British Journal of Nutrition (2023), 129, 1626–1644 doi:10.1017/S0007114522000228

Association between lifestyle patterns and overweight and obesity in adolescents: a systematic review

Luciana Jeremias Pereira, Patrícia de Fragas Hinnig, Luísa Harumi Matsuo, Patrícia Faria Di Pietro, Maria Alice Altenburg de Assis and Francilene Gracieli Kunradi Vieira*

Department of Nutrition, Health Sciences Center, Federal University of Santa Catarina, Campus Universitário Reitor João David Ferreira Lima, Trindade, Florianópolis, Santa Catarina 88040-900, Brazil

(Submitted 11 May 2021 – Final revision received 5 January 2022 – Accepted 17 January 2022 – First published online 28 January 2022)

Abstract

The purpose of this systematic review was to summarise the evidence from observational studies regarding the association between lifestyle patterns and overweight and obesity in adolescents. To our knowledge, no review study has analysed this association in this age group. A systematic search was conducted in Latin American and Caribbean Health Sciences Literature (LILACS), Scopus, PubMed Central and Web of Science databases, with no language or time restrictions. Studies that included adolescents (10–19 years old) were selected using data-driven methods that combined the diet domain with at least one of the following behavioural domains: physical activity, sedentary behaviour and sleep. Twenty-one articles met all eligibility criteria. Of these, twelve studies were used for synthesising the results. Studies differed in many aspects, such as sample size, behavioural assessment tools, and lifestyle pattern and weight status indicators. Overall, cross-sectional studies found no association between lifestyle patterns and overweight and obesity, even when the data were stratified by sex. However, when analysing the results stratified by risk of bias, a positive association between predominantly unhealthy and mixed lifestyle patterns with overweight/obesity was identified in cross-sectional studies with moderate risk of bias. A prospective study revealed an increase in BMI over time associated with mixed and predominantly unhealthy lifestyle patterns. Current findings regarding the association between lifestyle patterns and overweight and obesity in adolescents are inconsistent. More studies are needed to clarify possible associations.

Key words **Diet: Physical activity: Sedentary behaviour: Sleep**

There is evidence in the literature that lifestyle factors associated with energy balance influence weight status in adolescents[1]. Diet is a key factor in energy balance regulation. High intake of energy-dense, nutrient-poor foods is associated with overweight and obesity[2]. In contrast, high-quality diets[2], low levels of sedentary behaviour[3], regular physical activity[4] and adequate sleep[5] appear to be protective factors. No single factor can be identified as a universal causal factor in overweight/obesity, given that several behaviours and determinants at different levels contribute to this issue[1]. Many of these behaviours are interrelated within individuals and may have synergistic and cumulative effects on overweight/obesity[6].

Clustering of multiple lifestyle behaviours, also known as the study of lifestyle patterns, has been successfully applied to understand the co-occurrence of different behaviours[7].

Lifestyle patterns can be derived using exploratory data-driven methods[8]. These approaches aim to aggregate individuals who have similar behaviours or group behaviours that are highly correlated. Consequently, these techniques allow investigating the cumulative effect of combined behaviours on a given outcome[6].

Leech *et al.*[6] conducted a narrative review examining the clustering of diet, physical activity, and sedentary behaviour in children and adolescents. According to the authors, the association between cluster patterns and overweight/obesity was inconclusive. Studies examining lifestyle patterns and overweight/obesity often do not assess sleep-related factors. However, sleep, diet, physical activity, and sedentary behaviour all interact and influence each other to impact health[9]. A recent systematic review examined the associations between lifestyle patterns including diet, physical activity, sedentary behaviour, and sleep and adiposity in children. The authors concluded that unhealthy lifestyle patterns were more frequently associated with adiposity risk[10].

These previous reviews investigated studies conducted with children and adolescents (5–18 years)[6] or children (5–12 years) only[10], covering two distinct stages of life. Different from childhood, adolescence is a high-risk phase for weight gain,

* **Corresponding author:** Dr F. G. K. Vieira, email francilene.vieira@ufsc.br

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press

characterised by critical changes in body composition and lifestyle-related behaviours[9]. In adolescence, the participation in physical activity can reduce, particularly among girls[9]. Furthermore, dietary habits are altered with increasing autonomy[11].

Considering that: (i) there is a lack of consistent evidence about the relationship between lifestyle patterns and overweight/obesity in adolescents[6]; (ii) this phase is critical for weight gain, mainly in girls[9]; and (iii) adolescents with overweight/obesity may continue to be overweight/obesity during adulthood[12], it is pertinent to explore the direction of associations between lifestyle patterns and overweight/obesity in adolescents. We conducted a systematic analysis aimed at demonstrating the associations between lifestyle patterns and overweight/obesity in adolescents overall and by sex.

Methods

This systematic review followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Table S1, online Supplementary Material)[13]. The protocol (CRD42020151085) was registered with the International Prospective Register of Systematic Reviews (PROSPERO).

Eligibility criteria

Studies that met predefined criteria based on PECOS (Participants, Exposure, Comparison, Outcome and Study design) elements were considered eligible for inclusion in this systematic review (Table S2, online Supplementary Material). Inclusion criteria were as follows: (a) adolescents aged ≥10 to ≤19 years (or mean age within this range) according to the definition of the WHO[14]; (b) application of exploratory data-driven methods to identify lifestyle patterns (such as cluster analysis, principal components analysis, treelet transform, reduced rank regression and latent class analysis) and the assessment of the diet domain in conjunction with at least one of the following behavioural domains: physical activity, sedentary behaviour and sleep; and (c) weight status (overweight/obesity) as outcome, determined from age- and sex-specific BMI percentiles, BMI *Z*-scores, BMI standard deviation scores and BMI cut-off points proposed by the International Obesity Task Force (IOTF)[15], the WHO[16], the US Centers for Disease Control and Prevention (CDC)[17] or national references. Only observational (cross-sectional and prospective) studies were included. There were no language or time restrictions.

Exclusion criteria were as follows: (i) studies in children under 10 years of age, adults or seniors; or with well-characterised samples of non-healthy adolescents (e.g. individuals with type 2 diabetes, hypertension or eating disorders); (ii) studies that did not use exploratory data-driven methods to determine lifestyle patterns and that did not include diet domain; (iv) studies that did not include overweight/obesity as the outcome; and (v) conference proceedings, case reports and letters to the editor.

Information sources

Specific search strategies were created for the following databases (Table S3, online Supplementary Material): Latin American and Caribbean Health Sciences Literature (LILACS), Scopus, PubMed Central, and Web of Science. We had support from a librarian at the Federal University of Santa Catarina in the search process[18]. Descriptors came from Health Sciences Descriptors, Medical Subject Headings and words related to the subject. A search restriction for terms in the 'title or abstract' was made to increase the specificity of the systematic search, given the scope of the descriptors. An additional search of grey literature documents was performed using ProQuest Dissertations & Theses Global and Google Scholar; in Google Scholar, the search was restricted to the first 100 studies. The systematic search was conducted on 6 November 2019 and updated on 21 July 2020. The reference lists of full-text articles were visually screened to identify other relevant articles. When articles were not available online or in full text, we contacted the authors by email or through Research Gate.

Study selection

Search results were transferred to EndNote Web version X9, and duplicate hits were removed. Study selection was performed in three stages. First, two reviewers (LJP and LHM) independently screened the titles and abstracts of all identified records to identify potentially relevant articles. Then, the reviewers read in full all selected articles to determine which papers met the eligibility criteria. Articles that did not meet the eligibility criteria were excluded. In the third stage, the reviewers screened the reference lists of selected articles for other potentially relevant papers. Any discrepancy between the two reviewers was resolved by consensus with a third reviewer (PFH).

Data collection

Two reviewers (LJP and LHM) independently extracted the data. This process was guided by the use of a form previously prepared by the authors and subjected to a pilot test to ensure consistency across reviewers. Extracted data were subsequently compared for agreements and disagreements. Divergences were resolved by consensus with a third reviewer (PFH).

Data items

The following information was retrieved from selected studies: authors, year of publication, country, study design, survey year, age range or school grade, sample size, diet variables, diet assessment method, physical activity variables, physical activity assessment method, sedentary behaviour variables, sedentary behaviour assessment method, sleep variables, sleep assessment method, lifestyle patterns, lifestyle pattern assessment method, outcome indicator, outcome measurement method, cut-off reference, method of analysis, and associations identified between overweight/obesity and lifestyle patterns. Research funding data and conflicts of interest were also extracted from the articles.

Risk of bias assessment

The Joanna Briggs Institute critical appraisal tools were used to assess the quality of selected studies[19]. The instrument consists of eight items: (1) eligibility criteria; (2) study subjects and setting; (3) validity and reproducibility of exposure measures;

(4) criteria for patient diagnosis; (5) confounding factors; (6) strategies for dealing with confounding factors; (7) validity and reproducibility of the outcome measure; and (8) statistical analysis. We developed specific criteria for item scoring to facilitate the analysis (Table S4, online Supplementary Material). In Item 1, the authors from the selected studies should describe in detail whether adolescents with physical or mental disabilities, diseases, pregnancy, lactation or restrictive diet were excluded from the sample (Item 1). The authors also should provide a clear description of the sample studied, including sex, age or school grade, socio-economic status, year of the research, location, sampling, and sample size estimation (Item 2). The studies should clearly describe whether the instruments used to measure all exposure and outcome variables were subjected to validity and reproducibility tests with the same population of interest, presenting the respective reference. If the method used was considered a gold standard (i.e. objective measurement of weight and height, accelerometer), this assessment was not necessary (Items 3 and 7). We assessed whether the authors reported typical confounders such baseline characteristics (age, sex and socio-economic status) (Item 5). Finally, we considered appropriate studies those that used multivariate analysis adjusted (multivariate ANOVA and regression analysis) for typical confounders as a statistical method to evaluate associations (Items 6 and 8). Items are scored as yes, no, unclear or not applicable. Item 4 was excluded from analysis because it was not applicable to the nature of the selected studies. Thus, the risk of bias was determined using the other seven items of the instrument. Two reviewers (LJP and LHM) independently assessed each study and resolved disagreements with a third reviewer (PFH). For classification of the risk of bias, we calculated the proportion of 'yes' responses. The risk of bias was determined as 'high' when the study reached a 'yes' score up to 49 %, 'moderate' between 50 % and 69 %, and 'low' when it was above 70 %[20]. The results of risk of bias assessment are presented in Table S5, Supplementary Material.

Summary measures

Lifestyle patterns (principal independent variable) identified by exploratory data-driven methods and their associations with overweight/obesity (outcome) were described as OR or β1 coefficients and 95 % CI. Data were also subjected to univariate ANOVA and Pearson's χ^2 tests.

Synthesis of results

Given the heterogeneity of methods used to assess associations between lifestyle patterns and overweight/obesity in the selected studies, it was not possible to perform a meta-analysis. Therefore, the results are described according to the Synthesis Without Meta-analysis (SWiM) guideline. When the characteristics of the studies are very varied to produce a meaningful summary estimate of the effect, alternative methods of summarising the results may be adopted, such as counting votes based on the direction of the effect. As such, SWiM provides guidance for reporting these methods and results[21].

A wide variety of lifestyle patterns were identified; we chose to categorise them according to the healthiness or unhealthiness of related behaviours (Table S6, online Supplementary Material). Healthy behaviours included presence/high levels of physical activity, healthy diet, and adequate sleep habits as well as low levels/absence of sedentary behaviour and low consumption of unhealthy foods. Unhealthy behaviours were defined as presence/high levels of sedentary behaviour, unhealthy diet and inadequate sleep habits as well as low levels/absence of physical activity and low consumption of healthy foods. Moderate behaviours were defined as intermediate levels of diet quality, sleep quality, physical activity and sedentary behaviour. Lifestyle patterns that included only healthy behaviours were classified as completely healthy and those that included only unhealthy behaviours as completely unhealthy. Lifestyle patterns characterised by at least two healthy behaviours and one unhealthy or moderately unhealthy behaviour were classified as predominantly healthy, whereas lifestyle patterns including at least two unhealthy behaviours and one healthy or moderately healthy behaviour were classified as predominantly unhealthy. Finally, lifestyle patterns characterised by an equal proportion of healthy and unhealthy behaviours were classified as mixed. Only studies that used multivariate analysis adjusted for confounders (multivariate ANOVA and regression analysis) to assess associations between lifestyle patterns and overweight/obesity were included in the synthesis of results. The direction of association was described as positive, inverse or none. Positive and inverse associations were only considered valid for studies reporting statistically significant associations (i.e. $P < 0{\cdot}05$, zero not included in the 95 % CI for β1 or OR $\neq$ 1). To examine differences in the direction of associations, we recorded the number of positive, inverse or null associations reported in the studies. Subsequently, the number of associations was analysed by sex (based on data from studies that used sex stratification) and by risk of bias.

Results

Study selection

A total of 6017 articles were identified in the database search. Additionally, six articles were identified through other sources. After removal of duplicates, 3662 articles remained and were screened by title and abstract, revealing forty-three potentially relevant for eligibility assessment. Of these, twenty-two articles were excluded (Table S7, online Supplementary Material): seven did not focus on adolescents[22–28], one article did not use exploratory data-driven methods to identify lifestyle patterns[29], nine used outcomes that did meet our inclusion criteria[30–38] and five were not accessible[39–43]. Twenty-one articles were retained for systematic review (Fig. 1).

Study characteristics

A detailed description of the main characteristics of selected studies is provided in Table 1. Of the twenty-one articles selected, one reported the results of two studies with different samples (from Europe and Brazil), so their characteristics are presented separately in this review[44]. Two articles refer to a single study but used different designs; therefore, sample

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press

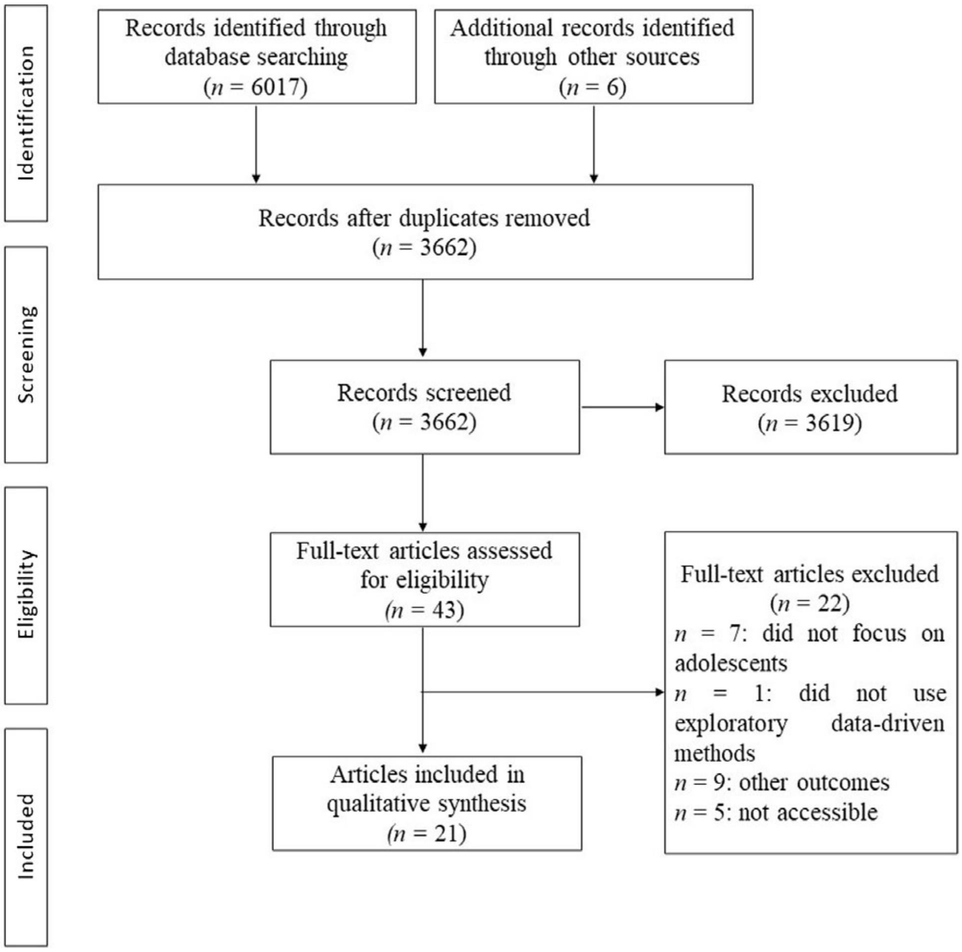

Fig. 1. Flowchart of literature search and selection criteria. Adapted from PRISMA.

characteristics are described once but associations with the outcome are presented separately[45,46]. Twenty studies were cross-sectional[27,44,45,47–63]. Most studies were performed in European countries[44,48–52,54–56,58–60,62–64], three in the USA[47,53,61], two in Brazil[44,57] and one in Canada[45,46]. Sample sizes ranged from 173[59] to 18 587[45] subjects. In one study, data collection was conducted before 2000[47], fifteen between 2001 and 2010[44,48–54,56,60–64], and five between 2011 and 2017[45,46,55,57–59] (Table 1). The statement of the funding and conflict of interest of the included studies can be found in Table S8, Supplementary Material. No notable concern about conflict of interest was observed from the studies.

Four studies investigated lifestyle patterns related to diet, physical activity, sedentary behaviour and sleep[54–56,59], sixteen analysed diet, physical activity, and sedentary behaviour[44–48,50–53,57,58,60–64], and one assessed diet and physical activity only[49]. Five studies included other health-related behaviours, such substance use (marijuana use, smoking and binge drinking)[45–48,60,63], dieting behaviours[47] and parental involvement[47] (Table 1). Lifestyle patterns composed of dieting behaviours and parental involvement in isolation were not considered in this systematic review.

The methods used to measure behaviours varied across studies. One study used the 24-h recall with a 3-d record (two consecutive weekdays and one weekend day) to collect dietary data[55], two used 2-d non-consecutive 24-h recall[44,52] and nineteen used FFQ[44–51,53,54,56–64]. Only one study used accelerometer to measure physical activity and sedentary behaviour[59]. One study used face-to-face interview to assess physical activity, sedentary behaviour and sleep habits[55], and all others used self-report questionnaires. Across the studies, dietary variables ranged from specific food groups such as soft drinks and fruit juices[54], fruits, vegetables, and junk foods[44,50,53,56,57,60,62,63] to dietary indices[48,49,51,52,59,64] or patterns based on the whole diet[55]. Physical activity variables assessed were total,[53,57,60] moderate and vigorous-intensity activities[44–46,49,52,55,59,61–63], physical activity at school[45,46,58,61], outside of school or on leisure time[47,48,50,51,56,58,62,64], organised sports/competitions[45–47,54,61,64], active commuting[48,54,55], and housework[47]. Most sedentary behaviour variables were time of watching television[44] and computer[48,50,54,58], screen time (e.g. television, video or DVD, computer, video console games, or mobile phone)[45–47,51–53,55–57,59–64], or non-screen activities (e.g. homework)[51,52,55]. The measure of sleep habits had the least variation, as most studies included a question about the number of hours that adolescents usually sleep at night. A single study sought to describe sleep habits through duration, discrepancy (sleep duration on weekend night – sleep duration on schools

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press
British Journal of Nutrition

Table 1. Characteristics of studies included in systematic review

Author and country	Design study	Survey year	Sample (*n*, age range or grade)	Diet variables	Diet assessment method	PA variables	PA assessment method	SB variables	SB assessment method	Sleep variables	Sleep assessment method	LP derivation method
Boone-Heinonen *et al.* 2008[47], USA	C	1996	*n* 8686 B = 4293 G = 4393 18–20 year	Diet beverages and regular beverages, juice, fruit, vegetables, low-fat foods, meat, added fat, sweets, fried food, dairy items, vitamins, fast food and meals per d	FFQ Self-report	Bouts of housework, hobbies, skating, sports, exercise, hanging out, participation in school clubs, team sports and individual sports	7-d recall Q Self-report	Time of TV (video), computer use and video console games	7-d recall Q Self-report	NA	NA	CA‡
Sabbe *et al.*, 2008[49], Belgium	C	2002	*n* 1725 10 years	Dietary diversity index Excess index	19-item FFQ*,† Self-report	Moderate PA Vigorous PA	FPAQ*,† Self-report	NA	NA	NA	NA	CA *k*-means
Landsberg *et al.*, 2010[48], Germany	C P	2004–2006 T0:2000 T1:2005	*n* 1894 14 years *n* 389 10–14 years	Healthy dietary pattern Risk-related pattern Mixed dietary pattern	26-item FFQ† Self-report	Time of unstructured PA outside of school, structured PA and commuting to school (active or inactive)	Q* Self-report	Media time: TV and computer use	Q* Self-report	NA	NA	CA‡ Two-step
Van DerSluis *et al.*, 2010[50], Norway	C	2005	*n* 724 6th and 7th grades	Fruits, vegetables, soda and snacking intake	FFQ Self-report	Time of PA outside school	Q Self-report	TV and computer use	Q Self-report	NA	NA	CA *k*-means
Seghers; Rutten, 2010[51], Belgium	C	2007	*n* 317 11–12 years	Health food index Risk-related food index	FFQ† Self-report	LTPA	FPAQ*,† Self-report	Screen-based media use: TV, computer, video console games and computer games Time of homework	Q Self-report	NA	NA	CA‡ *k*-means
Ottevaere *et al.*, 2011[52], Greece, Germany, Belgium, France, Italy, Spain, Sweden and Austria	C	2006–2007	*n* 2084 12–17 years	Diet Quality Index for Adolescents (DQI-A)	HELENA – DIAT 2-d 24-h recall† Self-report	MVPA	IPAQ*,† Self-report	Time of TV, computer games, video console games, use of internet for non-study and study reasons Time of studying and homework	HELENA Q* Self-report	NA	NA	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)
Spengler *et al.*, 2012[64], Germany	C	2003–2006	*n* 1643 11 and 17 years	Healthy nutrition score (HuSKY)	54-item FFQ† Self-report	Time of PA in sports clubs and during leisure time outside of sports clubs	MoMo-PAQ*,† Self-report	Electronic media use: TV, video console games and computer	KIGGS Q Self-report	NA	NA	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)
Veloso *et al.*, 2012[62], Portugal	C	2010	*n* 3069 12·9–16·9 years	Fruits, vegetables, soft drinks and sweets	HBSC FFQ Self-report	Frequency and time of MVPA and intense exercise out of school (sport or leisure)	HBSC Q Self-report	Screen time: TV, video console games, and computer use for game, internet, or homework	HBSC Q Self-report	NA	NA	CA *k*-means
Iannotti and Wang, 2013[53], USA	C	2005–2006	*n* 9206 11–16 years	Fruits, vegetables, sweets (chocolates and candy), sweetened soft drinks, chips and French fries	FFQ*,† Self-report	PA frequency	7-d recall Q*,† Self-report	Screen-based sedentary behaviour: TV (video and DVD), video console game, computer use for game, internet or homework	Q*,† Self-report	NA	NA	LCA (AIC, BIC and a-BIC)

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press

Table 1. (*Continued*)

Author and country	Design study	Survey year	Sample (*n*, age range or grade)	Diet variables	Diet assessment method	PA variables	PA assessment method	SB variables	SB assessment method	Sleep variables	Sleep assessment method	LP derivation method
Fernandez-Alvira *et al.*, 2013[54], Belgium, Greece, Hungary, the Netherlands, Norway, Slovenia and Spain	C	2010	*n* 5284 10–12 years	Soft drinks and fruit juices	2-item FFQ*,† Self-report	Time of active transportation to school and sports participation	Q*,† Self-report	Screen time: TV (video and DVD) and computer activities	Q*,† Self-report	Weekdays hours/d of sleep duration	Q*,† Parent report	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)
Perez-Rodrigo *et al.*, 2015[55], Spain	C	2013	*n* 208 13–17 years	Four dietary patterns derived by PCA Mediterranean Sandwich Pasta Milk-sugary food	1-d 24-h recall and 3-d record Face-to-face interview	MVPA and commuting-related PA	IPAQ† Face-to-face interview	Screen time: TV, video console games, computer use for games, internet Time of homework (not including classroom time)	Q† Face-to-face interview	Weekdays hours/d of sleep duration	Q*,† Face-to-face interview	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)
Berlin *et al.*, 2017[61], USA	C	2007	*n* 9295 8th grade	Milk, 100 % fruit juice, soda and fruit drink that are not 100 % juice, carrots, vegetable, fruits, salad, potato, fast food	9-item FFQ Self-report	Participation in school sports, engagement in non-school sports, days of vigorous PA and days of physical education	Q Self-report	Screen time: TV (video and DVD), video console games, computer use for games or internet	Q Self-report	NA	NA	LPA (BIC, AIC and LMR)
Laxer *et al.*, 2017[45], Canada	C	2012/2013	*n* 18 587 13–17 years	Breakfast consumption, fast food, snacking behaviour, sugar-sweetened beverage, fruit and vegetable consumption	5-item FFQ*,† *Validity and reliability tests to fruit and vegetable only Self-report	Time of hard and moderate PA, PA organised by the school orcompetitive school sports teams	Q*,† Self-report	Sedentary behaviour: TV, video console games, computer use for games or internet	Q*,† Self-report	NA	NA	LCA‡ (AIC, BIC, CAIC and a-BIC)
Laxer *et al.*, 2018[46], Canada	P	T0:2012–2013 T1:2013–2014 T2:2014–2015	*n* 5084 13–17 years									
Nuutinen *et al.*, 2017[56], Finland	C	2010	*n* 3865 B = 1814 G = 2051 13 and 15 years	Junk food, fruit and vegetable intake	HBSC FFQ*,† Self-report	Time of PA outside of school	HBSC Q*,† Self-report	Screen time: TV (video and DVD), video console games, computer use for internet, games or homework	HBSC Q*,† Self-report	Weekdays hours/d of sleep duration, discrepancy of sleep duration and sleep quality	Q*,† Self-report	CA *k*-means
Dantas *et al.*, 2018[57], Brazil	C	2017	*n* 578 B = 186 G = 392 12–18 years	Fruits, vegetables, sugary products and soft drinks	YRBS FFQ† Self-report	PA score	PAQ-A*,† Self-report	Screen time: TV, computer, video game, tablet and smartphone	Q Self-report	NA	NA	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)
Moreira *et al.*, 2018[44], Greece, Germany, Belgium, France, Italy, Sweden, Austria, Spain (HELENA), Brazil (ELANA)	C	HELENA 2006–2007	*n* 2057 B = 950 G = 1107 12, 5–17 years	Fruits, vegetables (excluding potatoes) and sugar-sweetened beverages	HELENA – DIAT 2-d 24-h recall*,† Self-report	MVPA	IPAQ-A†	Time of TV watching	HELENA Q*,† Self-report	NA	NA	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)
		ELANA 2010	*n* 968 B = 453 G = 515 13, 5–19 years	Fruits, vegetables (excluding potatoes) and sugar-sweetened beverages	72-item FFQ† Self-report	MVPA	IPAQ*,† Self-report	Time of TV watching	Q Self-report	NA	NA	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press

Table 1. (*Continued*)

Author and country	Design study	Survey year	Sample (*n*, age range or grade)	Diet variables	Diet assessment method	PA variables	PA assessment method	SB variables	SB assessment method	Sleep variables	Sleep assessment method	LP derivation method
Wadolowska *et al.*, 2018[58], Poland	C	2015–2016	*n* 1549 11–13 years	Consumption of breakfast, school meal and nine food items: dairy products, fish, vegetables, fruit, fruit/vegetable juices, fast foods, sweetened and energy drinks, and sweets	50-item SF-FFQ4Polish Children* Self-report	PA at school or leisure time	50-item SF-FFQ4Polish Children* Self-report	Screen time: TV or computer.	50-item SF-FFQ4Polish Children* Self-report	NA	NA	CA *k*-means
Sevil-Serrano *et al.*, 2019[59], Spain	C	2015	*n* 173 12·9 years (mean)	Healthy diet index	HBSC FFQ† Self-report	MVPA	Accelerometer over a 7-d	Sedentary time Screen time: TV, computer, video console game and mobile phone	Accelerometer over a 7-d YLSBQ Q Self-report	Weekdays and weekend sleep duration	Spanish version of Pittsburgh Sleep Quality Index Self-report	CA Hierarchical (Ward's method) and non-hierarchical (*k*-means)
Marttila-Tornio *et al.*, 2019[63], Finland	C	2001	*n* 4305 15–16 years	Sugary foods, fast food, fruits, vegetables and berries intake	5-item FFQ Self-report	Vigorous PA outside of school	Q Self-report	Screen time: TV, computer, video game	Q Self-report	NA	NA	CA‡ *k*-means
Dos Santos *et al.*, 2020[60], Portugal	C	2009–2010	*n* 4036 13·6 (median)	Fruits, vegetables, sweets, coke, or other soft drinks	HBSC FFQ Self-report	Time of PA	HBSC Q Self-report	Screen-based activities: TV, video game and computer	HBSC Q Self-report	NA	NA	CA‡ Two-step

PA, physical activity; SB, sedentary behavior; LP, lifestyle pattern; B, boys; G, girls; C, cross-sectional; Q, questionnaire; TV, television; NA, not applicable; FPAQ, Flemish physical activity questionnaire; T, time; LTPA, leisure-time physical activity; YRBS, youth risk behaviour survey; HELENA, healthy lifestyle in Europe by nutrition in adolescence; DIAT, dietary assessment tool; MVPA, moderate vigorous physical activity; IPAQ, international physical activity questionnaire; SF, short form; SF-FFQ4PolishChildren, multicomponent dietary questionnaire to assess food frequency consumption, nutrition knowledge and lifestyle in Polish schoolchildren; MoMo-PAQ, Motorik-Modul physical activity questionnaire; KIGGS, German health interview and examination survey for children and adolescents; HBSC, health behaviour in school-aged children; YLSBQ, Spanish version of youth leisure-time sedentary behaviour questionnaire; P, prospective; CA, cluster analysis; LCA, latent class analysis; PCA, principal component analysis; LPA, latent profile analysis; BIC, bayesian information criterion; AIC, akaike information criteria; a-BIC, adjusted bayesian information criterion; CAIC, consistent akaike information criterion; LMR, Lo–Mendell–Rubin test.

* Values for reliability reported or can be found through the reference(s) provided.

† Values for validity reported or can be found through the reference(s) provided.

‡ Also examined other behaviours (e.g. smoking, drugs and alcohol use, psychological factors, dieting behaviours, parental involvement and scholar aspects).

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press

nights) and quality of sleep[56]. Four studies reported both the reliability and validity for all assessed measures[49,53,54,56].

Cluster analysis was the most frequently used method to identify lifestyle patterns (*n* 18/21). The techniques used were a combination of hierarchical (Ward's method) and non-hierarchical (*k*-means) clustering[44,52,54,55,57,59,64], *k*-means[49–51,56,58,62,63] and two-step[48,60]. In addition, two studies applied latent class analysis[45,46,53], and one latent profile analysis[61] (Table 1).

Risk of bias assessment

Of the articles included in the synthesis of the results[44–47,50,55–60], only six out of eleven provided clear eligibility criteria. Most articles clearly specified their study population (*n* 9/11). No study used reliable and valid measures for all exposure variables, and five assessed their outcome measures objectively. Although all studies have established strategies to deal with confounders, these factors were adequately accounted for in only nine studies. Nine studies used appropriate statistical analysis models. Of these studies, six had a low risk of bias (54·5 %)[44,47,55,57,58,60], four moderate risk (36·4 %)[45,46,50,56] and one high risk (9·1)[59]. Risk of bias assessment of the studies is presented in Table S5, Supplementary Material.

Lifestyle patterns

Table 2 describes the lifestyle patterns identified in the twenty-one studies evaluated. We found sixteen completely healthy lifestyle patterns[49,50,52–56,58–63] and fourteen completely unhealthy patterns.[43,44,50,51,55,56,58,59,63] Among completely healthy lifestyle patterns, six included the diet, physical activity, sedentary behaviour and sleep domains[54–56,59], although different methods were used to measure indicators. Three completely healthy lifestyle patterns included low substance use[60,63]. Five of the fourteen completely unhealthy lifestyle patterns were determined on the basis of the four domains[55,56,59]. Two completely unhealthy lifestyle patterns included high substance use[63]. Predominantly healthy (*n* 24) and predominantly unhealthy (*n* 31) lifestyle patterns prevailed among adolescents. High levels of both physical activity and sedentary behaviour co-occurred in some predominantly unhealthy patterns[52,57,62]. However, most of the predominantly unhealthy lifestyle patterns included behaviours such as low physical activity levels, high sedentary behaviour levels, low healthy food consumption and low/moderate unhealthy food consumption[44,49,52–54,57,64]. Some lifestyle patterns were considered mixed (*n* 22), with a balance of healthy and unhealthy behaviours[44,45,48,51,54,58–60,62,64] (Table 2).

Associations with overweight and/or obesity

Table 3 provides details of the identified lifestyle patterns and their associations with overweight/obesity. In eleven studies, weight and height measurements were used to determine BMI[44,47,48,52,54,55,57,58,61,64]. Nine studies used self-reported weight and height[45,50,51,53,56,59,60,62,63], and one study used parent-reported weight and height[49]. Nine studies were based on IOTF cut-offs for overweight/obesity[48,49,51,52,54–57,62], one on IOTF and Polish standards[58], five on WHO[44,45,60,63], two on CDC[47,53,61], and one on national reference values[64].

Three studies used BMI as a continuous measure[46,50,59], and one was based on BMI *Z*-scores[61]. Eight studies used Pearson's χ^2 tests[48,49,51–54,63,64], one used the Bose-Chaudhuri-Hocquenghem (BCH) method[61], one used one-way ANOVA[62] and another used multivariate ANOVA[59] to describe lifestyle patterns according to weight status. Eleven studies used regression analysis to identify associations[44–47,50,55–58,60]. Regarding the degree of adjustment for confounding factors, seven studies adjusted for the three typical confounders (age, sex and socio-economic status or some proxy for this variable)[43,45,46,55,57,58,60]. Three studies did not adjust for age[44,50], and one did not adjust for socio-economic status[56]. The twelve studies that adopted adjusted analyses (multivariate ANOVA and regression analysis) were used here for synthesis of results of the total sample[44–47,50,55–60]. Five of these studies stratified data by sex[44,47,56,57].

Table 4 provides a synthesis of the results. Prospective analysis revealed positive associations between all predominantly unhealthy and mixed lifestyle patterns and overweight/obesity. In the cross-sectional studies, most lifestyle patterns were not associated with overweight/obesity. An inverse association between completely healthy lifestyle patterns and overweight/obesity was observed only once out of three times. For completely unhealthy lifestyle patterns, almost all associations (eight out of nine) were null. Two predominantly healthy lifestyle patterns were positively associated with overweight/obesity and nine were not associated. The association between predominantly unhealthy lifestyle patterns and overweight/obesity was positive in seven out of sixteen times. Only one mixed lifestyle pattern (out of twelve) was associated with overweight/obesity (Table 4).

When stratifying by sex, we observed a positive association between predominantly healthy lifestyle patterns and overweight/obesity in girls two out of five times. The association between predominantly unhealthy lifestyle patterns and overweight/obesity was tested eight times for girls and five times for boys, with three and two positive associations, respectively. No association was found between the other lifestyle pattern classifications and overweight/obesity in boys or girls (Table 5).

Table S9 presents the synthesis of the results according to the risk of bias. For cross-sectional studies with moderate risk of bias, a positive association between predominantly unhealthy lifestyle patterns and overweight/obesity was found in three out of four times. A positive association with overweight/obesity was also found for the single mixed lifestyle pattern. The positive associations found in the prospective analysis included in this systematic review come from studies with moderate risk of bias (Table S9, online Supplementary Material).

Discussion

This review sought to identify the association between lifestyle patterns identified by data-driven exploratory analysis and overweight/obesity in adolescents. It was possible to note a co-occurrence of healthy and unhealthy behaviours in lifestyle

Table 2. Summary of lifestyle patterns identified

Lifestyle pattern classification	*n*	HD/UD + PA (*n* studies = 1)	*n*	HD/UD + PA + SB (*n* studies = 12)	*n*	HD/UD + PA + SB + S (*n* studies = 4)	*n*	HD/UD + PA + SB + SU (*n* studies = 4)
Completely healthy (*n* 16)	1[49]	↑ HD, ↓ UD, ↑ PA	5[50,53,58,61,62]	↑ HD, ↓ UD, ↑ PA, ↓ SB	2[56]	↑ HD, ↓ UD, ↑ PA, ↓ SB, ↑ S	3[60,63]	↑ HD, ↓ UD, ↑ PA, ↓ SB, ↓ SU
			1[52]	↑ HD, ↑ PA, ↓ SB	2[55,59]	↑ HD, ↑ PA, ↓ SB, ↑ S		
					2[54]	↓ UD, ↑ PA, ↓ SB, ↑ S		
Completely unhealthy (*n* 14)			4[44,50,51,58]	↓ HD, ↑ UD, ↓ PA, ↑ SB	2[56]	↓ HD, ↑ UD, ↓ PA, ↑ SB, ↓ S	2[63]	↓ HD, ↑ UD, ↓ PA, ↑ SB, ↑ SU
			1[64]	↓ HD, ↓ PA, ↑ SB	1[56]	↓ HD, ↑ UD, ↓ PA, ↔ SB, ↓ S		
			1[47]	↓ HD, ↑ UD, ↓ PA	2[55,59]	↓ HD, ↓ PA, ↑ SB, ↓ S		
			1[47]	↓ HD, ↓ PA				
Predominantly healthy (*n* 24)	1[49]	↑ HD, ↑ UD, ↑ PA	4[44,57]	↓ HD, ↓ UD, ↑ PA, ↓ SB	3[54]	↓ UD, ↓ PA, ↓ SB, ↑ S	1[48]	↑ HD, ↓ UD, ↑ PA, ↓ SB, ↔ SU
	1[49]	↑ HD, ↓ UD, ↔ PA	1[44]	↑ HD, ↑ UD, ↑ PA, ↓ SB			1[45,46]	↑ HD, ↓ UD, ↔ PA, ↓ SB, ↓ SU
			5[44,51,57]	↑ HD, ↓ UD, ↓ PA, ↓ SB			1[60]	↔ HD, ↓ UD, ↓ PA, ↓ SB, ↓ SU
			1[51]	↑ HD, ↓ UD, ↔ PA, ↓ SB				
			2[52,64]	↑ HD, ↓ PA, ↓ SB				
			1[50]	↔ HD, ↓ UD, ↑ PA, ↔ SB				
			2[44,57]	↔ HD, ↓ UD, ↑ PA, ↓ SB				
Predominantly unhealthy (*n* 31)	1[49]	↓ HD, ↓ UD, ↓ PA	2[57,62]	↓ HD, ↑ UD, ↑ PA, ↑ SB	1[56]	↓ HD, ↔ UD, ↓ PA, ↑ SB, ↓ S	1[45,46]	↓ HD, ↑ UD, ↔ PA, ↑ SB, ↑ SU
	1[49]	↑ HD, ↑ UD, ↓ PA	1[44]	↓ HD, ↑ UD, ↓ PA, ↓ SB	2[54]	↑ UD, ↓ PA, ↑ SB, ↑ S	1[45,46]	↔ HD, ↑ UD, ↓ PA, ↑ SB, ↓ SU
			6[44,57]	↓ HD, ↓ UD, ↓ PA ↑ SB	1[54]	↔ UD, ↓ PA, ↑ SB, ↓ S	1[48]	↔ HD, ↑ UD, ↔ PA, ↑SB, ↑SU
			1[50]	↓ HD, ↓ UD, ↔ PA, ↑ SB				
			1[53]	↓ HD, ↓ UD, ↓ PA, ↔ SB				
			2[57]	↓ HD, ↑ UD, ↓ PA, ↔ SB				
			1[61]	↓ HD, ↔ UD, ↓ PA, ↔ SB				
			1[52]	↓ HD, ↑ PA, ↑ SB				
			1[64]	↓ HD, ↓ PA, ↓ SB				
			1[54]	↓ HD, ↓ PA, ↔ SB				
			1[44]	↑ HD, ↑ UD, ↓ PA, ↔ SB				
			2[53,61]	↔ HD, ↑ UD, ↔ PA, ↑ SB				
			1[44]	↔ HD, ↑ UD, ↓ PA, ↔ SB				
			1[54]	↔ HD, ↓ PA, ↑ SB				
Mixed (*n* 22)			1[57]	↓ HD, ↓ UD, ↑ PA, ↑ SB	2[54]	↓ UD, ↓ PA, ↓ SB, ↓ S	1[48]	↔ HD, ↔ UD, ↓ PA, ↔ S, ↓ SU
			7[44,57,58]	↓ HD, ↓ UD, ↓ PA, ↓ SB	1[59]	↓ HD, ↑ PA, ↓ SB, ↓ S	1[45,46]	↔ HD, ↑ UD, ↑ PA, ↔ SB, ↓ SU
			1[62]	↓ HD, ↔ UD, ↓ PA, ↓ SB	1[59]	↑ HD, ↓ PA, ↑ SB, ↑ S	1[60]	↔ HD, ↑ UD, ↑ PA, ↑ SB, ↓ SU
			1[51]	↑ HD, ↑ UD, ↑ PA, ↑ SB	1[59]	↑ HD, ↓ PA, ↓ SB, ↔ S	1[60]	↔ HD, ↔ UD, ↓ PA, ↔ SB, ↑ SU
			1[44]	↔ HD, ↑ UD, ↑ PA, ↑ SB	1[59]	↔ HD, ↔ PA, ↑ SB, ↔ S		
			1[64]	↔ HD, ↑ PA, ↔ SB				

n, absolute frequency; HD, healthy diet; UD, unhealthy diet; PA, physical activity; SB, sedentary behaviour; S, sleep; SU, substance use; ↑, high; ↓, low; ↔, moderate.
Adapted from D'Souza *et al.* (2020)[12].

Table 3. Associations between lifestyle patterns and overweight and obesity in adolescents

Reference	LP identified		Outcome measurement method	Outcome indicator	Method of analysis	Associations of LP and overweight and obesity	
Boone-Heinonen *et al.*, 2008[47]	Girls: (a) School clubs and sports (*n* 856) (b) Average diet and activity (*n* 1064) (c) High consumer of all food items, with particularly nutrient-dense foods (*n* 560) (d) Sedentary behaviors (*n* 328) (e) Junk food, low activity (*n* 913) (f) Restrictive diet and smoke (*n* 761)	Boys: (a) School clubs and sports (*n* 285) (b) Sports (*n* 527) (c) Moderately active (*n* 904) (d) Sedentary behaviors (*n* 339) (e) Junk food and smoke (*n* 671) (f) Dieters (*n* 444) (g) Low diet and activity (*n* 1188)	Weight and height measured	Presence of obesity (CDC)	Multivariate logistic regression adjusted for race, household income, highest parental, education attained, region, and wave-specific age and season.	Girls:* (a) Reference (b) Positive (OR: 2·02) (c) Positive (OR: 1·75) (d) Positive (OR: 2·02) (e) None (OR: 1·23) (f) Positive (OR: 2·37)	Boys:* (a) Reference (b) None (OR: 0·82) (c) None (OR: 0·88) (d) None (OR: 1·27) (e) Positive (OR: 0·49) (f) None (OR: 1·37) (g) None (OR: 1·37)
Sabbe *et al.*, 2008[49]	(a) Sporty healthy eaters (*n* 242) (b) Sporty mixed eaters (*n* 288) (c) Moderate active healthy eaters (*n* 221) (d) Unsporting unhealthy eaters (*n* 276) (e) Sedentary healthy eaters (*n* 318)		Weight and height reported by parents	Percentage of overweight (IOTF)	Pearson's χ^2 test.	None ($P > 0{\cdot}05$)	
Landsberg *et al.*, 2010[48]	(a) Low activity and low-risk behaviour (*n* 740/ 45·3 % girls) (b) High media time and high-risk behaviour (*n* 498/45·0 % girls) (c) High activity and medium-risk behaviour (*n* 656/63·6 % girls)		Weight and height measured	Percentage of overweight and obesity (IOTF)	Pearson's χ^2 test.	No association for total sample and boys ($P > 0{\cdot}05$) Girls in cluster "a" had higher prevalence of overweight (17·0 %) and cluster "c" had a lower prevalence of overweight (11·0 %). The prevalence of overweight in cluster "b" was 14·3 % ($P = 0{\cdot}017$).	
	(a) Low activity and low-risk behaviour (*n* 152/ 40·1 % girls) (b) High media time and high-risk behaviour (*n* 102/45·1 % girls) (c) High activity and medium-risk behaviour (*n* 135/57·8 % girls)			Percentage of overweight and obesity (IOTF)		Incidence rates of overweight to total sample were not significant. Incidence rates of obesity was higher in cluster 'a' (5·9 %) and lower in cluster 'c' (0·7 %). The incidence in cluster 'b' was 2·0 % ($P < 0{\cdot}05$).	
Van Der Sluis *et al.*, 2010[50]	(a) Healthy cluster (*n* 88) (b) Quite healthy (*n* 255) (c) Quite unhealthy (*n* 270) (d) Unhealthy (*n* 89)		Self-reported weight and height	BMI (kg/m^2)	Linear regression adjusted for sex and parental education level.	(a) Reference (b) None (β: −0·28; $P = 0{\cdot}56$) (c) None (β: −0·13; $P = 0{\cdot}79$) (d) Inverse (β: −1·27; $P = 0{\cdot}04$)	
Seghers and Rutten, 2010[51]	(a) Sporty media-oriented mixed eaters (*n* 50) (b) Academic healthy eaters (*n* 88) (c) Inactive healthy eaters (*n* 95) (d) Inactive media-oriented unhealthy eaters (*n* 84)		Self-reported weight and height	Percentage of overweight (including obesity) (IOTF)	Pearson's χ^2 test.	None ($P > 0{\cdot}05$)	
Ottevaere *et al.*, 2011[52]	(a) Unhealthy cluster (*n* 430) (b) Sedentary cluster (*n* 247) (c) Active, low-diet quality cluster (*n* 152) (d) Inactive, high-diet quality cluster (*n* 877) (e) Healthy cluster (*n* 378)		Weight and height measured	Percentage of overweight and obesity (IOTF)	Pearson's χ^2 test.	None ($P > 0{\cdot}05$)	

Table 3. (*Continued*)

Reference	LP identified	Outcome measurement method	Outcome indicator	Method of analysis	Associations of LP and overweight and obesity
Spengler *et al.*, 2012[64]	(a) High physical activity index, average media use and healthy nutrition indices (*n* 266) (b) High healthy nutrition index, below average physical activity, and media use (*n* 564) (c) Very high media use index, low physical activity and healthy nutrition indices (*n* 306) (d) Below average on all three indices (*n* 507)	Weight and height measured	Percentage of overweight (including obesity) (National cut points)	Pearson's χ^2 test.	The percentage of overweight was higher in cluster 'c' (22·2 %), followed by the cluster 'b' (16·7 %), 'a' (12·5 %) and 'd' (12·6 %) ($P < 0·001$).
Veloso *et al.*, 2012[62]	(a) Active gamers (b) Healthy (c) Sedentary	Self-reported weight and height	Percentage of overweight and obesity (IOTF)	One-way ANOVA	None ($P > 0·05$)
Iannotti and Wang, 2013[53]	(a) Healthful pattern (26·6 %) (b) Unhealthful pattern (26·4 %) (c) Typical (47·2 %)	Self-reported weight and height	Percentage of overweight and obesity (CDC)	Pearson's χ^2 test.	Adolescents in cluster 'c' (18·4 %) were more likely to have overweight compared with clusters 'a' (15·8 %) and 'b' (16·3 %). Girls in cluster 'c' were more likely to have overweight (17·4 %) and obese (12·7 %) compared with clusters 'a' (overweight: 14·3 % and obesity: 9·9 %) and 'b' (overweight: 15·2 % and obesity: 12·5 %).
Fernandez-Alvira *et al.*, 2013[54]	Girls: (a) Active pattern (*n* 641) (b) Long sleepers inactive pattern (*n* 615) (c) Sedentary sugared drinks consumers(*n* 436) (d) Short sleepers inactive pattern (*n* 529) (e) Low activity pattern (*n* 650) Boys: (a) Active pattern (*n* 540) (b) Long sleepers inactive pattern (*n* 479) (c) Sedentary sugared drinks consumers (*n* 240) (d) Short sleepers inactive pattern (*n* 753) (e) Sedentary pattern (*n* 401)	Weight and height measured	Percentage of overweight and obesity (IOTF)	Pearson's χ^2 test.	Girls in cluster 'd' were more likely to have overweight (22·4 %), followed by the cluster 'e' (21·7 %), 'c' (19·1 %), 'a' (15·5 %) and 'b' (12·0 %) ($P < 0·001$). Boys in cluster 'd' were more likely to have overweight (27·7 %), followed by the cluster 'e' (24·8 %), 'c' (20·1 %), 'b' (17·3 %) and 'a' (16·4 %) ($P < 0·001$). Girls in cluster 'd' were more likely to be obese (8·7 %), followed by the cluster 'c' (5·9 %), 'e' (3·7 %), 'b' (2·3 %) and 'a' (2·1 %) ($P < 0·001$). Boys in cluster 'd' were more likely to be obese (7·4 %), followed by the cluster 'e' (6·6 %), 'c' (5·1 %), 'b' (4·0 %) and 'a' (2·6 %) ($P < 0·001$).
Perez-Rodrigo *et al.*, 2015[55]	For girls and boys: (a) Unhealthier lifestyle pattern (b) Healthier lifestyle pattern	Weight and height measured	Presence of overweight and obese (IOTF)	Logistic regression adjusted for energy intake, sex, age, family educational level and socio-economic status (SES).	(a) Reference (b) None (OR: 2·00; 95 % CI (0·82, 4·86))
Berlin *et al.*, 2015[61]	(a) Active + healthy diet (b) Sedentary + unbalanced diet (c) Screen time + junk food	Weight and height measured	BMI *Z*-scores (CDC)	BCH method	The BMI *Z*-scores of the class 'c' (0·80) were the highest and significantly greater than class 'b' (0·69), which was significantly higher than class 'a' (0·60)
Laxer *et al.*, 2017[45]		Self-reported weight and height	Presence of overweight and obesity (WHO)	Logistic regression adjusted for school grade, sex, race, and total spending money.	(a) Positive (OR: 1·15; 95 % CI (1·03, 1·29)) (b) Positive (OR: 1·33; 95 % CI (1·19, 1·48)) (c) Reference (d) Positive (OR: 1·27; 95 % CI (1·14, 1·43))

Table 3. (*Continued*)

Reference	LP identified	Outcome measurement method	Outcome indicator	Method of analysis	Associations of LP and overweight and obesity
Laxer *et al.*, 2018[46]	(a) Traditional school athletes (24 %) (b) Inactive screenagers (43·3 %) (c) Health conscious (16 %) (d) Moderately active substance users (16·6 %)	Self-reported weight and height	BMI (kg/m²)	Linear mixed effects regression: Model 1: controlled for year and school Model 2: controlled for year, sex, grade, race and weekly spending money.	Model 1 (a) Positive (β: 0·410; 95 % CI (0·12, 0·68)) (b) Positive (β: 0·344; 95 % CI (0·10, 0·59)) (c) Reference (d) Positive (β: 1·041; 95 % CI (0·65, 1·44)) Model 2 (a) Positive (β: 0·232; 95 % CI (0·03, 0·50)) (b) Positive (β: 0·348; 95 % CI (0·11, 0·59)) (c) Reference (d) Positive (β: 0·759; 95 % CI (0·36, 1·15))
Nuutinen *et al.*, 2017[56]	Girls: (a) Healthy lifestyle (*n* 1112) (b) High screen time, unhealthy lifestyle (*n* 505) (c) Poor sleep, unhealthy lifestyle (*n* 434) Boys: (a) Healthy lifestyle (*n* 996) (b) High screen time, unhealthy lifestyle (*n* 308) (c) Low/moderate screen time, unhealthy lifestyle (*n* 510)	Self-reported weight and height	Presence of overweight (including obesity) (IOTF)	Logistic regression adjusted for age and educational aspiration.	Girls: (a) Reference (b) Positive (OR: 1·42; 95 % CI (1·05, 1·94)) (c) None (OR: 1·05; 95 % CI (0·73, 1·51)) Boys: (a) Reference (b) None (OR: 1·34; 95 % CI (0·97, 1·86)) (c) None (OR: 1·08; 95 % CI (0·81, 1·43))
Dantas *et al.*, 2018[57]	Girls: (a) Higher physical activity (*n* 70) (b) More sedentary behaviour (*n* 94) (c) Higher physical activity and greater sedentary behaviour (*n* 59) (d) High consumption of sugary products/soft drinks (*n* 40) (e) Low consumption of sugary products/soft drinks and less sedentary behaviour (*n* 71) (f) High consumption of fruits/vegetables, low consumption of sugary products/soft drinks and less sedentary behaviour (*n* 58) Boys: (a) Higher physical activity (*n* 41) (b) Sedentary behaviour (*n* 43) (c) Higher physical activity, greater sedentary behaviour (*n* 28) (d) High consumption of sugary products/soft drinks (*n* 16) (e) Low consumption of sugary products/soft drinks and less sedentary behaviour (*n* 32) (f) High consumption of fruits/vegetables, low consumption of sugary products/soft drinks and less sedentary behaviour (*n* 26)	Weight and height measured	Presence of overweight and obesity (IOTF)	Logistic regression adjusted for age and economy class.	Girls: (a) None (OR: 0·92; 95 % CI (0·70, 1·30)) (b) Positive (OR: 1·53; 95 % CI (1·06, 2·26)) (c) None (OR: 1·34; 95 % CI 0·95, 1·89)) (d) Positive (OR: 1·47; 95 % CI (1·05, 2·13)) (e) None (OR: 1·15; 95 % CI (0·87, 1·62)) (f) Reference Boys: (a) None (OR: 0·89; 95 % CI (0·65, 1·32)) (b) Positive (OR: 1·63; 95 % CI (1·12, 2·35)) (c) None (OR: 1·42; 95 % CI (0·99, 2·04)) (d) Positive (OR: 1·51; 95 % CI (1·05, 2·16)) (e) None (OR: 1·19; 95 % CI (0·88, 1·72)) (f) Reference

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press

Table 3. (*Continued*)

Reference	LP identified		Outcome measurement method	Outcome indicator	Method of analysis	Associations of LP and overweight and obesity	
Moreira *et al.*, 2018[44]	HELENA: Girls: (a) High TV and low MVPA (*n* 242) (b) High SSB and low MVPA (*n* 150) (c) High MVPA (*n* 172) (d) High F&V (*n* 209) (e) Low TV, MVPA, F&V and SSB (*n* 334)	HELENA: Boys: (a) High TV and low MVPA (*n* 178) (b) High SSB consumption (*n* 110) (c) High MVPA and low TV (*n* 189) (d) High F&V, low SSB consumption, low TV and low MVPA (*n* 168) (e) Low TV, low MVPA, and low F&V and SSB consumption (*n* 308)	Weight and height measured	Presence of overweight (including obesity) (WHO)	Logistic regression adjusted for socio-economic status and total energy intake	Girls: (a) None (OR: 1·25; 95 % CI (0·85, 1·85)) (b) None (OR: 1·11; 95 % CI (0·68, 1·79)) (c) None (OR: 0·95; 95 % CI (0·61, 1·48)) (d) None (OR: 0·85; 95 % CI (0·55, 1·33)) (e) Reference	Boys: (a) None (OR: 1·20; 95 % CI (0·79, 1·82)) (b) None (OR: 1·30; 95 % CI (0·77, 2·19)) (c) None (OR: 1·08; 95 % CI (0·72, 1·63)) (d) None (OR: 0·93; 95 % CI (0·59, 1·46)) (e) Reference
	ELANA: Girls: (a) High TV and low MVPA (*n* 179) (b) High SSB and low MVPA (*n* 61) (c) High MVPA (*n* 63) (d) High SSB and F&V (*n* 30) (e) Low TV, MVPA, F&V and SSB (*n* 182)	ELANA: Boys: (a) High TV and low MVPA (*n* 180) (b) High SSB consumption (*n* 78) (c) High MVPA and low TV (*n* 56) (d) High TV and high MVPA (*n* 33) (e) Low TV, low MVPA and low F&V and SSB consumption (*n* 126)	Weight and height measured	Presence of overweight (including obesity) (WHO)	Logistic regression adjusted for type of school and total energy intake	Girls: (a) None (OR: 1·42; 95 % CI (0·86, 2·35)) (b) None (OR: 1·60; 95 % CI (0·72, 3·55)) (c) Positive (OR: 2·19; 95 % CI (1·14, 4·19)) (d) Positive (OR: 2·89; 95 % CI (1·09, 7·62)) (e) Reference	Boys: (a) None (OR: 1·19; 95 % CI (0·70, 2·02)) (b) None (OR: 0·85; 95 % CI (0·39, 1·89)) (c) None (OR: 1·44; 95 % CI (0·72, 2·86)) (d) None (OR: 1·84; 95 % CI (0·79, 4·27)) (e) Reference
Wadolowska *et al.*, 2018[58]	(a) Prudent-active pattern (29·3 %) (b) Fast-food sedentary pattern (13·8 %) (c) Not prudent-not fast-food-low active (56·9 %)		Weight and height measured	Presence of overweight (including obesity) (IOTF and Polish cut points)	Logistic regression adjusted for sex, age, residence, family affluence scale (points), nutrition knowledge score.	(a) Inverse (International standards: OR: 0·62; 95 % CI (0·47, 0·84) and Polish standards: 0·67; 95 % CI (0·50, 0·91)) (b) None (International standards: OR: 0·82; 95 % CI (0·56, 1·19) and Polish standards: 0·92; 95 % CI (0·63, 1·34) (c) None (International standards: OR: 1·34; 95 % CI (0·86, 2·11) and Polish standards: 1·34; 95 % CI (0·84, 2·13))	
Sevil-Serrano *et al.*, 2019[59]	(a) Inactive unhealthy eaters (b) Non-technological sitters (c) Active (d) Technological sleepyheads (e) Ideal health (f) Inactive healthy eaters		Self-reported weight and height	BMI (kg/m²)	Multivariate ANOVA and Bonferroni's *post hoc* test.	None ($P=0·375$)	

Table 3. (*Continued*)

Reference	LP identified	Outcome measurement method	Outcome indicator	Method of analysis	Associations of LP and overweight and obesity
Marttila-Tornio *et al.*, 2019[63]	Girls (a) Healthy lifestyle (58 %; *n* 1340) (b) Unhealthy lifestyle (42 %; *n* 962) Boys (a) Healthy lifestyle (61 %, *n* 1215) (b) Unhealthy lifestyle (39 %; *n* 788)	Self-reported weight and height	Presence of overweight and obesity (WHO)	Pearson's χ^2 test.	No significant relationship between the identified clusters and BMI was identified for either the boys ($P = 0{\cdot}091$) or girls ($P = 0{\cdot}424$).
Dos Santos *et al.*, 2020[60]	(a) Active screen users (31·1 %) (b) Substance users (13·3 %) (c) Healthy (26·4 %) (d) Inactive low fruit and vegetable eaters (29·1 %)	Self-reported weight and height	Presence of overweight and obesity (WHO)	Multinomial regression adjusted for age, sex, family affluence scale, family structure, family communication, school attachment, academic achievement, evenings with friends, bullied others, participation in fights	(a) None (OR: 1·16; 95 % CI (0·94, 1·43)) (b) None (OR: 0·94; 95 % CI (0·72, 1·23)) (c) Reference (d) None (OR: 1·17; 95 % CI (0·94, 1·44))

LP, lifestyle pattern; CDC, Centers for Disease Control and Prevention; IOTF, International Obesity Task Force; HELENA, healthy lifestyle in Europe by nutrition in adolescence; MVPA, moderate vigorous physical activity; SSB, sugar-sweetened beverage; B, boys; G, girls; β1, coefficient beta.
* CI not described in the text, only in the figure.

patterns. Predominantly unhealthy lifestyle patterns were more frequently observed among adolescents. Overall, synthesis of the results of cross-sectional studies indicated that there was no association between lifestyle patterns and overweight/obesity, even when stratified by sex. However, analysis stratified by risk of bias showed a positive association between predominantly unhealthy and mixed lifestyle patterns and overweight/obesity in studies with moderate risk. Prospective analysis of a single study with moderate risk of bias suggested an increase in BMI over time with predominantly unhealthy and mixed lifestyle patterns.

We identified a variety of lifestyle patterns and weight status indicators in studies, hindering their comparison. The methods used to measure diet, physical activity, sedentary behaviour and sleep were heterogeneous across studies, as were the methods used to derive lifestyle patterns. Most studies used FFQ to collect food consumption data, while one study used 1-d 24-h recall combined with 3-d food record, and two studies used 2-d non-consecutive 24-h recall. FFQ refers to the respondent's usual intake of food over a specific period, and the estimation tasks are complex. Regarding to recall/record methods, at least 2 d are recommended to estimate usual intake of the population and their relationship with other indicators[20]. For synthesis of results, it was necessary to categorise lifestyle patterns according to their behaviours. Patterns were classified into completely or predominantly healthy or unhealthy and mixed (i.e. balance between healthy and unhealthy behaviours).

We emphasise that previous reviews were conducted with children and adolescents (5–18 years)[6] and only children (5–12 years)[10]. The first comprised a narrative review of studies that evaluated the clustering of diet, physical activity and sedentary behaviour[6]. The other systematically reviewed evidence on the clustering of diet, physical activity, sedentary behaviour and sleep[10]. Our systematic review is the first to analyse the association between lifestyle patterns and overweight/obesity in adolescents, which is a critical phase for weight gain. The above-mentioned reviews did not restrict the eligibility criteria regarding the behaviours included in the lifestyle patterns, so some studies reviewed contained only physical activity and sedentary behaviours in the patterns. In contrast to this, we considered the domain of diet as a fundamental behaviour in lifestyle patterns, as diet plays a major role in energy balance regulation[1]. Consumption of ultra-processed foods has been identified as a risk factor for increasing obesity[65]. Additionally, dietary patterns with a lower percentage of obesogenic foods appears to be effective in reducing the risk of developing obesity[2].

As reported in previous reviews[6,10], we identified the co-occurrence of both healthy and unhealthy behaviours in lifestyle patterns which indicates that protective and risk behaviours for overweight/obesity coexist in lifestyle patterns. This implies that we may not assume that healthy levels of a particular behaviour are indicative of an overall healthy lifestyle. The review studies[6,10] found a large number of clusters with high levels of sedentary behaviour, similar to our results. In the present review, almost all studies have assessed sedentary behaviour through screen time only. In addition, most lifestyle patterns found were composed of low levels of physical activity and high levels of sedentary behaviour[44–46,52,54,56,57]. This suggests that

https://doi.org/10.1017/S0007114522000228 Published online by Cambridge University Press

Table 4. Direction of associations between lifestyle patterns and overweight and obesity in adolescents

Study design	Lifestyle patterns classification	Number of times the association was tested	Direction of association		
			Positive	Inverse	No association
Cross-sectional	Completely healthy	3	0	1	2
	Completely unhealthy	9	0	1	8
	Predominantly healthy	11	2	0	9*
	Predominantly unhealthy	16	7†	0	9
	Mixed	12	1*	0	11†
Prospective	Completely healthy	0	0	0	0
	Completely unhealthy	0	0	0	0
	Predominantly healthy	0	0	0	0
	Predominantly unhealthy	2	2†	0	0
	Mixed	1	1*	0	0

* Included 1 lifestyle pattern with risk behaviours.
† Included 2 lifestyle patterns with risk behaviours.

Table 5. Direction of associations between lifestyle patterns and overweight and obesity in adolescents by sex

Lifestyle patterns classification	Number of times the association was tested	Direction of association		
		Positive	Inverse	No association
Boys				
Completely healthy	0	0	0	0
Completely unhealthy	4	0	0	4
Predominantly healthy	4	0	0	4
Predominantly unhealthy	5	2	0	3
Mixed	3	0	0	3
Girls				
Completely healthy	0	0	0	0
Completely unhealthy	2	0	0	2
Predominantly healthy	5	2	0	3
Predominantly unhealthy	8	3	0	5
Mixed	1	0	0	1

sedentary behaviour contributes strongly to adolescent lifestyle, which is somewhat worrying, given the positive association between sedentary behaviour and unfavourable health indicators[66]. Moreover, we identified lifestyle patterns composed of high levels of both physical activity and sedentary behaviour. These findings demonstrate that one behaviour is not necessarily a barrier to the other and that adolescents find time for physical and sedentary activities throughout the day[51,52,57].

Previous review from D'Souza *et al.*[10], who analysed studies on children only, concluded that unhealthy lifestyle patterns were more often associated with adiposity risk than healthy and mixed patterns. In contrast, Leech *et al.*[6] reported that the relationship of cluster patterns with excess weight was inconsistent. This was partially observed in the main findings analysed in the current review. Although we found some evidence of a positive association between lifestyle patterns and overweight/obesity in studies with moderate risk of bias, we considered these findings questionable due to the limited methodological quality of the studies. The associations found in cross-sectional studies are not, by themselves, evidence of causality. Prospective findings from a single study are insufficient. Additionally, all measured variables from these studies were based on self-reports, including weight and height variables, which compromises the quality of the findings[45,45,56]. There is a tendency to overestimate height and underestimate weight, leading to incorrect reports and inaccurate estimates of overweight/obesity rates[67]. Adolescents with overweight/obesity tend to underestimate their weight more often than normal-weight adolescents, and girls tend to underestimate their weight more often than boys[66]. Furthermore, children and adolescents who are overweight or obese were more likely to under-report energy intake when compared with their non-obese peers[68].

Unexpectedly, we found that some predominantly healthy lifestyle patterns were positively associated with overweight/obesity, particularly in girls. The following hypotheses may explain these controversial results. It is not possible to infer whether healthy behaviours reflected the development of overweight and obesity or whether the presence of the latter led to the adoption of healthier habits as a strategy for weight loss. Studies have shown that adolescents with overweight/obesity often try to lose weight[69], and that these behaviours are more likely in girls than in boys[70]. Furthermore, although predominantly healthy, these lifestyle patterns comprised inadequate behaviours in the diet domain, such as low consumption of healthy foods and high consumption of unhealthy foods, which could explain, at least in part, this result[44].

As in the recent review by D'Souza *et al.*[10], we considered four domains of energy balance-related behaviours associated with overweight/obesity. Of the studies used for synthesis of results, those conducted by Perez-Rodrigo *et al.*[55], Nuutinen *et al.*[56] and Sevil-Serrano *et al.*[59] addressed these four behaviours. The other studies included diet, physical activity and sedentary behaviour domains only, which represents a limitation, as sleep habits are related to overweight/obesity[5,71]. In the study by Nuutinen *et al.*[56] the indicators of sleep habits were related to duration, discrepancy and quality. The authors found a greater risk for overweight/obesity among girls in the high screen time, unhealthy lifestyle pattern, whose scores for sleep duration were moderate but for discrepancy and quality were low. This finding suggests that investigating only the effect of sleep duration on lifestyle patterns may not be enough. Future studies should consider this behaviour both in terms of duration and quality to understand the cumulative effects of sleep on weight status in adolescents.

Most studies evaluating the association between lifestyle patterns and overweight/obesity were carried out in European countries, that is, countries with high socio-economic levels. It is important to highlight that, whereas the prevalence of overweight/obesity among young people has stabilised in high-income countries, the prevalence is still on the rise in medium- to low-income countries(72). Thus, more studies need to be carried out in medium- and low-income countries for cultural, economic, and demographic variability and representativeness of data.

About 85·6 % of the reviewed studies applied the cluster analysis method to identify the lifestyle patterns. Although there is evidence to indicate that latent class analysis substantially outperforms the cluster analysis, our results demonstrate that the latter technique has been more applied by studies. Both methods are centred on individuals; however, the cluster analysis use the distance in order to separate observations into different groups while latent class analysis is a model-based approach. An advantage of using a model-based approach is less arbitrary and more rigorous statistical techniques. More precisely, in latent class analysis is assumed that a mixture of underlying probability distributions generates the data. Furthermore, there are more formal criteria to make decisions about the best model fit or number of classes(6,73).

The lack of evidence from longitudinal data precludes determination of whether, over time, lifestyle patterns contribute negatively to the weight status of adolescents. Only two studies with this population were found(46,48), and only one was considered for the synthesis of results, which had a moderate risk of bias(46). However, overall, the findings of the referred studies demonstrate that, in the long term, lifestyle patterns may have some effect on the weight status of adolescents. More longitudinal studies with well-designed methodology in other countries are needed to measure these effects over time. It could be also interesting for future prospective studies to examine the stability of the lifestyle patterns over time.

In the present review, five studies found that risk behaviours, such as substance use, tend to co-occur with energy balance-related behaviours(45–48,60,61). Risk behaviours are common among adolescents and tend to increase with age(45). Marijuana use, smoking and binge drinking are generally not the focus of studies evaluating the determinants of overweight/obesity. Excessive alcohol consumption can contribute to weight gain by increasing energy intake or stimulating consumption of other unhealthy foods(74). However, little is known about the relationship between overweight/obesity and other types of substances. Laxer *et al.*(45,46) found positive cross-sectional and prospective associations in the lifestyle patterns of moderately active adolescents with low healthy food consumption, high unhealthy food consumption and high substance use.

This systematic review was rigorous. We designed a search strategy including a range of terms relevant to the topic that was applied to a variety of databases. An appropriate tool was used to assess the risk of bias, and criteria based on the tool items were determined to facilitate the analysis(19). However, the review becomes limited by the quality of evidence from the included studies. Most studies were cross-sectional and used self-reported questionnaires to assess the behaviour of adolescents, increasing susceptibility to memory and social desirability bias. Not all studies adopted valid or reproducible methods for these measures, which may have implications for the accuracy and reliability of the findings. Nevertheless, the results may provide important insights into how obesogenic behaviours cluster together, which can help in the design and improvement of public health policies aimed at combating obesity.

This review included only studies that used data-driven methods as cluster analysis and latent class analysis to determine lifestyle patterns. The strength of our study is that the approach allowed separating individuals into mutual groups that share similar characteristics. However, some statistical techniques require that arbitrary decisions and subjective interpretations be made by the researcher. Importantly, the methods used to determine lifestyle patterns in each study were data-driven, and the lifestyle patterns found may only be specific to the populations and cultures studied, which limit the generalisability of the findings. Additionally, 'high' or 'low' levels of a particular behaviour may refer to the highest or lowest scores in a specific pattern or to the highest or lowest probabilities to belong to a pattern and may not even meet the guidelines for the behaviour. 'High' or 'low' behaviour in one study population may not be classified as such in another population. This may have implications for understanding the influence of different lifestyle patterns in relation to overweight/obesity.

Data-driven methods can produce different lifestyle patterns even when applied to the same dataset(75). Thus, comparison of results across studies employing different methods should be done with caution. Researchers should consider the choice of method based on their study objectives and subsequent analyses. It is also essential that authors justify the decisions made and the final model chosen. More studies including the four behavioural domains (diet, physical activity, sedentary behaviour and sleep) are needed. Studies should consider the use of objective methods, such as accelerometers or pedometers, to capture movement behaviours in order to obtain more accurate results. There is no consensus on which dietary assessment method is more accurate for adolescents(76). However, it is important to improve dietary assessment methods by including validated and reproducible measures to better capture dietary information. The choice of instrument should consider the objectives and the logistic of the study, which will influence the suitability and feasibility of different approaches

Finally, it is worth mentioning that we synthesised the directions of the association between lifestyle patterns and overweight/obesity, not the strengths of associations. It was not possible to carry out a meta-analysis because it was not clear whether the data were sufficiently comparable for quantitative analysis. In this case, vote counting based on the direction of association was the alternative adopted as an 'acceptable' method for the presentation and synthesis of the results. Vote counting can be used to synthesise results when there is inconsistency in the effect measures or data reported across studies[77]. This method has some limitations. Vote counting does not consider the magnitude of effects and the differences in the relative sizes of the studies and could difficult the assessment of the certainty of the evidence[21,77]. However, this method may be more advantageous compared with a narrative review that only describes results study by study, which comes with the risk that some studies are privileged above others without appropriate justification[77].

Conclusion

Adolescents tend to simultaneously exhibit healthy and unhealthy lifestyle behaviours with predominantly unhealthy lifestyle patterns more frequently observed. The presence of unhealthy behaviours together with healthy behaviours suggests the need to be alert, even with those adolescents who appears to be doing well in a domain. The large number of lifestyle patterns with high levels of sedentary behaviour suggests that this behaviour has become increasingly important in adolescents' lives. Overall, cross-sectional studies indicate that there is no association between lifestyle patterns and overweight and obesity in adolescents, even after sex stratification. However, when analysing the results stratified by risk of bias, a positive association between predominantly unhealthy and mixed lifestyle patterns with overweight/obesity was identified in cross-sectional studies with moderate risk of bias. The only prospective analysis of the topic found an increase in BMI over time associated with predominantly unhealthy and mixed lifestyle patterns. Because of the heterogeneity and quality of the studies, we consider the current evidence weak and inconsistent. Further research is needed, preferably longitudinal studies using objective methods or validated and reproducible tools to measure lifestyle behaviours in the adolescent population. Despite these limitations, the findings from this systematic review have considerable implications for public health policy and school-based health promotion initiatives, with an emphasis on integrated approaches. We highlight the importance of targeting multiple behaviours simultaneously to achieve more health benefits than when these behaviours are targeted separately.

Acknowledgements

None

This work was supported by Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES) (L.J.P., grant number: 88882.438755/2019-01; and L.H.M., grant number: 88887.498373/2020-00).

L. J. P., F. G. K. V. and P. D. F. H. designed the study; L. J. P. and L. H. M. conducted the searches, studies selection, data collection process and quality assessment; L. J. P., L. H. M., F. G. K. V. and P. D. F. H. analysed the data and interpreted the results; L. J. P., L. H. M., F. G. K. V., P. D. F. H., P. F. P. and M. A. A. D. A. wrote the manuscript and made substantial contributions to the final version.

The authors declare no conflicts of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114522000228

References

1. Narciso J, Silva AJ, Rodrigues V, *et al.* (2019) Behavioral, contextual and biological factors associated with obesity during adolescence: a systematic review. *PLOS ONE* **14**, e0214941.
2. Liberali R, Kupek E & Assis MAAD (2020) Dietary patterns and childhood obesity risk: a systematic review. *Child Obes* **16**, 70–85.
3. de Rezende LFM, Rodrigues Lopes M, Rey-López JP, *et al.* (2014) Sedentary behavior and health outcomes: an overview of systematic reviews. *PLOS ONE* **9**, e105620.
4. Jiménez-Pavón D, Kelly J & Reilly JJ (2010) Associations between objectively measured habitual physical activity and adiposity in children and adolescents: systematic review. *Int J Pediatr Obes* **5**, 3–18.
5. Fatima Y, Doi SAR & Mamun AA (2016) Sleep quality and obesity in young subjects: a meta-analysis. *Obes Rev* **17**, 1154–1166.
6. Leech RM, McNaughton SA & Timperio A (2014) The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. *Int J Behav Nutr Phys Act* **11**, 4.
7. Spring B, Moller AC & Coons MJ (2012) Multiple health behaviours: overview and implications. *J Public Health* **34**, i3–i10.
8. Carvalho CAD, Fonsêca PCDA, Nobre LN, *et al.* (2016) Methods of a posteriori identification of food patterns in Brazilian children: a systematic review. *Ciênc. Saúde Colet.* **21**, 143–154.
9. Alberga AS, Sigal RJ, Goldfield G, *et al.* (2012) Overweight and obese teenagers: why is adolescence a critical period? *Pediatr Obes* **7**, 261–273.
10. D'Souza NJ, Kuswara K, Zheng M, *et al.* (2020) A systematic review of lifestyle patterns and their association with adiposity in children aged 5–12 years. *Obes Rev* **21**, e13029.
11. Demory-Luce D, Morales M, Nicklas T, *et al.* (2004) Changes in food group consumption patterns from childhood to young adulthood: the Bogalusa heart study. *J Am Diet Assoc* **104**, 1684–1691.
12. Simmonds M, Llewellyn A, Owen CG, *et al.* (2016) Predicting adult obesity from childhood obesity: a systematic review and meta-analysis. *Obes Rev* **17**, 95–107.
13. Moher D, Liberati A, Tetzlaff J, *et al.* (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* **6**, e1000097.
14. World Health Organization (2021) Adolescence: A Period Needing Special Attention – Recognizing Adolescence. https://apps.who.int/adolescent/second-decade/section2/page1/recognizing-adolescence.html (accessed November 2021).
15. Cole TJ & Lobstein T (2012) Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes* **7**, 284–294.
16. de Onis M, Onyango AW, Borghi E, *et al.* (2007) Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* **85**, 660–667.
17. Kuczmarski RJ, Ogden CL, Guo SS, *et al.* (2002) 2000 CDC growth charts for the United States: methods and development. *Vital Health Stat* **11**, 1–190.
18. Lefebvre C, Glanville J, Briscoe S, *et al.* (2021) Chapter 4: Searching for and selecting studies. In *Cochrane Handbook for Systematic Reviews of Interventions Version 6.2* [JPT Higgins, J Thomas, J Chandler *et al.*, editors]. Cochrane. www.training.cochrane.org/handbook (accessed April 2020).

19. JBI Institute (2020) Critical Appraisal Tools. https://jbi.global/critical-appraisal-tools (accessed April 2020).
20. Hinnig PDF, Monteiro JS, De Assis MAA, *et al.* (2018) Dietary patterns of children and adolescents from high, medium and low human development countries and associated socioeconomic factors: a systematic review. *Nutrients* **10**, 436.
21. Campbell M, McKenzie JE, Sowden A, *et al.* (2020) Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline. *BMJ* **368**, l6890.
22. Kontogianni MD, Farmaki AE, Vidra N, *et al.* (2010) Associations between lifestyle patterns and body mass index in a sample of Greek children and adolescents. *J Am Diet Assoc* **110**, 215–221.
23. Moschonis G, Kalliora AC, Costarelli V, *et al.* (2014) Identification of lifestyle patterns associated with obesity and fat mass in children: the healthy growth study. *Public Health Nutr* **17**, 614–624.
24. Ferrar K & Golley R (2015) Adolescent diet and time use clusters and associations with overweight and obesity and socioeconomic position. *Health Educ Behav* **42**, 361–369.
25. Schmiege SJ, Gance-Cleveland B, Gilbert L, *et al.* (2016) Identifying patterns of obesity risk behavior to improve pediatric primary care. *J Spec Pediatr Nurs* **21**, 18–28.
26. Cabanas-Sánchez V, Martínez-Gómez D, Izquierdo-Gómez R, *et al.* (2018) Association between clustering of lifestyle behaviors and health-related physical fitness in youth: the UP&DOWN study. *J Pediatr* **199**, 41.e1–48.e1.
27. Spengler S, Mess F, Schmocker E, *et al.* (2014) Longitudinal associations of health-related behavior patterns in adolescence with change of weight status and self-rated health over a period of 6 years: results of the MoMo longitudinal study. *BMC Pediatr* **14**, 242.
28. Leech RM, McNaughton SA & Timperio A (2015) Clustering of diet, physical activity and sedentary behaviour among Australian children: cross-sectional and longitudinal associations with overweight and obesity. *Int J Obes* **39**, 1079–1085.
29. Werneck AO, Agostinete RR, Cayres SU, *et al.* (2018) Association between cluster of lifestyle behaviors and HOMA-IR among adolescents: ABCD growth study. *Medicina* **54**, 96.
30. Maia EG (2016) Patterns of risk and protective factors for excessive weight gain among Brazilian adolescents: A cluster analysis. PhD Thesis, Federal University of Minas Gerais. https://repositorio.ufmg.br/handle/1843/ANDO-A97KJ8 (accessed November 2021).
31. Maia EG, Mendes LL, Pimenta AM, *et al.* (2018) Cluster of risk and protective factors for obesity among Brazilian adolescents. *Int J Public Health* **63**, 481–490.
32. Sanchez-Oliva D, Grao-Cruces A, Carbonell-Baeza A, *et al.* (2018) Lifestyle clusters in school-aged youth and longitudinal associations with fatness: the UP&DOWN study. *J Pediatr* **203**, 317.e1–324.e1.
33. Tabacchi G, Faigenbaum A, Jemni M, *et al.* (2018) Profiles of physical fitness risk behaviours in school adolescents from the ASSO project: a latent class analysis. *Int J Environ Res Public Health* **15**, 1933.
34. Cuenca-García M, Huybrechts I, Ruiz JR, *et al.* (2013) Clustering of multiple lifestyle behaviors and health-related fitness in European adolescents. *J Nutr Educ Behav* **45**, 549–557.
35. Sena EDMS, Muraro AP, Rodrigues PRM, *et al.* (2017) Risk behavior patterns for chronic diseases and associated factors among adolescents. *Nutr Hosp* **34**, 914–922.
36. Fleary SA (2017) Combined patterns of risk for problem and obesogenic behaviors in adolescents: a latent class analysis approach. *J Sch Health* **87**, 182–193.
37. Höpker T, Lampert T & Spallek J (2014) Identification and characterisation of health behaviours in 11- to 17-year-old adolescents: a cluster analysis based on the German health interview and examination survey for children and adolescents. *Gesundheitswesen* **76**, 453–461.
38. Busch V, Van Stel HF, Schrijvers AJ, *et al.* (2013) Clustering of health-related behaviors, health outcomes and demographics in Dutch adolescents: a cross-sectional study. *BMC Public Health* **13**, 1118.
39. Turner K, Dwyer JJ, Edwards AM, *et al.* (2011) Clustering of specific health-related behaviours among Toronto adolescents. *Can J Diet Pract Res* **72**, e155–e160.
40. Zhang J, Feng XQ, Zhai Y, *et al.* (2018) Clustering of unhealthy lifestyle behaviours and associations with perceived and actual weight status among primary school children in China: a nationally representative cross-sectional study. *Prev Med* **112**, 6–14.
41. Spengler S, Mess F & Woll A (2017) Comparison of health-related behavior patterns of boys and girls in Germany: results of the MoMo study. *Gesundheitswesen* **79**, 993–999.
42. Mandic S, Bengoechea EG, Coppell KJ, *et al.* (2017) Clustering of (un)healthy behaviors in adolescents from Dunedin, New Zealand. *Am J Health Behav* **41**, 266–275.
43. Boone JE, Gordon-Larsen P & Adair LS (2007) High risk adolescent obesity behavior patterns: a comparison of clusters, factors, and an index measure. *Faseb J* **21**, A115.
44. Moreira NF, da Veiga GV, Santaliestra-Pasías AM, *et al.* (2018) Clustering of multiple energy balance related behaviors is associated with body fat composition indicators in adolescents: results from the HELENA and ELANA studies. *Appetite* **120**, 505–513.
45. Laxer RE, Brownson RC, Dubin JA, *et al.* (2017) Clustering of risk-related modifiable behaviours and their association with overweight and obesity among a large sample of youth in the COMPASS study. *BMC Public Health* **17**, 102.
46. Laxer RE, Cooke M, Dubin JA, *et al.* (2018) Behavioural patterns only predict concurrent BMI status and not BMI trajectories in a sample of youth in Ontario, Canada. *PLOS ONE* **13**, e0190405.
47. Boone-Heinonen J, Gordon-Larsen P & Adair LS (2008) Obesogenic clusters: multidimensional adolescent obesity-related behaviors in the US. *Ann Behav Med* **36**, 217–30.
48. Landsberg B, Plachta-Danielzik S, Lange D, *et al.* (2010) Clustering of lifestyle factors and association with overweight in adolescents of the Kiel obesity prevention study. *Public Health Nutr* **13**, 1708–1715.
49. Sabbe D, De Bourdeaudhuij I, Legiest E, *et al.* (2008) A cluster-analytical approach towards physical activity and eating habits among 10-year-old children. *Health Educ Res* **23**, 753–762.
50. van der Sluis ME, Lien N, Twisk JW, *et al.* (2010) Longitudinal associations of energy balance-related behaviours and cross-sectional associations of clusters and body mass index in Norwegian adolescents. *Public Health Nutr* **13**, 1716–1721.
51. Seghers J & Rutten C (2010) Clustering of multiple lifestyle behaviours and its relationship with weight status and cardiorespiratory fitness in a sample of Flemish 11- to 12-year-olds. *Public Health Nutr* **13**, 1838–1846.
52. Ottevaere C, Huybrechts I, Benser J, *et al.* (2011) Clustering patterns of physical activity, sedentary and dietary behavior among European adolescents: The HELENA study. *BMC Public Health* **11**, 328.
53. Iannotti RJ & Wang J (2013) Patterns of physical activity, sedentary behavior, and diet in U.S. adolescents. *J Adolesc Health* **53**, 280–286.
54. Fernandez-Alvira JM, De Bourdeaudhuij I, Singh AS, *et al.* (2013) Clustering of energy balance-related behaviors and

parental education in European children: the ENERGY-project. *Int J Behav Nutr Phys Act* **10**, 5.
55. Perez-Rodrigo C, Gil A, Gonzalez-Gross M, *et al.* (2015) Clustering of dietary patterns, lifestyles, and overweight among Spanish children and adolescents in the ANIBES study. *Nutrients* **8**, 11.
56. Nuutinen T, Lehto E, Ray C, *et al.* (2017) Clustering of energy balance-related behaviours, sleep, and overweight among Finnish adolescents. *Int J Public Health* **62**, 929–938.
57. Dantas MD, dos Santos MC, Lopes LAF, *et al.* (2018) Clustering of excess body weight-related behaviors in a sample of Brazilian adolescents. *Nutrients* **10**, 1505.
58. Wadolowska L, Hamulka J, Kowalkowska J, *et al.* (2018) Prudent-active and fast-food-sedentary dietary-lifestyle patterns: the association with adiposity, nutrition knowledge and sociodemographic factors in polish teenagers. The ABC of healthy eating project. *Nutrients* **10**, 1988.
59. Sevil-Serrano J, Aibar-Solana A, Abos A, *et al.* (2019) Healthy or unhealthy? The cocktail of health-related behavior profiles in Spanish adolescents. *Int J Environ Res Public Health* **16**, 3151.
60. dos Santos CS, Picoito J, Loureiro I, *et al.* (2020) Clustering of health-related behaviours and its relationship with individual and contextual factors in Portuguese adolescents: results from a cross-sectional study. *BMC Pediatr* **20**, 247.
61. Berlin KS, Kamody RC, Thurston IB, *et al.* (2017) Physical activity, sedentary behaviors, and nutritional risk profiles and relations to body mass index, obesity, and overweight in eighth grade. *Behav Med* **43**, 31–39.
62. Veloso SM, Matos MG, Carvalho M, *et al.* (2012) Psychosocial factors of different health behaviour patterns in adolescents: association with overweight and weight control behaviours. *J Obes* **2012**, 1–10.
63. Marttila-Tornio K, Ruotsalainen H, Miettunen J, *et al.* (2019) Clusters of health behaviours and their relation to body mass index among adolescents in Northern Finland. *Scand J Caring Sci* **34**, 666–674.
64. Spengler S, Mess F, Mewes N, *et al.* (2012) A cluster-analytic approach towards multidimensional health-related behaviors in adolescents: the MoMo-study. *BMC Public Health* **12**, 1128.
65. Costa CS, Del-Ponte B, Assunção MCF, *et al.* (2018) Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutr* **21**, 148–159.
66. Carson V, Hunter S, Kuzik N, *et al.* (2016) Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab* **41**, S240–S265.
67. Kuskowska-Wolk A, Karlsson P, Stolt M, *et al.* (1989) The predictive validity of body mass index based on self-reported weight and height. *Int J Obes* **13**, 441–453.
68. Walker JL, Ardouin S & Burrows T (2018) The validity of dietary assessment methods to accurately measure energy intake in children and adolescents who are overweight or obese: a systematic review. *Eur J Clin Nutr* **72**, 185–197.
69. Brown CL, Skelton JA, Perrin EM, *et al.* (2016) Behaviors and motivations for weight loss in children and adolescents. *Obesity* **24**, 446–452.
70. Chung A, Backholer K, Wong E, *et al.* (2016) Trends in child and adolescent obesity prevalence in economically advanced countries according to socioeconomic position: a systematic review. *Obes Rev* **17**, 276–295.
71. Fatima Y, Doi SAR & Mamun AA (2015) Longitudinal impact of sleep on overweight and obesity in children and adolescents: a systematic review and bias-adjusted meta-analysis. *Obes Rev* **16**, 137–149.
72. Abarca-Gómez L, Abdeen ZA, Hamid ZA, *et al.* (2017) Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *Lancet* **390**, 2627–2642.
73. Magidson J & Vermunt J (2002) Latent class models for clustering: a comparison with K-means. *Can J Mark Res* **20**, 37–44.
74. Battista K & Leatherdale ST (2017) Estimating how extra calories from alcohol consumption are likely an overlooked contributor to youth obesity. *Health Promot Chronic Dis Prev Can* **37**, 194–200.
75. D'Souza NJ, Downing K, Abbott G, *et al.* (2021) A comparison of children's diet and movement behaviour patterns derived from three unsupervised multivariate methods. *PLOS ONE* **16**, e0255203.
76. Pérez-Rodrigo C, Artiach Escauriaza B, Artiach Escauriaza J, *et al.* (2015) Dietary assessment in children and adolescents: issues and recommendations. *Nutr Hosp* **31**, Suppl. 3, 76–83.
77. McKenzie J & Brennan S (2021) Chapter 12: Synthesizing and presenting findings using other methods. In *Cochrane Handbook for Systematic Reviews of Interventions Version 6.2* [JPT Higgins, J Thomas, J Chandler *et al.*, editors]. Cochrane. www.training.cochrane.org/handbook (accessed November 2021).