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Diet and body fat in adolescence and early adulthood: a systematic review of longitudinal studies

Dieta e gordura corporal na adolescência e início da vida adulta: uma revisão sistemática de estudos longitudinais

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Abstract *Adipose tissue is a vital component of the human body, but in excess, it represents a risk to health. According to the World Health Organization, one of the main factors determining excessive body adiposity is the dietary habit. This systematic review investigated longitudinal studies that assessed the association between diet and body fat in adolescents and young adults. Twenty-one relevant papers published between 2001 and 2015 were selected. The most used method for estimating body fat was the body mass index (15 studies). Diet was most commonly assessed by estimating the consumption of food groups (cereals, milk and dairy products) and specific foods (sugar-sweetened beverages, soft drinks, fast foods, milk, etc.). Ten studies found a direct association between diet and quantity of body fat. During adolescence, adhering to a dietary pattern characterized by high consumption of energy-dense food, fast foods, sugar-sweetened beverages and soft drinks, as well as low fiber intake, appears to contribute to an increase in body fat in early adulthood. The findings of the present study suggest that the frequent consumption of unhealthy foods and food groups (higher energy density and lower nutrient content) in adolescence is associated with higher quantity of body fat in early adulthood.*

Key words *Diet, Body fat, Adolescent, Early adulthood*

Resumo *O tecido adiposo é um componente vital do corpo humano, mas em excesso representa risco à saúde. Conforme a Organização Mundial da Saúde, um dos principais fatores determinantes do excesso de peso é o hábito alimentar. Essa revisão sistemática investigou estudos longitudinais que avaliaram a relação entre dieta e gordura corporal em adolescentes e adultos jovens. Vinte e um artigos publicados de 2001 a 2015 foram selecionados. O método mais utilizado para estimar gordura corporal foi o índice de massa corporal (15 estudos). A dieta foi avaliada principalmente pelo consumo de grupos alimentares (cereais, leite e produtos lácteos) e alimentos específicos (bebidas açucaradas, refrigerantes, "fast foods", leite e etc.). Dez estudos encontraram uma associação direta entre dieta e quantidade de gordura corporal. Um padrão alimentar com alto consumo energético e de gordura e baixo de fibras e o hábito de consumir "fast foods", bebidas açucaradas e refrigerantes na adolescência, contribuíram para um aumento da gordura corporal no início da vida adulta. Os achados deste estudo sugerem que o consumo de alimentos específicos e grupos de alimentos não saudáveis (alta densidade energética e baixo conteúdo de nutrientes) na adolescência e início da vida adulta estão associados com maior quantidade de gordura corporal.*

Palavras-chave *Dieta, Gordura corporal, Adolescente, Adulto jovem*

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Introduction

Adipose tissue is a vital component of the human body. It helps maintain thermal homeostasis and is the main energy store during periods of nutritional shortage[1]. The total body fat (BF) content oscillates throughout life, and although varying widely among populations, it generally represents around 15% of men's body weight and 25% of women's body weight[1,2].

Obesity is defined as an abnormal or excessive fat accumulation that poses a risk to health[3]. A crude population measure of obesity is the body mass index (BMI), calculated by dividing a person's weight (in kilograms) by the square of its height (in meters). An individual with a BMI ≥ 30 kg/m² is considered as obese[3]. Obesity is an independent risk factor for the development of cardiovascular diseases (CVD) and is associated with a shortening of life expectancy at the population level[3,4]. According to the World Health Organization, over 1.9 billion adults aged 18 years or more were overweight in 2014. Of these, over 600 million were obese[5]. The etiology of excess BF is multifactorial, involving biological, economic, social and cultural aspects. Among these factors, a positive energy balance is considered as a direct determinant of fat accumulation[6,7]. The frequent consumption of high energy-dense food, rich in simple sugars, saturated fat, sodium, and food additives, as well as low fiber and micronutrients intake, have been associated with excessive accumulation of BF[8].

Adolescence is a critical period for the development of obesity[1]. There is an increase in the number of adipose cells, frequent in the morphologic and physiologic changes associated with inadequate dieting, elevate the risk of developing obesity[1,7].

To our best knowledge, no systematic review or meta-analysis has been conducted addressing the relationship between diet and excess BF in adolescents and young adults. Therefore, the aim of the present study was to investigate the longitudinal association of diet on the amount of BF, in adolescents and young adults, through a systematic review.

Methods

Search strategy

Articles indexed on the *U.S National Library of Medicine and the National Institutes Health* (PubMed) electronic database and published up to March 2015 were searched. We opted to conduct searches only in this database because a previous study has shown that the large majority of articles on this topic is available in PubMed.

A combination of terms involving the exposure (diet), the outcome (body fat), age group (adolescence and early adulthood) and study design (longitudinal) was employed. The following search terms were selected: "(*body fat* OR *fat mass* OR *adiposity*) AND (*diet* OR *food consumption* OR *pattern diet* OR *dietary pattern* OR *food intake* OR *dietary food*) AND (*adolescent* OR *adolescence* OR *teenage* OR *teenager* OR *young adult* OR *early adult*) AND (*longitudinal studies* OR *cohort* OR *prospective* OR *follow up* OR *panel*)". We included only those articles published in Portuguese, Spanish and English, in which the selected search terms appeared in the title and/or abstracts.

In addition, the references cited in the selected articles were reviewed in order to identify other potentially eligible studies.

Eligibility Criteria

The following eligibility criteria were adopted: 1) to have a longitudinal design; 2) to address the relationship between diet and BF; 3) to evaluate the exposure during adolescence (age 10 to 19 years); 4) to evaluate the outcome during adolescence or early adult life.

We considered as eligible all studies applying any available method to estimate the body fat (BF), such as BMI, skinfold thickness, fat mass index (FMI) and adiposity index (AI). Similarly, studies using any available method for assessing diet were considered, including the assessment of specific food or nutrients, food groups, macronutrients (carbohydrate, protein and fat), energy consumption, dietary patterns (DP) or dietary index.

Selection of studies

Two authors of the article (B.C.S. and S.P.O.) carried out, independently, the selection of the studies. Initially, the articles were retrieved from an electronic database and, subsequently, the abstracts were reviewed considering the eligibility criteria. A third evaluator (S.C.D.) conducted the assessment of the articles in case of absence of consensus.

The development and presentation of this study followed the recommendations of the

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MOOSE - *Meta-analysis of Observational Studies in Epidemiology*[9], which is a checklist that summarizes the main specifications that must be considered in systematic reviews of observational studies.

Exploratory data analysis

From each of the articles selected, we extracted data on the study site and year of publication, sample size, population under study, age of participants at baseline, follow-up period, method and tool used to evaluate diet, body measurements, equipment used to evaluate BF, periods of evaluation of exposure and outcome, main findings and adjustment variables.

Results

Initially, 1,062 titles were retrieved. Based on the eligibility criteria, the researchers selected 23 articles for deeper analysis, one of which was identified through the revision of the references cited in the selected articles. Of the studies initially selected, the reviewers disagreed over twelve articles and, after assessment by a third reviewer (S.C.D.), three of those were excluded. The main reasons for disagreement between the reviewers were related to the age at the assessment of the exposure or of the outcome. Studies that assessed body fat only in adulthood were excluded. At the end of the selection process, 21 articles matched the eligibility criteria. Further details of the selection process are shown in Figure 1.

The selected studies were published between 2001 and 2015 and half of them were carried out in the United States. The samples varied from 196[10] to 14,610[11] individuals, with an average size of 2645.5 (SD = 3849.3) and median of 856. Four studies included only females[10,12-14]. The age at baseline ranged from two[15] to 18 years old[16,17]. Follow-up had a minimal duration of two years[11,18,19] and maximum of 13 years[15,20]. The average duration of follow-up was 6.0 years (SD = 2.9) and median of five years. Chart 1 presents details of the articles selected.

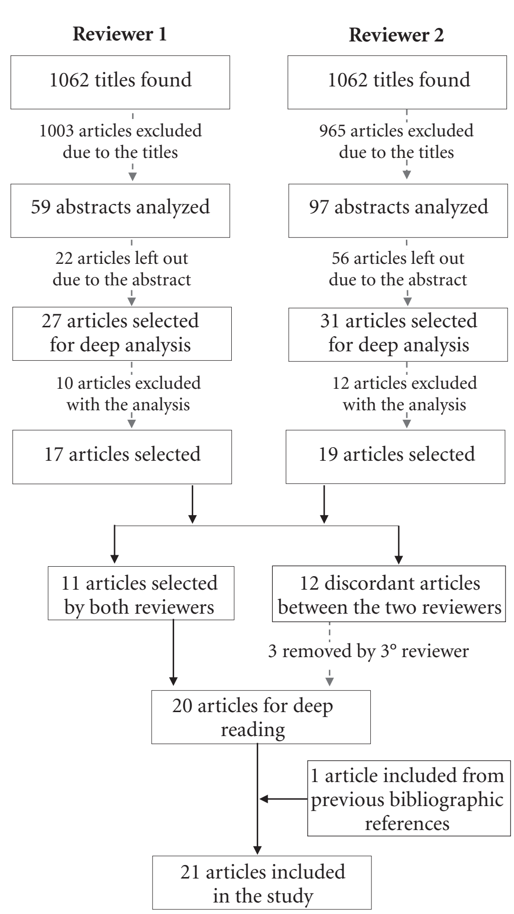

Figure 1. Selection of scientific articles flowchart.

Dietary evaluation methods

The exposure (diet) was evaluated using several methods, such as food group consumption (milk and dairy products, cereals, etc.) by six studies[10,12,19,21-23], specific food (sugar-sweetened beverages, soft drink, fast food, etc.) by seven[11,16-18,24-26], macronutrients (carbohydrate, protein and fat) by three[15,27,28], total energy intake by one[29], dietary index by one[13] and DP by three investigations[14,20,30]. The tools used for estimating food consumption were the food frequency questionnaire (FFQ) in ten studies[10-12,19,22,25,26,28-30], food record (FR) in nine[14-17,20,21,23,27] and 24-hour recall (R24h) in three studies[12,18,24]. The use of FFQ together with R24h was observed in one study[12].

Body Fat evaluation methods

The BF outcome was evaluated based on BMI in fifteen studies[10,11,14-19,22,23,25,26,28-30], %BF in thirteen[10-14,16-18,21,24,26,28,29], BF kg in two[23,25], FMI or AI in two[20,27] and skinfold – tricipital (TS) and subscapular (SS) – thickness in one study[15].

Chart 1. Summary of selected articles.

Author, Year Country	Sample	Exposure	Outcome	Main findings
Bigornia et al., 2014 U.S.A	- N: 2,455; - Age: 10 years (baseline) followed until 13 years; Participants of the *Avon Longitudinal Study of Parents and Children* (ALSPAC).	- Diet: dairy consumption (total, full, and reduced fat) in grams/day; - Instrument: 3 days food records;	- Body Mass Index (BMI): Weight (kg)/ height $(m)^2$ studied like overweight (25 kg/m2) and obese (30 kg/m2); - Excess adiposity: top 20% of Total Body Fat Mass in kg (TBFM) measure by dual-energy X-ray absorptiometry and adjusted for age, height and sex; Analyzed at 13 years of age.	The highest vs. lowest quartile of total dairy consumers at 10 years did not have an increased risk of excess TBFM and BMI at 13 years; Adjustments for age 10 y, gender, height at 10 y, total dairy at 13 y, adiposity at 10 y, maternal education, maternal overweight status, physical activity at 13 y, pubertal stage at 13 y, dieting at 13 y, age-10-y intakes of fruit juice, fruit and vegetables, total fat, total protein, sugar-sweetened beverages, fiber, and cereal, dietary reporting errors at 13 y and total dairy intakes.
Assmann et al., 2013 Germany	- N: 140 female and 122 male; - Age: girls 9-14 years and boys 10-15 years in baseline and followed in young adulthood (18-25 years); - Participants of the DONALD Study.	- Diet: habitual animal and plant protein intake; - Instruments: 3-day weighed food records; Dietary variables were presented energy-adjusted tertiles of intake.	- Fat Mass Index (FMI): percentage body fat (%BF) * body mass) /100. To estimate %BF was use from triceps, biceps, scapular and iliac skinfolds using Durnin and Womersley equations; Analyzed at in young adulthood.	In men, a higher animal protein intake was related to lower FMI (3.4 kg/m; 95% CI 3.0-3.8; ptrend = 0.001); The plant protein intake was not associated with FMI among either sex; Adjustments for free fat mass index (FFMI) in adulthood, FMI at baseline, breast feeding, birth weight, maternal overweight, maternal education, status, glycemic index, intakes of fiber, calcium and energy.
Gopinath et al., 2013 Australia	- N: 856; - Age: 12 at baseline and followed for 5 years.	- Diet: glycemic index (GI), glycemic load (GL) of diets and intakes of carbohydrate, sugars, fiber and the main carbohydrate containing food groups (vegetables, fruits, cereals and soft drinks); Measured at 12 years; - Instrument: semi quantitative FFQ.	- Body Fat Percentage (%BF): bioimpedance analysis; - BMI: Weight (kg)/ height $(m)^2$; Measured at 17 years;	In girls, each 1SD increase in dietary GL was associated with a concurrent 0.77 kg/ m2 increase in BMI ($p < 0.01$), and each 1SD increase in dietary fiber intake was associated with a concurrent 0.44 kg/m2 decrease ($p < 0.02$); In girls, soft drinks consumption 1 or more time per day vs. never/rarely consumed, had a 4.5% increase in %BF after 5 years ($p < 0.01$). Adjustments for age, ethnicity, parental education, passive smoking, change in energy intake and height, screen viewing time and physical activity.

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Chart 1. continuation

Author, Year Country	Sample	Exposure	Outcome	Main findings
Ambrosini et al., 2012 United Kingdom	- N: 6,772; - Age: 7 years old (baseline) followed until 15 years old; - Participants of the *Avon Longitudinal Study of Parents and Children* (ALSPAC).	- Diet: an energy-dense, high-fat and low-fiber Dietary Pattern (DP) designed by principal component analysis (PCA); - Instruments: Food record of 2 weekdays and 1 weekend day completed by the 7, 11 and 13-year-old participants; DPs were presented in z-scores and quintiles;	- Fat Mass Index (FMI): (FM(kg) / Height(m))^x, in which x = log FM/ log height and varies according to gender and age. FMI was log-transformed to obtain normal distributions, standardized to a *z*-score and divided in quintiles. Individuals in the top quintile of FMI *z*-scores were classified as having "excess adiposity". Analyzed at 11, 13 and 15 years of age.	Positive association between DP *z*-scores at 13 years and FMI at 15 years. A 1 SD unit increase in DP *z*-score was associated with an increase in FMI *z*-score of 0.03 SD units (95% confidence interval (CI), 0.01–0.05). Adjustments for gender, age of evaluation, dietary misreporting, physical activity at 11 years. The association had no appreciable effect. With each 1SD unit increase in DP z-score, the odds of excess of adiposity increased by 0.13 (CI95% 0.01–0.27). Adjustment for pubertal development + maternal education and pregnancy BMI.
Fraser et al., 2012 United Kingdom	- N: 14,610; - Age: 13 years followed until 15 years; - Participants of the ALSPAC.	- Diet: fast foods; - Instruments: Food Frequency Questionnaire (FFQ); Analysed at 13 years of age.	- BMI: Weight (kg)/ height (m)^2; - %BF: verified with Dual energy x-ray absorptiometry (DEXA); Analyzed at 13 and 15 years of age.	The consumption of fast food was associated with a higher BMI SD score (β = 0.08, 95% CI = 0.03, 0.14); higher %BF (β = 2.06, 95% CI = 1.33, 2.79); and increased odds of being obese (OR = 1.23, 95% CI = 1.02, 1.49). Adjustment for gender, physical activity and food consumption.
Laska et al., 2012 U.S.A.	- N: 693; - Age: average of 14.6 years of age. Followed for 2 years; - Participants of the *Identifying Determinants of Eating and Activity* (IDEA) and *Etiology of Childhood Obesity* (ECHO).	- Diet: sugar-sweetened beverage, diet soda, breakfast and fast food; - Instruments: 24h dietary recalls and questions about food consumption from the previous month; Consumption measured at baseline.	- BMI: Weight (kg)/ height (m)^2; - %BF: Bioelectrical Impedance; Body composition measured in a follow-up assessment, 24 month after baseline.	There was no statistically significant association between the consumption of sugar-sweetened beverage, diet soda, fast food, and breakfast and BMI and %BF; Adjustment for physical activity, pubertal development, socioeconomic status, race/ ethnicity, parents education, age and total energy intake.

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Chart 1. continuation

Author, Year Country	Sample	Exposure	Outcome	Main findings
Feeley et al., 2012 South Africa	- N: 1,298; - Age: 13 (baseline), 15 and 17 years; - Participants Birth to twenty (Bt20) study.	- Diet: snacking while watching television, fast-food consumption, confectionery consumption and sweetened beverage consumption, etc.; Instruments: unquantified FFQ; Measured at 13. 15 and 17 years.	- BMI: Weight (kg)/ height (m)^2; - Fat Mass (kg): dual-energy X-ray absorptiometry; Measured at 17 years.	In males, the sweetened beverage consumption > 2times/week at 13 years was positively associated with both BMI Z-score ($\beta = 0.04$ 95%CI 0.022-0.067; $p < 0.001$) and fat mass ($\beta = 0.02$ 95%CI 0.002-0.04; $p < 0.01$) at 17 years; Adjustment for change in socio-economic status between birth and age 12 years.
Lin et al., 2012 China	- N: 5,968; - Age: 11 years (baseline). Followed again at 13 years of age; - Participants of the Hong Kong 1997 Birth Cohort.	- Diet: Consumption of milk and dairy products; - Instruments: FFQ; Consumption measured at 11 and 13 years of age.	- BMI: Weight (kg)/height (m)^2 standardized to a *z*-score; Measured at 11 and 13 years of age.	There was no association between the consumption of milk and/or dairy products at 11 years of age and BMI at 13; Adjustment for gender, BMI at 11 years, order of birth, maternal age, parents education, family income, physical activity, consumption of vegetables, fruit and soft drinks.
Stoof et al., 2011 Netherlands	- N: 114 males and 124 females; - Age: 13 years at baseline and followed until 24-30 years; - Participants of Amsterdam Growth and Health Longitudinal Study (AGAHLS).	Diet: intake of sugar-containing beverages (SCB) divided into two categories: total SCB and SCB excluding 100% fruit juices; - Instruments: dietary history; Consumption measured at 13 years.	- %Total Fat and %Trunk Fat, obtained through dual-energy X-ray absorptiometry; - BMI: 25 kg/m^2 and obesity as 30 kg/m^2; Measured at 24-30 years of age.	Intake of SCB excluding 100% fruit juices at 13 years was not related to BMI in adulthood; Intake of total SCB at 13 years was not related to %total fat, %trunk fat and BMI in adulthood; In males, each additional daily serving of SCB excluding 100% fruit juices at 13 years was associated with 1.14% higher %total fat (95% CI 0.04, 2.23%) and 1.62% higher %trunk fat (95% CI 0.14, 3.10%) in adulthood; Adjusted for BMI at baseline, developmental age, physical activity level and total energy intake.

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Chart 1. continuation

Author, Year Country	Sample	Exposure	Outcome	Main findings
Noel et al., 2011 U.S.A.	- N: 2,245; - Age: 10 years and followed until 13 years; - Participants of the *Avon Longitudinal Study of Parents and Children* (ALSPAC).	- Diet: types of milk (total, full fat and reduced fat); - Instruments: food records of 3 days; - Consumption measured at 10 and 13 years.	- %BF: verified with DEXA; Measured at 10 and 13 years.	Total milk intake at 10 years was associated with %BF at 11 ($p = 0.01$), the association remained after additional adjustment for total energy intake ($p = 0.03$); Total milk intake at 10 years was not associated with %BF at 13 years; Full-fat and reduced-fat milk at 10 years was not related to %BF at 11 and 13 years; Adjustment for age, gender, height, physical activity, pubertal development, maternal BMI, maternal education, intake of total fat, sugar-sweetened beverages, consumption of fruit, ready-to-eat cereals and baseline BMI.
Libuda et al., 2011 Germany	- N: 364; - Age: 3 to 18 years (baseline) and followed for 5 years; - Participants of the *Dortmund Nutritional Anthropometric Longitudinally Designed Study* (DONALD *study*).	- Diet: Salt intake; - Instruments: 3 food records with weighting; Urinary samples were collected to analyze amount of sodium excreted; Salt intake and urinary samples were analyzed at baseline and 5 years afterwards.	- BMI: Weight (kg)/height (m)^2 standardized to a *z*-score; - %BF: verified by triceps and subscapular skinfolds; Measured at baseline (3 to 18 years of age) and the last visit (5 years afterwards).	There was no significant association between the alterations in the urinary excretion of sodium and the changes in BMI and/or the %BF; Adjustment for age, parents BMI, energy and sugar-sweetened beverages intake at baseline.
Cutler et al., 2011 U.S.A.	- N: 2,516; - Average age: 15 years. Followed until 20 years of age; - Participants of the *Project Eating Among Teens* (EAT).	- Diet: DP obtained by Principal Component Analysis (PCA); - Instruments: self-assessed semi quantitative FFQ validated by 152 food items; DP identified at 15 years of age and afterwards at 20.	- BMI: Weight (kg)/ height (m)^2; Measured at 15 and at 20 years.	Boys with high adherence to DPs loading heavily on starchy food were 30% less likely to be overweight ($p < 0.05$); Adjustment for race/ethnicity, socioeconomic status, physical activity, weight at 15 years.

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Chart 1. continuation

Author, Year Country	Sample	Exposure	Outcome	Main findings
Albertson et al., 2009 U.S.A.	- N: 2,379 girls; - Age: Average of 11.5 years and followed until 18.5 years; - Participants of the *National Heart, Lung, and Blood Institute Growth and Health Study.*	- Diet: Cereal intake; - Instruments: 24h dietary recalls and FFQ; Verified at 13.5, 15.5, 16.5 and 18.5 years of age.	- %BF: Bioelectrical Impedance; Measured at 18.5 years of age.	Regular cereal intake during the beginning of adolescence is associated with a significant lower %BF (-0.04 ± 0.01 p = 0.01); Adjustment to the region of the study, maternal education and physical activity at baseline.
Cheng et al., 2009 Finland	- N: 396 girls; - Age: 10 to 13 years (baseline) and followed for 7 years.	- Diet: Dietary intake index (protein, calcium, potassium, phosphorus, and magnesium); - Instruments: Food records of 3 days (2 weekdays and 1 weekend day); Measured at baseline	- %BF: verified with DEXA; Measured from 17 to 20 years of age.	In a linear model, the dietary intake index at baseline was related to 25% of the changes in the %BF 7 years afterwards; The highest dietary intake index at baseline predicted a lower %BF (12%); Adjustment for menarche age, physical activity, parents education and maternal body composition.
Fulton et al., 2009 U.S.A.	- N: 472; - Age: 11 to 14 years (baseline). Followed for 4 years; Participants of the *Heart Beat Project*.	- Diet: Energy intake; - Instruments: FFQ (regarding the intake from the previous week); Measured at baseline.	- BMI: Weight (kg)/ height (m)2; - %BF: Bioelectrical Impedance; Measured after 4 years.	There was no relation between the energy intake and the %BF and BMI; Adjustment for gender, race/ethnicity, age and pubertal development.

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The AI proposed by Ambrosini et al.[20] is based on a mathematical equation calculated as BF in kg divided by height in meters raised to the logarithmic power of the ratio of these measurements. The index was log-transformed to provide an approximation of a normal distribution and expressed in quintiles of z-score, with the highest score classified as "excess adiposity". The FMI proposed by Assmann et al.[27] used the equation: %BF*body mass/100. Out of twelve studies that evaluated %BF, five used electric bioimpedance[10,12,18,28,29], five Dual Energy X-ray Absorptiometry (DEXA)[11,13,21,24,26] while the remaining studies used skinfold thickness for estimating this body component[14,16,17]. Nine studies used BMI measures concomitantly with %BF[10,11,14,16-18,26,28,29].

Chart 1. continuation

Author, Year Country	Sample	Exposure	Outcome	Main findings
Libuda et al., 2008 Germany	- N: 244; - Age: 9 to 18 years and followed for 5 years; - Participants of the *Dortmund Nutritional Anthropometric Longitudinally Designed Study* (DONALD *study*).	- Diet: Beverage intakes: regular soft drink, diet soda, and sugar-sweetened beverages; - Instruments: Food record of 3 consecutive days with beverages weighting; Measured at 9-18 years of age and 5 years afterwards.	- BMI: Weight (kg)/height (m)^2 standardized to a *z*-score; - %BF: verified by triceps and subscapular skinfolds; Measured at baseline (9-18 years of age) and at the final visit (5 years afterwards).	In girls, the consumption of regular soft drinks and sugar-sweetened beverages at 9-18 years of age was related to an increase in the z-score of BMI (β = 0.070 p = 0.01 and β = 0.096 p = 0.01, respectively) 5 years afterwards. Adjustment for age, residual energy at baseline, changes in residual energy, birth weight, maternal BMI.
Ritchie et al., 2007 U.S.A.	- N: 2371 girls; - Age: 9-10 years followed until 19-20 years of age; - Participants of the *National Heart, Lung, and Blood Institute Growth and Health Study cohort.*	- Diet: DP obtained by Cluster analysis (habitual DP, snacks DP, meals DP, and sweets and cheese DP); - Instruments: Food record of 3 days (2 weekdays and 1 weekend day); DP measured at baseline.	- BMI: Weight (kg)/ height (m)^2; - %BF: verified by triceps and subscapular skinfolds; Measured at baseline and 10 years afterwards.	The average of BMI and %BF at 19-20 years of age was not significantly different between the DPs at baseline; Adjustment for BMI, menarche age, pregnancy, parents education, physical activity, and TV time at baseline.
Mundt et al., 2006 Australia	- N: 208; - Age: 8 to 15 at baseline and followed for 7 years; Participants of the *University of Saskatchewan's Pediatric Bone Mineral Accrual Study* (PBMAS).	- Diet: Sugar-sweetened intake; - Instruments: 24h dietary recalls; Consumption verified during the first 3 years of monitoring.	- %BF: verified with DEXA; Annually measured during the 7 years of monitoring.	There was no significant relation between the consumption of sugar-sweetened beverages and %BF in girls and boys. ($p > 0.05$); Adjustment for pubertal development, lean body mass, total dietary energy intake.

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Relationship between diet and body fat

Of the 21 studies that evaluated the relationship between diet and BF, only ten found evidence of an association[11-13,17,20,25-28,30]. The findings of these studies will be described in the following sections, according to the method used for estimating body fat.

Chart 1. continuation

Author, Year Country	Sample	Exposure	Outcome	Main findings
Berkey et al., 2005 U.S.A.	- N: 6,149 girls e 4,620 boys; - Age: 9 to 14 (baseline). Followed for 4 years; - Participants of the *Growing Up Today Study.*	- Diet: milk, calcium, foods and drinks dairy and fat; - Instruments: Semi quantitative FFQ consisting of 132 food items with a recording period of 1 year; Annually measured during the 4 years of monitoring.	- BMI: Weight (kg)/ height $(m)^2$. Measured at baseline and annually assessed during the 4 years of monitoring.	A 150-kcal/d increase in total energy from the prior year predicted a BMI gain for boys (0.012 Kg/m² p = 0.003) and for girls (0.008 Kg/m² p = 0.03); And there was no association statistically significant adjustment for dairy fat, dietary calcium, milk intake and total energy intake.
Phillips et al., 2003 U.S.A.	- N: 196 girls; - Age: average of 10 years (baseline). Followed until the average of 17 years of age.	- Diet: dairy products (foods and calcium); - Instruments: semi quantitative FFQ consisting of 116 food items; Consumption assessed at baseline.	- %BF: Bioelectrical Impedance; - BMI: Weight (kg)/height $(m)^2$ standardized to a *z*-score; Measured at 17 years of age.	There was no statistically significant connection between the consumption of dairy products and BMI; There were no relevant associations between the daily consumption of portions of dairy products or percentage of daily calories from dairy products and %BF; Adjustment for physical activity, percentage of energy from proteins, grams of proteins, total energy intake and parents overweight.
Magarey et al., 2001 Australia	- N: 243; - Age: 2 to 15 years; - Participants of a birth cohort from the South of Australia.	- Diet: macronutrients (fat, protein and carbohydrate); - Instruments: Food record of 3 days with food weighting at 2, 4 and 6 years of age and Food diary of 4 days at 8, 11, 13 and 15 years of age.	- BMI: Weight (kg)/ height $(m)^2$ - Were verified triceps (TS) and subscapular (SS) skinfolds; Measurements converted to z-score and assessed at 2, 4, 5, 6, 7, 8, 11, 13, and 15 years.	There was no difference between z-score BMI, SS and TS according to the consumption of macronutrients; Macronutrients intake at 11 or at 13 years of age does not predict the %BF at 15; Adjustment for energy intake.

Body Mass Index (BMI). The intake of some specifics foods was shown to be positively associated with BMI in adolescents and young adults. Fraser et al.[11] found that the habit of consuming fast food at the age of thirteen increases 1.23-fold (95%CI, 1.02 to 1.49) the chance of becoming obese at the age of fifteen. According to the authors, this eating habit increases the BMI in this age group by 0.08 kg/m^2 (95%CI, 0.03 to 0.14). In Australia girls, Gopinath et al.[28] found that each

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1SD increase in a dietary glycemic load was associated with 0.77 kg/m^2 increase in BMI ($p < 0.01$) five years later; in addition, each 1SD increase in a dietary fiber intake was associated with 0.44 kg/m^2 decrease ($p < 0.02$) in BMI. Similarly, results from the *Dortmund Nutritional Anthropometric Longitudinally Designed Study* showed that sugar-sweetened beverages and regular soft drink consumption during adolescence increased BMI Z score by 0.07 ($p = 0.01$) and 0.1 ($p = 0.01$), respectively, in females during early adulthood. This association was not found among young males[17]. In South Africa, Feely et al.[25] found that the sugar-sweetened beverages consumption twice a week or more at age 13 years by males increased 0.04 kg/m² (95% CI 0.02-0.07) BMI Z-score at 17 years ($p < 0.001$). Conversely, a study evaluating 693 participants with average age at baseline 14.6 of two American longitudinal projects: *Identifying Determinants of Eating and Activity (IDEA) and Etiology of Childhood Obesity (ECHO),* found no evidence of association between consumption of sugar-sweetened beverages, diet soft drink, fast food and BMI two years later[18]. In the Netherlands, results from the *Amsterdam Growth and Health Longitudinal Study* (AGAHLS) showed that adolescents who consumed sugar-containing beverages and sugar-containing beverages (excluding 100% fruit juices) at age 13 years was not associated with changes in BMI in adulthood[26].

Two studies assessed the association between DP and BF measured using BMI, finding different results. The first study investigated the adherence to habitual DP, snacks DP, meals DP and sweet products and cheese DP by female adolescents and found no relationship with BMI after ten years of follow-up[14]. The second study found that young males who adhered to a DP rich in starch food sources at the age of fifteen had a 30% ($p < 0.05$) lower chance of being obese five years later[30]. There was no evidence of association between BMI and consumption of macronutrients (carbohydrate, protein and fat - % calories/day)[15], intake of dietary salt[16], energy intake[29] and the habit of consuming milk, dairy products and calcium[10,22,23].

Body fat (BF). The intake of fast food at 13 years of age was associated with higher % BF (95% CI, 1.33 to 2.79) at age fifteen[11]. Gopinath et al.[28] found, in Australian girls aged 12 years, that the consumption of soft drinks consumption once a day or more increased % BF by 4.5% at age 17 years, in comparison with those who never/rarely consumed soft drinks. In contrast, the regular intake of cereals during early adolescence reduced %BF at the end of this period by 0.04 ($p = 0.01$) percentage points[12]. Similarly, Cheng et al.[13] tested the longitudinal association between a diet index based on the intake of several nutrients (protein, calcium, potassium, phosphorus and magnesium) and %BF. The authors found that a higher score for the diet index between ten and thirteen years of age predicted lower %BF (12% of variability) seven years later. The index measured at the beginning of adolescence explained 25% of variability of %BF at early adulthood.

Others studies found no association between the intake of sugar-sweetened beverage, diet soft drink, fast food, dairy products, calcium intake, energy consumption and %BF measured through bioelectrical impedance[10,18,29]. The studies assessing the associations of %BF (measured with DEXA) with the intake of milk, dairy products and sugar-sweetened beverage also did not find evidence of association[19,21,24]. There was also no significant relationship between dietary salt intake (g/day and excretion sodium) and DP (habits, meals and sweets and cheese) with %BF estimated by subscapular and tricipital skinfold thickness[14,16].

Fat Mass Index (FMI) and Adiposity Index (AI). An association has been observed between DP z-score based on high intake of energy and fat, as well as low intake of fiber, between ten and thirteen years of age and AI Z-score at fifteen years of age. For each 1 SD increase in DP z-score, the odds of presenting excess adiposity in this period increased by 0.13 times (95% CI, 0.01 to 0.27)[20]. Assmann et al.[27] evaluated the habitual animal and vegetable protein consumption between nine and fifteen years and FMI in adulthood. The researchers found a positive association to animal protein consumption and FMI, but only in men.

Skinfolds. The consumption of macronutrients (%calories/day – carbohydrate, protein and fat) at ages 11 and 13 years did not predict subcutaneous BF measured using skinfold thickness (in millimeters) at age 15 years[15].

Statistical analyses

The selected studies applied statistical tests derived from multiple linear regressions and generalized linear models. The main variables used for adjustment were: age[13,14,16-18,20,21,23,25,26,28,29], physical activity[10-12,18-21,23,26,28,30], maternal education[12-14,18-21,23,27,28], BF (BMI, FM, FMI, adiposity or weight) at baseline[14,19,21,23,26,27,30] and energy intake[10,15-18,22,24,26-28].

Discussion

This systematic review compiled 21 studies that investigated the longitudinal relationship between diet and BF in adolescence and early adulthood. Ten out of the 21 articles selected showed an association between some aspect of diet and estimative of the quantity of body fat[11-13,17,20,25-28,30] , measured by different methods. It was observed that diet, measured using a dietary index at the beginning of adolescence, explains 25% of variability of body fat at the beginning of adult life[13]. It has been shown that the diet has effects on body energy balance and efficiency of body fat deposition due to the influence on satiety, hunger, food acceptance and metabolism[23]. An association between high intake of fat energy and low intake of dietary fibers with higher levels of adiposity in adolescence was also found in the present review[20]. The following characteristics have been considered as main risk factors for obesity: sedentary lifestyle; high intake of energy-dense, micronutrient-poor foods; heavy marketing of energy-dense foods and fast food outlets; sugar-sweetened soft drinks and fruit juices; adverse social and economic conditions in developed countries, especially among women[25]. During adolescence, eating behaviors are influenced by several aspects such as eating away from home, food advertising and promotion, time limitations for eating and meal preparation, family, friends, university, work, etc. In addition, the food industry has responded to this social demand by increasing convenience foods and ready-prepared meals rich in fat, sugar, salt and conservatives. Consumption of high calorie foods, associated with a lack of physical activity, contributes to an increase in body fat over time. In this vein, the present systematic review also identified that the habit of consuming fast food increased the chance of young people becoming obese by 23%[11]. It has also been pointed out that the intake of sugary beverages and regular soda during adolescence contributes toward an increase in BMI among females in early adult life[17]. In females, the high percentage of fat in adolescence and early adulthood also influences reproductive ability through hormonal mechanisms[23].

Conversely, although the studies mentioned above found significant associations between diet and body fat, another study found no significant relationship between the intake of some of these foods (sugar-sweetened beverages, regular soft drink and fast food) and body fat. The inconsistency of these results can be attributed to the inherent variability in the methods used for assessing the diet and body fat, together with the variability in the methodological errors of the studies and the use of inaccurate and imprecise techniques.

In the studies selected for the present review, body fat was estimated through several approaches, such as BMI, % body fat (equations derived from skinfold thickness, DEXA and bioelectrical impedance), adiposity index and measurement of subcutaneous fat (subscapular and tricipital skinfold thickness). This lack of standardization in the methods, besides hampering comparisons, also reduces the accuracy of information presented in the studies[31]. Most of studies used BMI as the outcome variable. The frequent use of BMI to evaluate adiposity is questionable, because it is a method based only on body weight and does not distinguish lean mass from fat mass. Thus, the method can wrongly classify an individual as thin, when, in fact, they have a large quantity of body fat, or conversely, it can indicate a more common situation: define an individual with a considerable quantity of lean body mass as overweight/obese[31,32]. BMI is a proxy of obesity and using it for assessing body composition (e.g. percentage body fat), or body fat distribution (e.g. waist circumference or waist-hip ratio) may result in misclassification. The same was observed for the exposure (diet), where most of the reviewed studies investigated specific aspects of food intake, focusing on energy or macronutrient intake, as well as cereals, milk and dairy products, fast food, etc. This kind of investigation precludes the evaluation of the existence of possible interaction effects between food and body composition. It was observed that, along with the different methodologies adopted in the studies, the use of diet assessment tools able to provide a more complex analysis of food intake was not properly explored.

Besides the disparity in methods for assessing exposure and outcome variables, additional factors that can be related to lack of consistency of findings among the studies are: *a)* diversity of adjustment variables used by researchers in statistics analyses, which can interfere directly in the significance of the associations; *b)* the broad age variation of participants, which can interfere in the way of measuring exposure and outcome as well as in the magnitude of errors of information and measurement. The duration of follow up is another important aspect. Short periods do not allow exposure to establish its effect upon the outcome, whereas long periods can allow the ef-

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fect to be influenced by other factors or even lose magnitude for not corresponding to the period of life in which the exposure would have been meaningful[33,34].

Further studies should include broad evaluation of the diet, taking into account the interaction of food in the human body and the effect of this on body composition. The tools used to measure dietary aspects should investigate food habits for a considerable period of time. Accurate methods capable of specifying the content of this body component should be used to evaluate body fat, thereby avoiding classification errors[31,32].

Conclusions

This review draws attention to the methods used for assessing diet and BF, as the existent heterogeneity hampers the reliability of the studies, as well as the comparability between them. We found insufficient evidence on the link between diet and BF in adolescence and early adulthood. However, the findings of this revision suggest that the consumption of unhealthy food or food groups (higher energy density and lower amount of nutrients) appears to be associated with higher quantity of BF in adolescence and early adulthood. We highlight the need for longitudinal studies assessing BF through more precise methods.

Collaborations

BC Schneider performed the search and selection of the articles and drafted the manuscript. SC Dumith helped to select articles and reviewed the manuscript. SV Orlandi contributed to the search and selection of articles. MCF Assunção was responsible for the study and helped to draft the manuscript. All authors read and approved the final manuscript.

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