block FFQ at 0, 6 and 18 months	Dietary variety within seven main food groups expressed as a percentage (number of foods in group consumed weekly/total number of foods in group) × 100	Measured body weight (kg)	From 6 to 18 months, variety in low-fat breads was negatively associated with body weight ($\beta=-0·25$; $P<0·01$)	−

DDS, Dietary Diversity Score; Q3, quartile 3; Q1, quartile 1; BPRHS, Boston Puerto Rican Health Study; FV, fruits and vegetables; WC, waist circumference; INCAP, Institute of Nutrition of Central America and Panama; FVS, Food Variety Score; RFS, Recommended Foods Score; NRFS, Non-Recommended Foods Score; N/A, not available; DVQ, Diet Variety Questionnaire; DEXA, dual-energy X-ray absorptiometry; NHANES III, National Health and Nutrition Examination Survey III; DDS-R, Dietary Diversity Score for Recommended Foods; RFBS, Recommended Foods and Behavior Score, Q4, quartile 4.

* + Denotes a positive association; − denotes an inverse association; NS denotes a non-significant association; NS− denotes a non-significant but inverse trend; NS+ denotes a non-significant but positive trend.

Table 3. Variety in non-recommended foods and food groups and measures of body adiposity

Reference	Study design, name, location and year	Sample characteristics (*n*, age, sex)	Dietary assessment method	Dietary diversity measure	Outcome measures	Results	Overall conclusion*
Cross-sectional studies							
Gregory *et al.*[21]	Cross-sectional follow-up study of the INCAP Nutrition Cohort Study, Guatemala, 2002–4	Convenience sample of 1220 Guatemalan adults aged 25–42 years	Interviewer-administered fifty-two-item FFQ for consumption over the past 3 months	All scores based on foods consumed at least weekly including: FVS 1 point for every food, RFS with a maximum of 16, NRFS with a maximum of 15	Measured BMI and WC	NRFS not significantly associated with BMI ($\beta = 0{\cdot}03$, 95 % CI $-0{\cdot}08$, 0·14) in men or women ($\beta = 0{\cdot}004$, 95 % CI $-0{\cdot}05$, 0·06). NRFS not significantly associated with WC ($\beta = -0{\cdot}01$, 95 % CI $-0{\cdot}08$, 0·07) in men or women ($\beta = -0{\cdot}001$, 95 % CI $-0{\cdot}09$, 0·09)	NS
Brunt & Rhee[33]	Cross-sectional study of Canadian college students, Canada, year unknown	Convenience sample of 557 undergraduate students aged 18–56 years	Forty-two-item DVQ for consumption over past 3 d	Variety within food groups five dairy; seven meat; three meat alternatives; five vegetables; five fruits; seven grains; seven fatty sugary snacks	Self-reported prevalence of BMI <19, 19–24·9, 25–25·9, >30 kg/m^2	Meat variety score higher in obese *v.* normal weight ($P = 0{\cdot}01$)	+
Woo *et al.*[41]	Longitudinal study from the Dietary and Cardiovascular Risk Prevalence Survey, Hong Kong, 1995–2004	Random sample of 1010 Chinese adults living in Hong Kong aged 25–74 years	Validated FFQ with seven broad categories and 266 items	Food variety ratio-variety of food groups inversely correlated with body fatness: variety of food groups positively correlated with body fatness	Measured incidence of BMI >23, 25–29 and >30 kg/m^2	Food variety ratio associated with 36 % greater odds of overweight (OR 1·36, 95 % CI 1·01, 1·82). Snack variety associated with 45 % greater odds of overweight (OR 1·45, 95 % CI 1·06, 1·98)	+
Lyles *et al.*[38]	Cross-sectional study of former weight management participants, Alabama, USA, 2004–5	Convenience sample of seventy-four adults aged 22–75 years	4 d food records	Diabetic exchange-based variety score with unique foods able to count towards the carbohydrate, protein or fat variety score or multiple categories	Measured BMI, WC and body fat via DEXA	Fat (r 0·33) and protein (r 0·36) variety positively correlated with BMI ($P < 0{\cdot}05$), 1-unit increase in fat and protein variety associated with a 0·96 and 1·98 kg/m^2 increase in BMI. No significant association with other measures of adiposity	+ for BMI, NS for other adiposity measures
Roberts *et al.*[28]	Cross-sectional study of CSFII, USA, 1994–6	Nationally representative random sample of 1174 healthy white adults aged 21–90 years (adults 21–60 *v.* >61 years old)	Two interviewer-administered 24 h recalls using the multiple-pass method	Six variety scores: (1) total variety; (2) food group variety (0–5); (3) micronutrient-dense variety; (4) micronutrient-weak variety; (5) energy-dense variety; (6) energy-weak variety	Self-reported BMI and prevalence of BMI <22, 22–24·99, ≥ 25 kg/m^2	Energy-dense variety positively associated with BMI ($\beta = 0{\cdot}118$; $P < 0{\cdot}001$); interaction by age group and BMI with low BMI older adults with less energy-dense variety than higher BMI older adults. No significant association between BMI and micronutrient-weak variety was noted	+

Table 3. *Continued*

Reference	Study design, name, location and year	Sample characteristics (*n*, age, sex)	Dietary assessment method	Dietary diversity measure	Outcome measures	Results	Overall conclusion*
Intervention studies							
Raynor *et al.*[44]	Randomised intervention study from Providence, RI and Knoxville, TN, USA, 2006–9	Convenience sample of 202 overweight adults aged 21–65 years	Three random (two weekdays, one weekend) 24 h recalls via phone over a 1-week period at 0, 6, 12 and 18 months	Subjects randomised to one of two 18-month weight-loss interventions: (1) Standard lifestyle counselling or (2) Lifestyle + low variety where subjects chose two non-nutrient-dense, energy-dense foods to eat during the study	Measured percentage of weight loss	No significant difference in the percentage of weight loss was observed at 18 months (−9·9 (SD 7·6) *v.* −9·6 (SD 9·2) % in the intervention *v.* control group)	NS
Raynor *et al.*[43]	Randomised intervention study with subjects from Providence, RI, USA, year unknown	Convenience sample of thirty overweight adults aged 21–65 years	8-week food diaries with weekly feedback to increase dietary adherence	Subjects randomised to one of two 8-week weight-loss interventions: (1) Reduced variety – subjects chose one very liked snack to eat ≥4 times/week; (2) Control – limit portion size of snack foods	Measured weight at 0 and 9 weeks and BMI	No significant difference in BMI or weight loss between the two groups (each group met dietary prescription of 8 lb weight loss)	NS
Raynor *et al.*[37]	Randomised controlled trial with a 18-month follow-up period with subjects from Minnesota and Providence, RI, USA, year unknown	Convenience sample of 122 overweight men and women aged 25–50 years at baseline	Self-administered sixty-item semi-quantitative Block FFQ at 0, 6 and 18 months	Dietary variety within seven main food groups expressed as a percentage (number of foods in group consumed weekly/total number of foods in group) × 100	Measured body weight (kg)	From 0 to 6 and 6 to 18 months, variety in high-fat foods was associated with an increase in body weight ($\beta = 0{\cdot}26$; $P< 0{\cdot}01$) and ($\beta = 0{\cdot}24$; $P< 0{\cdot}01$), respectively	+
Mattes *et al.*[42]	7-week intervention study with subjects from Indiana, USA, year unknown	Convenience sample of 109 weight- and activity-stable adults between the ages of 20–60 years, with a BMI 25–35 kg/m^2	3 d food records	Group 1: replace one meal with a single variety of cereal and fruit. Group 2: replace one meal with a variety of cereal and fruit. Groups 3 and 4: diet and non-diet control	Measured body weight and fat mass via bioelectric impedance	Change in body weight was greatest in the single cereal compared with a variety of cereal group (P=0·025), no significant difference in fat mass change except in the first 2 weeks. The variety group lost significantly more weight than the non-diet control group ($P< 0{\cdot}001$), but not more than the diet control group (P=0·09).	+

INCAP, Institute of Nutrition of Central America and Panama; FVS, Food Variety Score; RFS, Recommended Foods Score; NRFS, Non-Recommended Foods Score; WC, waist circumference; N/A, not available; DVQ, Diet Variety Questionnaire; DEXA, dual-energy X-ray absorptiometry; CSFII, Continuing Survey of Food Intake by Individuals.

* + Denotes a positive association; − denotes an inverse association; NS denotes a non-significant association; NS− denotes a non-significant but inverse trend; NS+ denotes a non-significant but positive trend.

or variety within energy-dense or non-recommended foods (r 0·30–0·72)[21,46,48–51]. Importantly, weight-loss participants with greater variety in energy-dense foods consume more energy each day, and those who restrict variety in some food groups may be more effective at reducing energy intake compared with those who only practise portion control[37,43]. Given the strength of the association between dietary variety and energy intake, it is important to examine whether dietary variety also influences body adiposity.

We reviewed a total of twenty-six studies examining the associations between varying definitions of dietary variety and measures of body adiposity. We noted that the relationship between dietary variety and body adiposity is multifaceted and moderated by the foods or food groups used to measure dietary variety. Furthermore, total food variety has been multiply defined and measured across studies, limiting comparisons between studies. Taken together, studies that assess usual total dietary variety (i.e. total variety over more than a 2 d period) found that dietary variety is either protective against overweight and obesity or does not influence body adiposity[18,21–23]. This is consistent with the hypothesis that a total diet approach is necessary to achieve nutrient adequacy within the diet[52]. However, this association was more volatile when studies assessed usual dietary variety using one or two 24 h recalls; five of the nine studies examined reported non-significant findings, though many approached significance and varied in whether they were positively or inversely associated with adiposity measures. When variety measurements are limited to only healthful or recommended foods, we consistently observe that dietary variety is either inversely associated with measures of body adiposity or does not substantively influence adiposity in most populations. Conversely, when variety measures only include non-recommended or energy-dense foods, greater variety is reliably associated with increased measures of adiposity, though associations become less consistent among intervention studies.

Although the relationship between dietary variety and excess adiposity is complex, it is important to consider the factors that contribute to a limited understanding of the relationship between dietary variety and body adiposity. In part, relying on self-reported weight and height to calculate BMI may introduce bias, as underestimation of weight and overestimation of height are common in some populations[53]. Additionally, the clinical relevance of adiposity outcome measures should be taken into consideration. While the present review noted inconsistencies between dietary variety and obesity using all measures of adiposity (BMI, WC, WHR and percentage of body fat), some of these measures (e.g. WHR) are more predictive of chronic disease risk, and therefore may be more appropriate for assessing the diet–disease relationship[54]. For example, Iranian adults who consumed a more varied diet had a higher BMI than adults who consumed a less varied diet; however, there was no difference in measures of abdominal adiposity, and adults consuming varied diets had better metabolic profiles[19]. However, only eight of the twenty-six studies used a method other than BMI to determine excess adiposity, which limits our understanding of the association between dietary variety and obesity.

Consistent and comprehensive definitions of dietary variety are also needed to clarify the relationship between dietary variety and excess adiposity. Importantly, the definition and measurement of total variety appear to be inconsistently assessed across studies, which limits comparison across studies. The number and healthfulness of the food groups included in the variety scores differ considerably across studies, which also limits accurate assessment. When dietary variety scores only measure variety within recommended foods or non-recommended foods, they exclude other food groups that may affect measures of body adiposity in the context of the total diet. Similarly, pure count methods introduce bias because individuals may be misclassified or insufficiently distinguished from one another. When the diet is divided into food groups that individuals either consume or do not consume in the time period examined, an individual who eats a single serving of fruit is categorised identically to the person who consumes three servings, for example[9]. These techniques have the effect of constraining variety scores within food groups, which also have the effect of attenuating risk associations by failing to distinguish between individuals who consume a minimally varied diet *v.* a highly varied diet.

Dietary proportionality and quality components are also missing from existing scores, which are important confounders in the relationship between dietary variety and excess adiposity. National recommendations provide guidance on the proper balance of each food group in the diet (i.e. proportionality), and it is possible that variety in energy-dense sources is less detrimental to body weight when consumed in appropriate portions. Moreover, most dietary variety scoring methods used in epidemiological studies fail to account for dietary quality. This means that an individual who consumes a large number of nutrient-dense foods will receive the same score as an individual who consumes the same number of nutrient-poor foods. Consequently, the failure to include (1) all foods consumed, (2) a measure of proportionality and (3) a dietary quality component in dietary variety scores probably contributes to the mixed findings between dietary variety and measures of body adiposity within the literature.

Measurement error associated with diet assessment methods may also adversely affect conclusions[55]. Dietary variety as assessed from one or two 24 h recalls may not capture true usual long-term intake[24], and, without appropriate statistical adjustment, is insufficient for assessing the association between dietary variety and body adiposity. FFQ are designed to measure usual intake, but are prone to random and systematic error[56], which may be especially problematic in the context of assessing dietary variety. There is high participant recall burden when trying to report usual intake over an extended period of time, which can be especially difficult with episodically consumed foods. Additionally, predefined food lists artificially constrain variety measurement and may exclude a number of foods consumed by various cultural groups. These biases are amplified in the context of assessing causal relationships from primarily cross-sectional studies.

Further, study populations require careful consideration, as small or non-representative populations can introduce bias and make conclusions non-generalisable to the larger

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population. Notably, many of the experimental studies are small ($n < 200$) and use successful weight-loss participants, who differ substantively from the general US population. Similarly, generalisability may be problematic when extrapolating data from populations undergoing nutrition transitions or with a relatively low socio-economic status. Dietary variety has been shown to increase proportionally with income, and foods that are selected are typically highly palatable, energy-dense items[57,58]. Consequently, this may confound associations when analyses do not adjust for socio-economic status.

In summary, we are limited in our ability to draw strong inferences from the existing research for a number of reasons. First, study outcomes vary between studies and may have limited clinical relevance. Definitions of total variety, variety in recommended foods and variety in non-recommended foods are inconsistent. Further, measurement error in dietary assessment instruments is not sufficiently addressed statistically, which results in biased estimates. Additional bias is introduced because important confounding variables are not accounted for when count-based scores are employed. Finally, the use of non-representative populations limits the generalisability of conclusions.

The present systematic review addresses a number of gaps in the existing literature. By thoroughly examining all relevant studies and methods for assessing dietary variety, we are able to provide a more specific understanding of the ambiguities in the existing literature. We concur with Kennedy[2] that observed inconsistencies are partly a consequence of the varying definitions and measures of dietary variety used within nutrition studies. However, this review also detected important gaps that limit the robustness of existing conclusions including: (1) insufficient use of clinically relevant outcomes; (2) measurement error and bias in the assessment of dietary variety; (3) inconsistent definitions of dietary variety; (4) excessive generalisation based on non-representative samples.

In conclusion, the present review is an important first step in clarifying the associations between dietary variety and excess adiposity, which is currently limited by the methods used to assess variety. In the present review, we found that (1) dietary variety within recommended and low-energy foods alone do not increase the odds of overweight and obesity, (2) greater variety within less healthful, energy-dense foods increases the odds of overweight and obesity and (3) the association between total dietary variety and adiposity is mixed and accurate evaluation of this association requires a consistent and theoretically valid measurement tool.

The clinical implications of these conclusions are noteworthy. Dietary variety recommendations have largely been removed from the US Dietary Guidelines secondary to the concern about its association with excess energy intake and adiposity. While it may be prudent to avoid broadly recommending dietary variety, limitations in the measurement and interpretation of these constructs may be generating excessive caution. Dietary variety must be understood utilising a total diet approach in order to make concrete recommendations, and the methods used to measure dietary variety must move beyond simple count methods.

Future research requires a dietary variety scoring method that captures all distinct foods consumed in the diet along with a measure of proportionality and a measure of quality in order to accurately assess the associations between dietary variety and excess adiposity. Using a comprehensive dietary variety score to evaluate these associations in a large, nationally representative US sample will help clarify this relationship and provide researchers with a tool that can be used cross-culturally in order to more effectively and consistently evaluate the associations between dietary variety and adiposity. A clear understanding of the role of dietary variety in obesity management is important in the context of the current obesity epidemic and may aid in the development of simple, actionable national nutrition recommendations to facilitate healthful weight management.

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