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Clustering of energy balance-related behaviors among youth: overview and implications

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Thesis submitted to the Graduate Program of Physical Education at Federal University of Santa Catarina as requirement to obtain the Physical Education Doctor title on the Physical Activity and Health research area.

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Gabrielli Thais de Mello

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I dedicate this document to my parents, Lorena and Edimilson Mello, for always supporting me in the choices that I have made.

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In the constant process of becoming an outlier.

(Gabrielli T. De Mello, 2024)

RESUMO

Introdução. Comportamentos como a atividade física (AF), o comportamento sedentário (CS), o sono e a dieta coexistem e se agrupam de forma positiva e negativa entre crianças e adolescentes. A decisão de adotar ou não estes comportamentos podem ser influenciados por fatores socioeconômicos e experiências culturais, bem como por aspectos demográficos, como o sexo e a idade. Além disso, o tipo e a quantidade de comportamentos que se combinam parecem influenciar diretamente a saúde física e mental de jovens, por exemplo, combinar um maior número de comportamentos não saudável tem sido associado a maior chance de ter obesidade, resistência à insulina, ansiedade e sintomas depressivos, quando comparado ao acúmulo de comportamentos saudáveis. Neste sentido, esta tese propõe investigar uma visão geral dos agrupamentos de AF, CS, sono e dieta encontrados na literatura em termos de tipos, correlatos, diferenças entre os sexos e níveis de renda dos países. **Métodos.** Um macroprojeto de revisão sistemática foi desenvolvido e registrado no *The Prospective Register of Systematic Reviews* (PROSPERO; número de registro CRD42018094826). Cinco bases de dados foram acessadas. Os critérios de elegibilidade dos estudos incluíram jovens com idade de 0 a 19 anos, a combinação dos comportamentos-alvo da presente tese 1) AF, CS e dieta; 2) AF e CS; 3) AF, CS, sono e dieta e a utilização de análise de agrupamentos. O processo de extração de informações foi realizado por dois revisores independentemente e um terceiro resolveu as possíveis discrepâncias. **Resultados.** Três situações de agrupamentos de comportamentos foram analisadas em produtos (artigos). Considerando a primeira combinação de comportamentos (AF, CS e dieta), 57 artigos cumpriram os critérios de inclusão e 55 tipos de agrupamentos foram identificados com maior variedade presente em países de alta renda. Os agrupamentos mais prevalentes, independentemente do nível de renda do país, foram “alto CS e consumo de alimentos ultraprocessados” (*n*=17) e “alta AF” (*n*=13). O agrupamento mais saudável “alta AF e consumo de frutas e verduras (FV), baixo CS, e consumo de alimentos ultraprocessados” (n=12) esteve presente em países de baixa-média e alta renda. O agrupamento menos saudável “baixa AF e consumo de FV e alto CS e consumo de alimentos ultraprocessados” (n=6) esteve presente somente em países de alta renda. A segunda combinação investiga o agrupamento da AF e do CS, onde foram incluídos 17 estudos que apresentaram nove, 12 e dez tipos de agrupamentos para ambos os sexos; em meninos e meninas, respectivamente. As meninas foram alocadas em maior proporção em agrupamentos com “baixa AF e baixo CS” e “baixa AF e alto CS”, enquanto os meninos compuseram os agrupamentos “alta AF e alto CS” e “alta AF e baixo CS”. Maior índice de massa corporal (IMC) foi o correlato associado ao agrupamento “alta AF e alto CS”; e menor IMC, circunferência da cintura, sobrepeso e obesidade associaram-se ao agrupamento “alta AF e baixo CS”. A terceira situação investiga os agrupamentos dos quatro comportamentos (AF, CS, sono e dieta), com a inclusão de 23 estudos. Dos tipos de agrupamentos identificados (n=66), 34 estiveram presentes em ambos os sexos, dez apenas nos meninos e 11 nas meninas. A maior diferença encontrada nos perfis de comportamentos entre os sexos foi que meninas estiveram em agrupamentos com maior duração de sono, enquanto os meninos estiveram em agrupamentos com maior participação em AF. Observou-se predominância de associações nulas entre os tipos de clusters e os indicadores de saúde física e mental. **Conclusões**. Agrupamentos de comportamentos caracterizados pela presença de pelo menos um comportamento não saudável foi observado para ambos os sexos, nas três situações de agrupamentos analisadas [1)

AF, CS e dieta; 2) AF e CS; 3) AF, CS, sono e dieta]. A maioria dos estudos analisados foram desenvolvidos em países de alta renda, mas percebeu-se perfis de agrupamentos diferentes entre países com diferentes rendas. Enquanto a duração do sono tende a estar mais presente no agrupamento de comportamentos nas meninas, a AF se faz mais presente entre os agrupamentos nos meninos. A relação entre os tipos de agrupamentos e os desfechos de saúde apresentou resultados inconclusivos. Com o intuito promover a saúde de crianças e adolescentes, os achados da presente tese podem nortear tomadas de decisões para intervenções focadas na mudança de múltiplos comportamentos, considerando o público prioritário e seu contexto.

Palavras-chave: Adolescente; Criança; Análise de agrupamentos.

ABSTRACT

Introduction. Behaviors such as physical activity (PA), sedentary behavior (SB), sleep, and diet coexist and cluster positively and negatively among children and adolescents. The decision to adopt or not adopt these behaviors can be influenced by socioeconomic factors and cultural experiences, as well as demographic aspects such as sex and age. Furthermore, the type and quantity of behaviors that combine seem to directly influence the physical and mental health of young people. For example, combining a greater number of unhealthy behaviors has been associated with a higher likelihood of obesity, insulin resistance, anxiety, and depressive symptoms compared to the accumulation of healthy behaviors. In this sense, this thesis proposes to investigate an overview of the clusters of PA, SB, sleep, and diet found in the literature in terms of types, correlates, differences between sexes, and income levels of countries. **Methods.** A macro project of systematic review was developed and registered in The Prospective Register of Systematic Reviews (PROSPERO; registration number CRD42018094826). Five databases were accessed. The eligibility criteria for studies included young people aged 0 to 19 years, the combination of the target behaviors of this thesis 1) PA, SB, and diet; 2) PA and SB; 3) PA, SB, sleep, and diet, and the use of cluster analysis. The process of information extraction was carried out by two reviewers independently, with a third resolving any possible discrepancies. **Results.** Three situations of clustering of behaviors were analyzed in products (articles). Considering the first combination of behaviors (PA, SB, and diet), 57 articles met the inclusion criteria, and 55 types of clusters were identified with greater variety present in high-income countries. The most prevalent clusters, regardless of the country's income level, were "high SB and consumption of ultra-processed foods" (n=17) and "high PA" (n=13). The healthiest cluster, "high PA and consumption of fruits and vegetables (FV), low SB, and consumption of ultra-processed foods" (n=12), was present in low-middle and high-income countries. The least healthy cluster, "low PA and consumption of FV and high SB and consumption of ultra-processed foods" (n=6), was only present in high-income countries. The second combination investigates the clustering of PA and SB, and17 studies were included. Nine, twelve, and ten types of clusters were identified for both sexes, in boys, and girls, respectively. Girls were allocated in a higher proportion to clusters with "low PA and low SB" and "low PA and high SB", while boys composed the clusters "high PA and high SB" and "high PA and low SB". Higher body mass index (BMI) was the correlate associated with the cluster "high PA and high SB"; and lower BMI, waist circumference, overweight, and obesity were associated with the cluster "high PA and low SB". The third situation investigates the clustering of the four behaviors (PA, SB, sleep, and diet), with the inclusion of 23 studies. Sixty-six types of clusters were identified and 34 were present in both sexes, ten only in boys, and eleven in girls. The greatest difference found in behavior profiles between the sexes was that girls were in clusters with longer sleep duration, while boys were in clusters with higher participation in PA. There was a predominance of null associations between the types of clusters and indicators of physical and mental health. **Conclusions.** Clusters of behaviors characterized by the presence of at least one unhealthy behavior were observed for both sexes in the three clustering situations analyzed [1) PA, SB, and diet; 2) PA and SB; 3) PA, SB, sleep, and diet]. Most of the studies analyzed were conducted in high-income countries, but different clustering profiles were observed among countries with different incomes. While sleep duration tends to be more present in behavior clusters in girls, PA is more

prevalent among clusters in boys. The relationship between clustering types and health outcomes yielded inconclusive results. With the aim of improving the health of children and adolescents, the findings of this thesis can guide decision-making for interventions focused on changing multiple behaviors, considering the priority audience and their context.

Keywords: Adolescent; Children; Cluster analysis.

RESUMO EXPANDIDO

Introdução

Comportamentos como a atividade física (AF), o comportamento sedentário (CS), o sono e a dieta coexistem e se agrupam de forma positiva e negativa entre crianças e adolescentes. A decisão de adotar ou não estes comportamentos podem ser influenciados por fatores socioeconômicos e experiências culturais, bem como por aspectos demográficos, como o sexo e a idade. Além disso, o tipo e a quantidade de comportamentos que se combinam parecem influenciar diretamente a saúde física e mental de jovens, por exemplo, combinar um maior número de comportamentos não saudável tem sido associado a maior chance de ter obesidade, resistência à insulina, ansiedade e sintomas depressivos, quando comparado ao acúmulo de comportamentos saudáveis. Neste sentido, esta tese te como objetivo geral investigar uma visão geral dos agrupamentos de AF, CS, sono e dieta encontrados na literatura em termos de tipos, correlatos, diferenças entre os sexos e níveis de renda dos países.

Objetivos

Com o intuito de responder ao objetivo geral da tese, foram desenvolvidos três artigos científicos. O primeiro estudo teve como objetivo identificar os tipos de agrupamentos envolvemtno dieta, AF e CS em jovens de acordo com a renda dos países. O segundo estudo identificou os tipos de agrupamentos considerando o constructo comportamental envolvendo somente AF e CS em jovens de acordo com a sexo biológico e verificou associações destes agrupamentos com desfechos de saúde. Por fim, o terceiro estudo identificou tipos de agrupamentos envolvendo AF, CS, sono e dietade acordo com o sexo biológico e verificou associãções destes agrupamentos com desfechos de saúde.

Métodologia.

Um macroprojeto de revisão sistemática foi desenvolvido e registrado no *The Prospective Register of Systematic Reviews* (PROSPERO; número de registro CRD42018094826). Cinco bases de dados foram acessadas. Os critérios de elegibilidade dos estudos incluíram jovens com idade de 0 a 19 anos, a combinação dos comportamentos-alvo da presente tese 1) AF, CS e dieta; 2) AF e CS; 3) AF, CS, sono e dieta e a utilização de análise de agrupamentos. O processo de extração de informações foi realizado por dois revisores independentemente e um terceiro resolveu as possíveis discrepâncias.

Resultados e Discussão.

Três situações de agrupamentos de comportamentos foram analisadas em produtos (artigos). Considerando a primeira combinação de comportamentos (AF, CS e dieta), 57 artigos cumpriram os critérios de inclusão e 55 tipos de agrupamentos foram identificados com maior variedade presente em países de alta renda. Os agrupamentos mais prevalentes, independentemente do nível de renda do país, foram “alto CS e consumo de alimentos ultraprocessados” (*n*=17) e “alta AF” (*n*=13). O agrupamento mais saudável “alta AF e consumo de frutas e verduras (FV), baixo CS, e consumo de alimentos ultraprocessados” (n=12) esteve presente em países de baixa-média e alta renda. O agrupamento menos saudável “baixa AF e consumo de FV e alto CS e consumo de alimentos ultraprocessados” (n=6) esteve presente somente em países de alta renda. A segunda combinação investiga o agrupamento da AF e do CS, onde foram incluídos 17 estudos que apresentaram nove, 12 e dez

tipos de agrupamentos para ambos os sexos; em meninos e meninas, respectivamente. As meninas foram alocadas em maior proporção em agrupamentos com “baixa AF e baixo CS” e “baixa AF e alto CS”, enquanto os meninos compuseram os agrupamentos “alta AF e alto CS” e “alta AF e baixo CS”. Maior índice de massa corporal (IMC) foi o correlato associado ao agrupamento “alta AF e alto CS”; e menor IMC, circunferência da cintura, sobrepeso e obesidade associaram-se ao agrupamento “alta AF e baixo CS”. A terceira situação investiga os agrupamentos dos quatro comportamentos (AF, CS, sono e dieta), com a inclusão de 23 estudos. Dos tipos de agrupamentos identificados (n=66), 34 estiveram presentes em ambos os sexos, dez apenas nos meninos e 11 nas meninas. A maior diferença encontrada nos perfis de comportamentos entre os sexos foi que meninas estiveram em agrupamentos com maior duração de sono, enquanto os meninos estiveram em agrupamentos com maior participação em AF. Observou-se predominância de associações nulas entre os tipos de clusters e os indicadores de saúde física e mental.

Considerações Finais
Agrupamentos de comportamentos caracterizados pela presença de pelo menos um comportamento não saudável foi observado para ambos os sexos, nas três situações de agrupamentos analisadas [1) AF, CS e dieta; 2) AF e CS; 3) AF, CS, sono e dieta]. A maioria dos estudos analisados foram desenvolvidos em países de alta renda, mas percebeu-se perfis de agrupamentos diferentes entre países com diferentes rendas. Enquanto a duração do sono tende a estar mais presente no agrupamento de comportamentos nas meninas, a AF se faz mais presente entre os agrupamentos nos meninos. A relação entre os tipos de agrupamentos e os desfechos de saúde apresentou resultados inconclusivos. Com o intuito promover a saúde de crianças e adolescentes, os achados da presente tese podem nortear tomadas de decisões para intervenções focadas na mudança de múltiplos comportamentos, considerando o público prioritário e seu contexto.

Palavras-chave: Adolescente; Criança; Análise de agrupamentos.

DOCUMENT STRUCTURE

This Doctoral thesis is structured according to the format required by the Federal University of Santa Catarina and the Graduate Program in Physical Education. The document is organized using the compilation of scientific articles format (6th article of norm 02/2023). This thesis presents three chapters: 1) Introduction, the rationale and justification for the research problem, its aims, significance, and innovation; 2) Results, presented in the form of three research articles: two already published and one under review; and 3) Final considerations, including the strengths and limitations, the conclusion, implications, and dissemination. A method section is present as an appendix. The references and annexes sections are presented at the end of the document.

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LIST OF ACRONYMS

EBRBs	Energy balance-related behaviors
PA	Physical activity
F&V	Fruit and vegetables
SB	Sedentary behavior
SSB	Sugar, salt, and beverages
UPF	Ultra-processed foods

LIST OF SYMBOLS

♀ Female
♂ Male

SUMMARY

1 INTRODUCTION

Different theories explain how behaviors coexist and mainly cluster in healthy and unhealthy forms in children and adolescents[1–4]. The Compensatory Healthy Beliefs Theory posits that the negative effects of an unhealthy behavior (e.g., eating junk food) can be compensated or neutralized by a healthy behavior (e.g., exercising)[1]. In contrast, the Problem Behavior Theory[5] posits that engaging in an unhealthy behavior (e.g., excess screen time) increases the likelihood of participating in another unhealthy behavior (e.g., drinking sugar sweetened beverages) and vice versa. These make clear that positive and negative behaviors cluster together and may result in lifestyle profiles where behaviors can coexist in different ways, impacting health in the long term.

Behaviors that tend to cluster together include low levels of physical activity (PA), high time spent in sedentary behavior (SB), inadequate sleep duration, and energy-dense, nutrient-poor dietary intake[2–4]. These behaviors, known as Energy Balance-Related Behaviors (EBRBs), are considered suboptimal in terms of energy balance, encompassing energy intake and expenditure[6]. They have been linked to various health issues, including mortality, obesity, hypertension, type 2 diabetes, cardiovascular diseases, and cognitive disorders[7,8].

The behavior and quality of the PA, SB, sleep, and diet are also mutually dependent and directly involved in increasing the risk of chronic diseases and all-cause mortality over and above the addictive effects of individual behaviors[9]. Also, these clustering behaviors are strongly related to the physical and mental health of children and adolescents[10–14]. For example, an increase in PA is associated with a decrease in SB and a better quality of diet[13,15]. Poor sleep has been associated with higher sweet and fast-food consumption, dysregulation of appetite control, an increase in SB, and a decrease in PA[16–18]. SB (i.e., television viewing) has also been positively associated with sleep disorders and lower quality of diet[19,20]. Together, these studies demonstrate a deep connection between PA, SB, sleep, and dietary habits and their close relationship with health.

PA, SB, sleep, and diet are parameters of EBRBs operating within a complex feedback loop, regulating body homeostasis, altering metabolic pathways, and influencing overall health[21–23]. In addition, the adoption of these clusters behaviors can be influenced by macro-level characteristics (e.g., country economic level, culture) and

individual-level factors (e.g., biological sex, behavioral knowledge, and intention to change)[24,25]. The literature has already demonstrated that PA, SB, sleep, and diet are associated with social, economic, and cultural determinants that do not equally affect individual behaviors among children and adolescents[24,26]. According to ecological theories these contextual levels interact in a complex way to influence individual responses to eating and drinking patterns, as well as 24-hours movement behaviors (PA, SB, and sleep) adoption, influencing health[27]. Thus, while experienced at the individual level, behaviors are strongly determined by the social context, which may include cultural, socioeconomic factors, and family environment. However, a better understanding of the influence of social and individual aspects on EBRBs is essential for developing effective health prevention actions.

Considering that multiple EBRBs are strongly related to each other, that their co-occurrence influences health, and that individual and social aspects influence them, the investigation of the clustering of PA, SB, sleep, and diet has gained researchers' attention. What is already known is that children and adolescents' behavior profiles usually include at least one of these behaviors in an unhealthy form[3]. Considering the context aspects, the cluster of high PA and fruit and vegetable (FV) consumption, low SB, and ultra-processed food (UPF) consumption was only observed in upper-middle and high-income countries, while the least healthy cluster type of low PA and FV consumption, high SB and UPF was present only in high-income countries[3].

Considering individual context, distinct clustered behavior patterns are observed according to biological sex, where boys fall in clusters characterized by high PA, and the opposite in girls[28–30]. Moreover, SB components are different, with boys engaging in SB by playing videogames, watching television, and using computers. In contrast, girls engage in SB with socializing activities such as sitting and talking to their friends[31–34]. Considering diet, a higher proportion of girls fall in profiles with better quality of diet compared to boys[35,36], and researchers found that sleep time generally did not differ in the determination of cluster allocation between boys and girls[37–39]. In addition, studies have presented pieces of evidence considering the combination of different numbers of EBRBs (e.g., PA and SB; PA, diet and SB, and PA, SB, sleep, and diet)[2,11,40,41], and have revealed that profiles characterized by higher numbers of unhealthy behaviors have been associated with higher chance to have obesity, insulin resistance, and low-density lipoprotein compared with their peers at healthier cluster[42–

[45]. Also, children and adolescents allocated in multiple risk behaviors get worse mental health indicators than their peers[46].

Given the body of evidence aforementioned, there is a need to (i) explore different combinations of behaviors (I. PA, SB and diet; II. PA, SB; III. PA, SB, sleep and diet) and map the clustering patterns (cluster types) among children and adolescents by sex and by country income; (ii) describe which clusters are most prevalent by sex and by country income; (iii) examine health outcomes that have been associated with cluster types in youth and their direction. Furthermore, this understanding may contribute to adapting interventions, according to the priority audience and their context, with the aim of encouraging adoption and maintenance of healthy habits and enhancing long term population health outcomes[35–37].

1.1 PURPOSE

1.1.1 General purpose

To summarize the clustering of energy balance-related behaviors among children and adolescents around the world according to types, health-related outcomes, and indicators of macro- and individual-related determinants.

1.1.2 Specific purposes

(i) To identify the clustering types involving diet, PA and SB in youths according to countries income;

(ii) To identify the clustering types considering only PA and SB in youths according to sex, and their relationship with health-related outcomes;

(iii) To identity the clustering types considering only PA, SB, sleep, and diet in youths according to biological sex, and their relationship with health-related outcomes.

1.2 SIGNIFICANCE AND INNOVATION

Developing this thesis is relevant because it has been known that children and adolescents are involved in multiple unhealthy behaviors such us low PA and sleep, high SB, and poor quality of diet[3,4,23]. Also, initiatives to promote health should

centerpiece efforts on risks behaviors once they are related to biomarkers with the onset of chronic disease[9,47]. Although there are evidence about how these behaviors interact with each other[41,48] in youth; it is still unclear how these behaviors clusters according to income countries and biological sex[23,47–49]. These are important to be investigate once behaviors together increases the risk of chronic diseases and mortality[9]. Exploring how PA, SB, sleep, and diet cluster together and their association with different health indicators may help researchers elucidate the etiology of children and adolescents' mental and physical health[50]. The results of this thesis can emphasize the importance of promoting PA, SB, sleep, and diet behaviors in youths[51] and help in the development of change strategies addressing an wide range of risks behaviors at the same time[48]. Initiatives to child and adolescence are crucial once risk behaviors emerge during youth and could interrupt the trajectory towards poor adult health[47].

2 RESULTS

The results section is presented as a compilation of scientific articles in accordance to the 6th article inside the norm 02/2023 from the Graduate Program in Physical Education at Federal University of Santa Catarina. More information about the project that derived the studies below can be found in Appendix A. Also, supplementary material from each publication can be found in Appendix B, C and D. Also, all published articles can be found at the journal websites on the link provided below.

2.1 CLUSTERING OF PHYSICAL ACTIVITY, DIET AND SEDENTARY BEHAVIOR AMONG YOUTH FROM LOW-, MIDDLE-, AND HIGH-INCOME COUNTRIES: A SCOPING REVIEW

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middle-, and high-income countries: a scoping review. International Journal of Environmental Research and Public Health. 2021. 18(20), 10924.

Clustering of physical activity, diet and sedentary behavior among youth from low-, middle-, and high-income countries: a scoping review.

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Abstract

Background: The interaction between physical activity (PA), diet, and sedentary behavior (SB) plays an important role on health-related outcomes. This scoping review (Prospero CRD42018094826) aims to identify and appraise clusters of PA, diet, and SB among youth (0–19 years) according to country income. Methods: Five databases were searched. Fifty-seven articles met the inclusion criteria. Results: Fifty-five cluster types were identified, with greater variety in high-income than lower income countries. The most prevalent profiles were "*High SB and consumption of sugar, salt, and beverages (SSB)*" (*n* = 17) and "*High PA*" (*n* = 13–5), both of which presented in all income countries. The healthiest profile, "*High PA and fruit and vegetables (F&V); Low SB and SSB*" (*n* = 12), was present in upper-middle and high-income countries, while the unhealthiest "*Low PA and F&V; High SB and SSB*" (*n* = 6) was present only in high-income countries. Conclusions: High SB and unhealthy diet (SSB) were more prevalent in clusters, mainly in high-income countries. The results support the need for multi-component actions targeting more than one behavior at the same time.

Keywords: cluster analysis; diet; exercise; sedentary behavior

Introduction

Physical activity (PA), dietary patterns, and sedentary behavior (SB) are recognized as obesity behavioral determinants[52], which have commonly been targeted on interventions[53,54] due to their effects on energy balance. Their interaction also plays an important role in overweight[55] and other health outcomes[37,38,56] in children and adolescents. When these behaviors are individually evaluated, especially for not accounting for collinearity in traditional analyses, their effects on health outcomes can be reduced or even nullified[48]. Understanding PA, diet, and SB patterns among the pediatric population can be used to guide strategies to promote behavior change in this population[57].

A previous narrative review identified that PA, diet, and SB cluster in healthy and unhealthy patterns[41], which was also observed in recent studies[37,39]. A multicentric study conducted in ten European cities identified that 42% of adolescents were allocated to a cluster characterized by low levels of PA and SB, and high-quality diet[36]. Another study conducted in Brazil observed that 45% of 102,072 adolescents were allocated in a cluster characterized by healthy PA and diet profile, although spending almost four hours daily in SB[58]. Furthermore, these clusters have been associated with social, economic, and cultural aspects that do not affect individual behaviors equally[24,26] and may be attributed to the demographic context and population characteristics[24,25]. Socioeconomic status (SES) or its derivatives (e.g., income, education, and occupation) in a country has been recognized as an important health determinant due to its influence on people's attitudes, experiences, and exposure to several health risk factors throughout their lives[59,60]. Thus, patterns of health-related behaviors are expected to vary between nations due to sociodemographic and cultural distinctions. For example, Collese and colleagues [24] found that European (HELENA study) and Brazilian girls (BRACAH study) have similar cluster patterns. However, among boys, a cluster characterized by higher levels of PA was observed only in the Brazilian sample. Further, Dumuid and colleagues[37] identified distinct lifestyle behavior clusters among 12 countries from low- to high-income classification. The “all-round” cluster, characterized by low screen time, healthy eating pattern, and moderate PA/SB was observed among 9 out of 12 sites, which excluded Brazil, Kenya, and South Africa. Thus, differences in PA, diet, and SB patterns in socially and economically distinct regions remain unclear.

Previous reviews have presented interesting findings on behaviors clusters among adolescents. Parker and colleagues systematically reviewed activity-related behavior typology (i.e., PA and SB), but their combination with dietary profiles were not included [2]. Another study evaluated PA, diet, and SB clusters in a non-systematic way, which limited the findings found [41]. In addition, findings on behavior profiles can be used to guide interventions in order to propose strategies to subgroups of children and adolescents to promote behavior change. Interventions with strategies aimed at individuals or subgroups are more likely to be effective in comparison to those targeted to adolescent's population as a whole.

Based on previous evidence on the world's health and income inequalities[61] and on associations between socioeconomic determinants and clusters[24,41,58], this study proposes the following advancements: (a) conducting a systematic scoping review on clusters of PA, diet, and SB among the pediatric population; (b) identifying if behavioral clusters differ according to country income; and (c) if critical appraisal within sources of evidence is found. This systematic scoping review can be used to inform readers about the state of evidence and to provide guidance for future research priorities in the clustering of obesogenic behaviors theme.

Methods

Protocol and Registration

This scoping review is part of a comprehensive project (PROSPERO register number: CRD42018094826) and was reported in accordance to the Preferred Reporting Items for Systematic reviews and Meta-analyses for Scoping Reviews (PRISMA-ScR, see checklist in Appendix B Table S1)[62]. The search strategy included five electronic databases (PubMed, Web of Science, LILACS, Scopus, PsycINFO). The final search was conducted in December 2019 with no restriction in regard of publication year. Searches considered particularities from each database and Booleans operators and truncation symbols ($, * or "") were used. The final search string can be found in Appendix B Table S2. Reference lists of included studies and previous reviews were examined as additional searches.

Eligibility Criteria

Criteria for inclusion were that the articles must: (1) include children and/or adolescents (aged 0–19 years); (2) simultaneously analyze PA, diet, and SB by applying data-based cluster statistical procedures (studies could also include additional behaviors); and (3) be published in English, Portuguese, or Spanish. Exclusion criteria was that articles must not include clinical populations (e.g., disabilities, metabolic and/or cardiovascular diseases).

Screening Process

Duplicates were identified and withdrew in EndNote software. Firstly, trained independent peers (GTM/RMC and GTM/MVVL) screened titles and abstracts. Discrepancies were solved by a fourth author (GM). If the relevance of an article was unclear, it was retained for full text screening. Secondly, full-text assessments were conducted (GTM/GM and RMC/MVVL) with a third reviewer (MVVL and GTM for the first and second pair, respectively) solving discrepancies. Reference list were checked by MVVL and RMC.

Data Extraction and Synthesis

Data were extracted by the same peers of the full-text review process. Cluster characteristics were identified by GTM and MVVL, and disagreements were also solved by consensus (GTM, MVVL, GM, and RMC).

Data extraction included: (1) general characteristics (e.g., publication year, country, design, sample size and age); (2) instruments and procedures used to measure PA, diet, and SB); PA, diet, and SB domain and components (e.g., leisure-time PA, habitual PA, fruits, vegetables, snacks, daily time spent on TV, computer, videogames), as well as other evaluated behaviors (e.g., sleep, tobacco and alcohol consumption) (see Appendix B Table S3); and (3) cluster results (e.g., number of outcomes included in clustering procedures, cluster statistical approach, clusters descriptions and prevalence).

Cluster characteristics were extracted in accordance to authors' original descriptions. When textual description was not available, quantitative data was considered. PA, diet, and SB components on each cluster were categorized as "Low",

“Average”, or “High”, and were used to define labels. For example (for a study that applied the k-means technique), a cluster characterized by screen time estimates similar to the overall sample, and by physical activity estimates higher in at least 0.30 SD above the overall sample would be classified as *High PA and Average SB*. However, as the interest is in the comparison, the “average” term was omitted from labels as commonly performed by authors when describing behavioral patterns. The cut point for classification (e.g., ±0.30 SD) varied between studies due to sample particularities and distinct clustering techniques. This is the reason we choose to label according to the authors description when properly presented. Dietary patterns, referring to ultra-processed food consumption, were named as sugar, salt, and beverages (SSB) (i.e., snacks, sweetened beverages, excessive salty foods, candies, and fried meals) and fruits, green salads, and vegetables (F&V) (i.e., fruits, vegetables, and fiber consumption). Dietary profiles that did not fit in SSB and F&V patterns were defined as “Specific Diet” (e.g., milk and meat consumption). For example, a cluster described as lower consumption of snacks and soft drinks, higher consumption of fruits and vegetables, and average time spent in PA and SB was labeled as *High F&V and Low SSB*. The “Average” category was omitted from labels.

Self-reported instruments applied to measure PA, diet, and SB were classified as: (1) Defined, if referred to consolidated or previously validated instrument; (2) Undefined, if authors did not clearly report question and/or response options, as well as the reference of the instrument used; (3) Undefined–Reproductible, if authors clearly reported question and response options allowing for replication but did not mention the reference used.

A country’s income classification was performed according to The World Bank (low income, lower middle income, upper middle income and high income) considering data collected year of each study (https://datahelpdesk.worldbank.org/; accessed at July 07th, 2021).

A narrative synthesis of findings was conducted and structured around the descriptive characteristics of included studies (e.g., year of publication, continent, sample procedures, instruments, and others). Additionally, behaviors (PA, diet, and SB) were described considering: details of their components; measurement instrument; and number of outcomes used in clusters procedures. In addition, we detailed the data-based cluster statistical procedures used to identify number and clusters types found in the studies. The descriptive analysis was based on the total

number of studies; thus, articles originated from the same study were represented by the article with the largest sample. Thus, in cluster description results, the same clusters from the same population presented in different articles were reported once. Since this, cluster descriptions were made according to analysis used to identify patterns: (a) cluster analysis (i.e., k-means, Ward's method, latent class analysis, and latent profile analysis) and (b) dimensionality reduction procedures (i.e., principal component analysis, multiple corresponding analysis, and factorial analysis).

Critical Appraisal of Individual Sources of Evidence

We performed a critical appraisal of included studies to map the quality research on clustering of obesogenic behaviors in different countries as an optional step for scoping reviews and a fundamental element for the research implications of this study. For this, an adapted 17-point version of the quality assessment tool for quantitative studies of the Effective Public Health Practice Project (EPHPP) was used [63]. Original papers were assessed by four methodological domains: (1) selection bias (sample characteristics in relation to the review target population (*strong* or 1: ≥80%; *moderate* or 0: 79–60%; *weak* or −1: ≤60%)); (2) study design (information about study representativeness (yes = 1; no = 0); described sampling methods (yes = 1; no = 0); appropriate sampling method (random = 1; not described = 0; convenience = −1))—*strong* for 1 in all three items, *moderate* for combinations: 1-1-0, 1-0-1, 1-0-0, and 0-0-1, and *weak* for all other combinations; (3) information about instruments to evaluate PA, diet, and SB (report of its previous validation (yes = 1; no = 0), and information that would enable reproducing PA, diet, and SB assessment (yes = 1; no = 0))—studies using an accelerometer to measure PA and/or SB were assigned a score of "1", that is, it was considered that there was a previous validation report of the instrument—*strong* for 1 in both outcome items, and *weak* for all other combinations; and (4) flow of people throughout the study (report in terms of numbers and/or reasons (yes = 1; no = 0) and percentage of participants completing the study (≥80% = 1 or strong; 60–79% = 0 or moderate; ≤59% = −1 or weak))—*strong* for 1 in both items or 0 and 1, *moderate* for combinations 1 and 0 or 0 and 0, and *weak* for all other combinations. The classification (low (strong), moderate (moderate) and high (weak)) for each domain was performed based on a study distribution (see Table S3). Two independent

reviewers (GTM and GM) assessed the risk of bias in included studies, and a third reviewer evaluated disagreements (MVVL).

Results

Selection of Sources of Evidence

A total of 11,910 articles were identified, of which 57 were included in the present work. Of these, 40 different studies were identified. A summary of each review phase and reasons for exclusion is available in the flowchart of Figure 1.

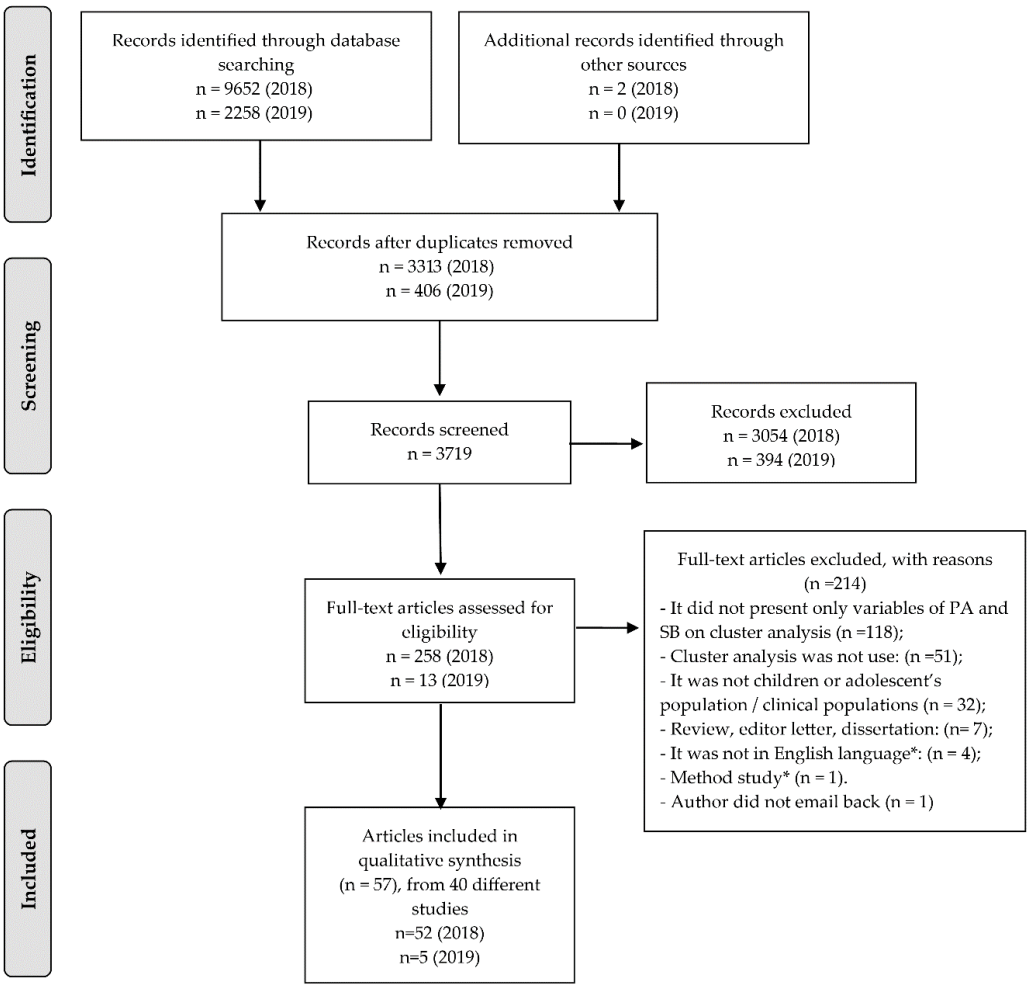

Figure 1 – PRISMA flowchart of the study selection procedure.

Note: * French (*n* = 1), German (*n* = 1), and Polish languages (*n* = 2). * Explained how to use cluster analysis—did not present original findings. PA: physical activity.

Characteristics of Sources of Evidence

Characteristics of studies are present in Figure 2 and Appendix B Table S4. Studies from the same sample data were presented once, considering the largest sample (see Appendix B Table S6). Three articles used HBSC data with samples from their respective countries (Italy[64], Finland[43], and Portugal[65]). Thus, we considered three articles to represent the HBSC study. Forty-two studies were considered to describe the characteristics of the studies. The publication year ranged from 2006 [66,67] to 2019[68], and the majority included cross-sectional design (*n* = 26)[37,43,44,64–66,69–88]. The studies were developed in 29 different countries, the majority were carried out in USA (*n* = 6), Brazil (*n* = 6), and Australia (*n* = 4), and five [37,39,73,74,89] provided data from more than one country. Regarding country income, 35 studies[39,42–44,64–67,69,71–77,79,82–84,86–99] were developed in high-income countries, followed by six [70,78,80,81,85,100] in upper middle-income countries, and one [37] involved data on countries with more than one income.

The age group ranged from two[89,101] to nineteen[58,81] years. Most studies exclusively investigated adolescents (*n* = 23)[43,64–66,68,70,71,73,74,76,78–81,84–87,94,96–98,100], nine[37,44,69,72,77,82,88,90,93] both children and adolescents, and seven (*n* = 7)[39,42,83,89,91,92,99] only children. In three studies[67,75,95], the sample was composed of children/adolescents but did not report the age group. The sample size ranged from 284[38] to 109,104[78] participants, representing a total of 362.471 children and adolescents.

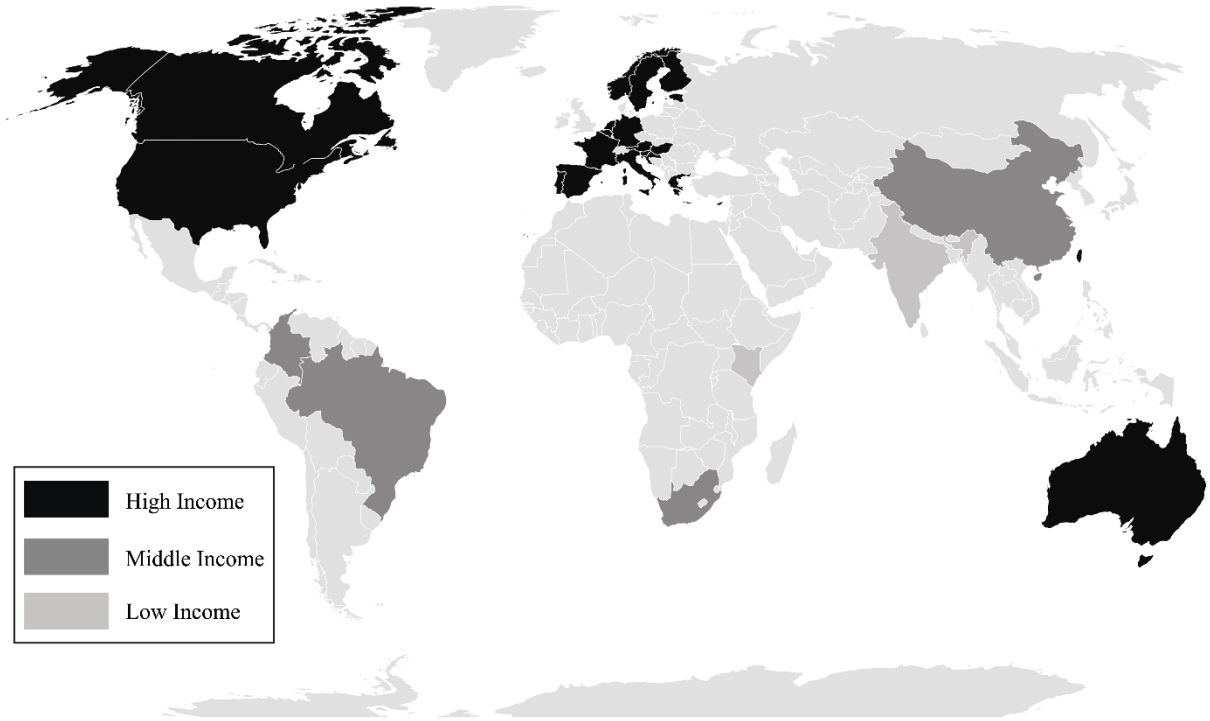

Figure 2 – Countries included in the scoping review by income levels.

Critical Appraisal within Sources of Evidence

Disagreement percentage among risk of bias evaluators was approximately 30.7% (kappa = −0.03–1.0), ranging from 5.2% (“Question 6. Is there information that enables replicating the tool?” for diet) to 62.1% (“Question 8. Indicate the percentage of participants completing the study”).

In risk of bias assessment (see Appendix B Table S4), several studies from high-income countries failed to achieve at least 60% of the eligible response, which compromised the sample representativeness. This occurred at a lower frequency among studies from middle-income countries. In addition, a percentage of ≥ 80% of participants who completed the study was observed in less than half of included studies, regardless of the income level of the countries. On the other hand, almost all studies in all income levels, except one[71], presented information that enables replication of the tool of PA, diet, and SB. In Figure 3, a higher frequency of studies with a high risk of bias was observed for items selection bias among those from high-income countries and assessment tool of SB for studies from middle-income countries. The assessment tool of PA and diet were the items most frequently classified with low risk of bias among studies for both income levels of the countries (Figure 3). In the two studies from low-income countries, a low risk of bias for the assessment tool of PA and

diet was observed. Half the studies showed a low risk of bias, and half a moderate risk for the selection bias, assessment of SB, and withdrawals/dropout items. For the study design item, one study was classified as having a moderate risk of bias and the other study with a high risk of bias (data not shown).

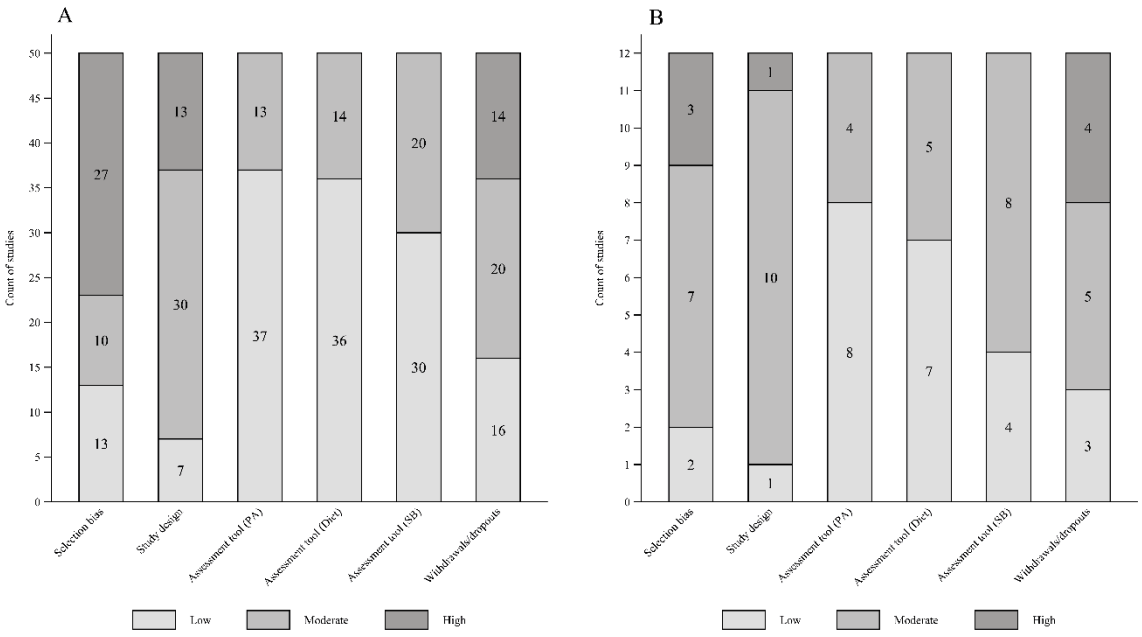

Figure 3 – Risk of bias assessment of studies from high (A), and middle-income (B) countries.

Behavior Measurement

Information about assessment tool classifications is available in Appendix B Figure S1. Objective measures were identified on five [37,39,72,90,98] and two [90,98] studies to evaluate PA and SB, respectively. Questionnaires were the most prevalent instrument used to measure PA (n = 35)[24,39,43,44,56,66–71,73–89,91–97,99,100], diet (n = 33)[24,38,39,43,56,66–68,70–72,74–76,78–81,83–97,99,100], and SB (n = 37)[24,38,39,43,44,56,66–89,91–97,99,100]. Most questionnaires applied[24,37,39,56,66,67,71,73,74,76–82,84–91,95–97,99,100] were consolidated or previously validated to PA (n = 85; 77.6%), diet (n = 83; 9.2), and SB (n = 93; 49.5%). However, six[44,69,85,92,94,96], four [66,72,92,94], and twelve[37,44,69,72,80,81,84–86,92,94,96] studies that used undefined questionnaires (authors did not clearly report question and/or response options, and instrument reference) for PA, diet, and SB, respectively. One[42] study used a diary to evaluate PA, diet, and SB; six studies[44,69,73,77,82,98] evaluated diet applying recalls.

All outcomes for PA, diet, and SB used in cluster procedures can be observed in Figure S2). The most common outcomes for PA were *weekly* PA (*n* = 22 articles)[36,64,65,70,71,75,76,78–80,82,85,87,91,93,94,96,97,99,100,102,103] , followed by *weekly leisure-time* PA (*n* = 15 articles)[43,56,58,66–68,77,78,84,86,89,94,95,99,104] and *accelerometer measured* PA (*n* = 9 articles)[37,38,55,72,90,98,101,105,106]. *Daily* PA, PA in *physical education classes*, and *daily leisure-time* PA were used by seven[24,42,73,74,88,92,107], six[39,78,81,83,94,97], and four[44,45,69,108] articles, respectively. Only one [83] article used *leisure-time* PA (i.e., yes or no).

For SB, *daily* screen time was the most commonly used outcome (*n* = 30 articles)[24,37,38,42,44,45,64,68,69,72–77,79,80,82,85,86,92,95,96,99,104–108] followed by *daily* TV time (*n* = 16 articles)[42,43,55,56,58,64,76,78,81,83,88–90,93,94,103]. Other articles used *daily* videogame time (*n* = 9)[43,56,58,64,76,88,93,94,103], *daily* computer time (*n* = 8)[42,43,64,76,88,93,94,103], *weekly* TV time (*n* = 7)[67,71,87,91,97,101,102], and *weekly* computer time (*n* = 6)[67,71,87,91,97,102]. *Daily* non-screen activities[56,58,73,78], *daily* stationary time[37,55,90,98], and *weekly* screen time[65,84,89,100] were used in four articles. Finally, three[84,87,97] articles used *weekly* non-screen activities, three[36,70,88] articles used *daily* SB, two[71,97] articles used *weekly* videogame time, and only one[66] article used *weekly* SB.

Regarding diet, the outcomes most used were *daily* consumption of F&V (*n* = 23)[24,39,42–45,55,66,72,75,77,81,83,87,88,90,92,93,97,99,103,107,108], followed by *weekly* consumption of SSB (*n* = 21)[56,58,64,65,70,76,78–80,83,89,91,93–95,100–103,105,106], *weekly* consumption of F&V (*n* = 20)[56,58,64,65,67,70,76,78–80,89,91,94,95,100–102,105,106], *daily* consumption of SSB (*n* = 17)[24,39,42,44,45,55,66,74,77,81,88,90,92,97,99,107,108], *weekly* consumption of fast foods (*n* = 14)[56,58,64,67,70,76,78,79,91,93,94,99,102,103], and diet score (*n* = 12)[36–38,69,82,84–86,96,98,104,105]. Other articles used *daily* consumption of diverse foods (e.g., dairy, grain, beans, and/or fiber) (*n* = 8)[43–45,77,83,88,97,108], *daily* consumption of fast foods (*n* = 6)[42,43,77,88,92,97], *daily* consumption of meats (e.g., bovine, chicken, fish, and/or pork) (*n* = 6)[44,45,77,88,97,108], *weekly* consumption of diverse foods (*n* = 5)[78,91,94,102,105], *weekly* consumption of meats (*n* = 3)[91,99,102], and *monthly* consumption of SSB (*n* = 2)[68,72]. *Monthly* consumption of fast foods[68], *monthly* consumption of F&V[68], and *monthly* consumption of diverse foods[72] were used once in each article. Additionally, one study evaluated dietary balance, dietary diversity, dietary quality, and meal index[73].

Analytical Approaches

Several data-driven clustering methods were used to determine clusters (see Figure S3). From 57 articles, 26 used k-means cluster analysis[24,36–39,43,55,64,65,68,73,74,78,80–82,84,86,89,90,95,97,100,101,104,105], and 15 of these applied the combination of Ward and k-means methods to identify the number of meaningful clusters to assign individuals into clusters[24,37–39,73,74,80–82,86,89,100,101,104,105]. Only one study exclusively applied the Ward method[72]. The use of latent class analysis was observed from 2011 and increased in 2017[42,75,76,92–94,98,103,106,107]. A similar trend was observed for the use of the two-step cluster analysis[56,58,71,79,87,88,96].

Cluster Profile

A total of 55 cluster types were identified. A large number of studies used four[56,58,72–74,79,81,82,89,95,100,101] outcomes in data-driven procedures. In addition, outcomes number ranged from three[36,86,98,104] to 41[99] (see Appendix B Figure S4). Twenty-five studies identified clusters considering only three behaviors (PA, diet, and SB)[36–38,55,56,58,65,66,69,72,73,76,77,81,84,86,89–91,95,98,100–102,104]. Studies included other behaviors in clustering procedures beside these three, such as: sleep (*n* = 13)[24,39,42–45,74,80,82,88,105,106,108], risk behaviors (*n* = 11) (e.g., aggression, alcohol, tobacco, drugs, unprotect sex, bullying, violence)[64,68,70,71,75,85,87,93,97,99,103], weight control behavior (e.g., vomiting or taking laxatives or pills)(*n* = 4)[75,92,94,107], weight perception (*n* = 1)[107], PA environment (*n* = 1)[97], family-related variables (e.g., family structure and medical history, father and mother PA levels, and excess weight) (*n* = 2)[83,99], socioeconomic and demographic aspects (e.g., schooling, birth data) (*n* = 1)[99], hygiene (*n* = 1)[88], and diet habits (e.g., eating with parents/guardians, eating in front of television or studying and having breakfast) (*n* = 1)[78]. Nineteen studies stratified clusters by sex[24,36,43,68,70,74,75,78,80–82,84,88,89,97,98,100,101,105], five by age[55,77,82,90,101], and one by country[37].

Cluster Analysis

By applying cluster analysis (i.e., k-means, Ward's method, latent class analysis, and latent profile analysis), 51 cluster types were identified, and 42 included at least one negative behavior (e.g.; low consumption of F&V). Two [39,105] studies identified clusters considering a sample of more than one country income levels and

were not included in counts. Clusters that appeared the most across studies presented in all income classifications, Figure 4, were the "*High SB and SSB"* (*n* = 17)[24,37,38,43,55,72,74,76,88,90,92,94,96,101,106,107], "*High PA"* (*n* = 13)[38,72,75,80,81,86,89,96,97,100,101,104], "*Low PA High SB"* (*n* = 8)[37,38,42,55,81,90,93,100,103], and "*High PA and Low SB"* (*n* = 7)[24,37,38,80,81,87]. Cluster type "*High SB"* (*n* = 9)[36,64,71,74,75,80,89,97,100,101] was found only in upper middle and high-income countries. The healthiest, characterized by all behaviors being healthy, "*High PA and F&V Low SB and SSB"* profile (*n* = 12)[24,39,42,43,65,68,72,73,76,80,82,94,95,98], was present only in upper-middle- and high-income countries, while the unhealthiest, characterized by all behaviors being unhealthy, *"Low PA and F&V High SB and SSB"* profile (*n* = 6)[39,43,68,84,86,95,98,104] was present only in high-income countries.

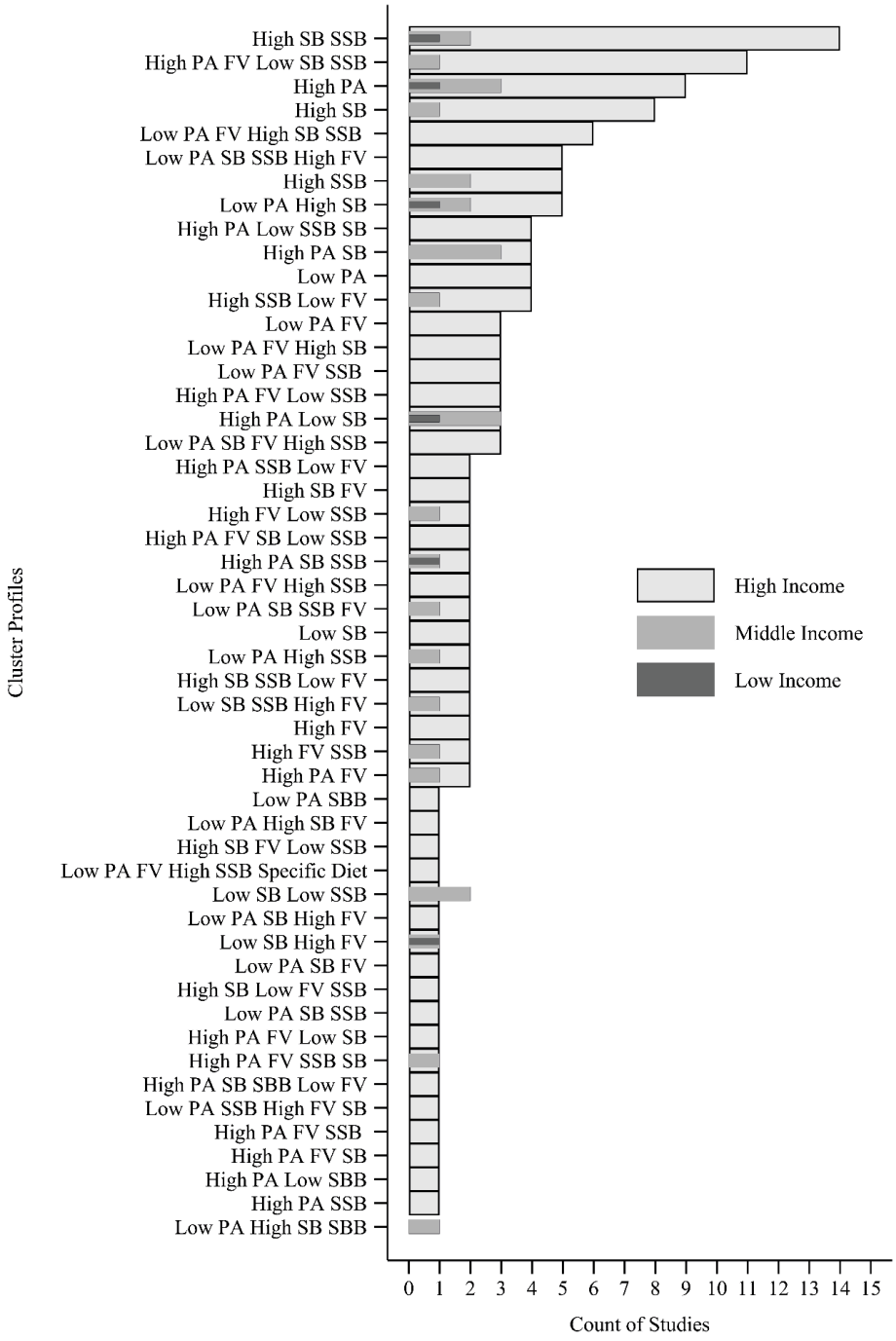

Figure 4 – Characteristics of clustering patterns of obesogenic behaviors applying cluster analysis (latent class analysis, latent profile analysis, two-step and K-means) across studies.

Note: Middle income includes lower-middle- and upper-middle-income countries. F&V: fruits and vegetables; SSB: ultra-processed food consumption, named sugar, salt, and beverages; SB: sedentary behavior; PA: physical activity. Country income classified by The World Bank (https://datahelpdesk.worldbank.org/, accessed at July 07th, 2021) according to year of data collected of each study.

Dimensionality Reduction Techniques

By applying dimensionality reduction procedures (i.e., principal component analysis, multiple corresponding analysis, and factorial analysis), 15 cluster types were identified, and nine included at least one negative behavior (Figure 5). The two most prevalent cluster types found in high-income countries were also present in upper-middle-income countries. There was no evidence from low-income countries, and few cluster types were found in upper middle-income compared to high-income countries. A large proportion of studies reported clusters characterized by "*High SB and SSB"* (*n* = 7)[44,45,66,67,70,91,102,108], followed by "*High PA"* (*n* = 5)[44,45,69,99,102,108], "*Specific Diet"* (*n* = 3)[44,45,83,108], and "*High F&V"* consumption (*n* = 3)[44,45,91,108].

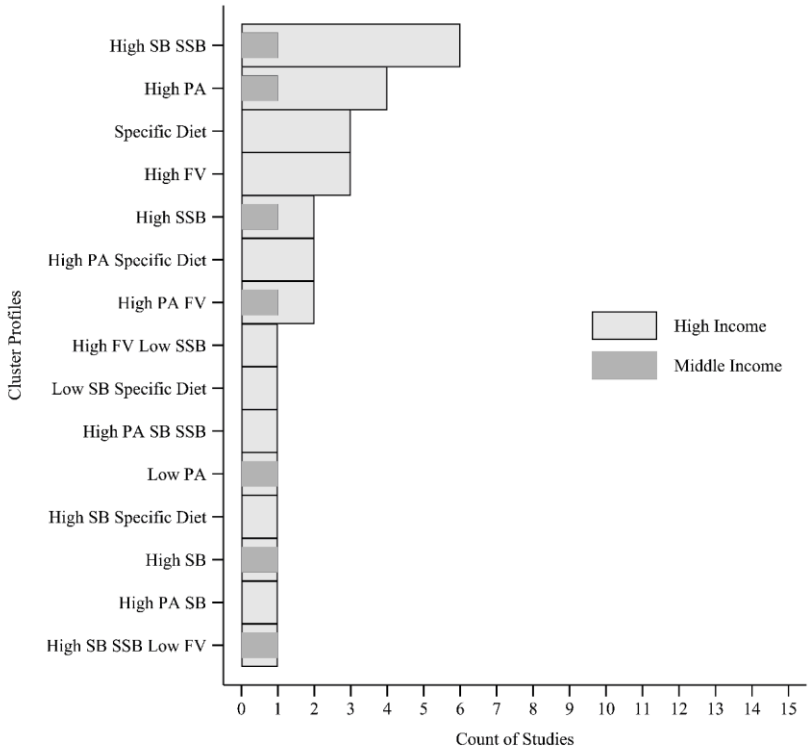

Figure 5 – Characteristics of clustering patterns of obesogenic behaviors applying factors procedures (principal component analysis, factorial analysis and multiple corresponding analysis) across studies.

Note: F&V: fruits and vegetables; SSB: ultra-processed food consumption, named sugar, salt, and beverages; SB: sedentary behavior; PA: physical activity. Country income classified by The World Bank (https://datahelpdesk.worldbank.org/, accessed at July 07th, 2021) according to year of data collected of each study.

Discussion

This scoping review found that sundries data-driven procedures and diverse PA, diet, and SB outcomes have been used to identify clusters behaviors. The present results identified 55 cluster types in children and adolescents, and a high diversity of their types was found in data-driven cluster analysis procedures. Studies from low- and upper-middle-income countries were less well represented than those from high-income countries. The types clusters identified presented co-occurrence of healthy and unhealthy behaviors; however, unhealthy clusters were more prevalent.

Risk of Bias

Independently of country income, the risk of bias for sample selection is high/moderate for most of the studies. Contrarily, for design, withdrawals, and dropouts, the risk of bias was low for most studies. This result indicates that the studies' representativeness of their target population, as well as the losses and withdrawal rate and participants who completed the study, has not been reached or is poorly reported among studies. In addition, knowing the withdrawals and losses of a study, as well as its reasons, enables a better interpretation of results. In this sense, cluster studies could report the selection process of participants, losses, and withdrawals more comprehensively. SB measurement was the third item with the highest frequency of high risk of bias. The lack of standardized instruments to measure SB makes comparison among studies difficult.

Studies Characteristics

Studies regarding the clustering of PA, diet, and SB are relatively recent, as the oldest publication included in this review was conducted in France and Taiwan in 2006. In addition, Europe was the continent with the largest number of included studies. This result may indicate the intensification of debate in high-income countries about this issue. Once sociodemographic outcomes seem to affect cluster formation [41], investigating obesogenic clusters in low- and middle-income countries is also necessary to improve the understanding on the topic. In addition, most studies investigated only adolescents and more studies investigating children are necessary.

Once these unhealthy behaviors start at the beginning of childhood, remaining in adolescence and frequently in adulthood[109].

Questionnaires were the instrument most commonly used, and some studies[37,38,44,64,66,69,72,85,92,94,96,104,107] did not report sufficient information to replicate the instrument measurement for PA[44,64,69,85,92,94,96,107], SB[37,38,44,64,69,72,85,92,94,96,104,107], and diet[64,66,72,92,94,107]. Objective measures were used by few studies[37,38,55,72,76,90,98,101,105,106], being restricted to PA and SB assessment. Recalls and diaries to evaluate diet behavior were also less frequently observed than in questionnaires[42,44,69,73,77,82,98]. The lack of information on the instruments used is not the factor that determines the formation of clusters; however, the lack of validated and replicable instruments makes comparisons among studies difficult.

Outcomes

Different outcomes for PA, diet, and SB were analyzed. The number of outcomes observed in PA was smaller compared to diet and SB. Weekly PA and daily screen time were the most commonly used PA and SB outcomes, respectively. The dietary outcomes used in studies varied according to consumption frequency, such as daily or weekly consumption of F&V, SSB, meat, and diverse foods (e.g., milk). Thus, in contrast to diet variety outcomes (treatment variables) simultaneously presented in cluster procedures (e.g., consumption of fruits, ultra-processed foods, milk, and meat), only few studies analyzed more than one of PA and SB outcome simultaneously. PA, diet, and SB are complex behaviors characterized by multiple components that need to be available. Therefore, future studies should explore other outcomes of these behaviors, such as volume and different types of PA and screen time components such as cellphone time, which differently affect health.

Analysis

There was substantial heterogeneity in the types of clustering methods used, varying from factor-based approaches (e.g., exploratory factorial analysis) to cluster analysis (e.g., k-means and latent class analysis). If the aim is to identify cluster behaviors, both types of methods seems to be efficient, which is similar to findings reported in previous study[48]. It is noteworthy that cluster analysis has only recently

been applied. It seems that over time, the authors had used cluster methods that minimize the arbitrariness in clustering formation and started to use criteria to establish the number of clusters (models fit); however, the subjectively is reduced and/or conditioned according to advance in analyses. In addition, the subjectivity in cluster labels was considerable present, and many times, cluster was named and characterized according to the "main behaviors" (the ones which present extreme values in the cluster). It is important to consider that labeling is a matter of transforming data into text that is more intelligible. However, authors should include a very comprehensive description of each variable for each cluster. When analysis allows, it is important to report the prediction importance of each variable to form the cluster (e.g. PA could discriminate population more than diet).

Clusters

Diverse cluster types were found, and the two most prevalent were present in all country income levels and stand out in terms of characteristics. The most prevalent clusters in decreasing order were characterized as "*High SB and SSB"*, "*High PA"*, and "*High PA and F&V Low SB and SSB".* From the 55 cluster types, 43 profiles included at least one negative behavior in distinct combinations. The most common cluster had a combination of high time in SB with high consumption of SSB foods. A possible explanation for this finding is that watching television makes individuals eat more because they are distracted, which reduces internal satiety due to the delay of normal mealtime satiety[110–113]. Another explanation is the high number of advertisements that screen users are exposed to, which may influence the type of food consumed[114]. In addition, watching television is associated with poorer diet quality, including high consumption of SSB foods[110,115].

The two other most prevalent clusters types were "*High PA*" cluster, present in all country income levels, and *"High PA and F&V Low SB and SSB"*, present only in upper-middle- and high-income countries. These cluster types results corroborate with other studies, which emphasize that PA is positively associated with healthier eating habits and better quality of diet[66,116] and negatively associated with consumption of unhealthy foods[66,117,118]. However, no studies were found in the literature comparing clusters behaviors with country income levels. The unhealthiest cluster type (*Low PA and F&V High SB and SSB*) was present only in high-income countries. Even so, it is

worth highlighting that more than 75% of cluster types had the presence of at least one unhealthy behavior. This predominance of unhealthy clusters in children and adolescents supports the need for the development of multi-component actions targeting more than one behavior at the same time.

Strengths and Limitations

To the best of our knowledge, this was the first study to systematically review clusters of PA, diet, and SB in children and adolescents. Another positive point is that this study showed cluster types of these behaviors by countries of different incomes. One of the limitations of this study was the subjectivity of cluster data extraction; however, a sequence of criteria and agreement was used, so that parsimonious information was obtained. Since this, the wide range of instruments used to measure PA, diet, and SB as well as variation of outcomes within each behavior may have interfered to more intelligible/readable synthesis of the present results. In addition, some articles included behaviors other than PA, diet, and SB, and the comparability with studies that did not include these are complex. It is noteworthy that strong differences and/or similarities between cluster type and country income categories may not be found due to the low number of studies carried out in lower income strata. All these aspects should be considered when interpreting the results.

Futures Researches

Our study identifies the number and cluster types according to country income. However, we could not conclude that clusters in low- and middle-income countries are equivalent to those of high-income countries, as: (I) there are few studies using data-driven cluster procedures in countries with lower incomes, mainly in low-income countries; (II) there is high bias in the sample selections; (III) a high variety of instruments and indicators were used for each behavior; and (IV) there is a lack of information about validity of the instruments used. Future studies should be developed in countries with lower incomes. In addition, they should improve methodological aspects, including more reliable measurements and representative samples. In addition, investigations should identify how cluster behaviors vary over time, and the

effect of interventions considering cluster behaviors. No papers included in the review used longitudinal data driven cluster procedures.

Conclusions

Types of clusters considering PA, diet, and SB were identified, and even the low number of studies developed in lower income countries allowed differences in obesogenic behaviors patterns to be identified. Research on this theme has gained scientific interest in recent years; however, methodological fragilities in the studies were identified, especially in the sample selection and the quality of instruments. High SB and unhealthy diet (SSB) were more prevalent in clusters, mainly in high-income countries. The results support the need for multi-component actions targeting more than one behavior at the same time.

2.2 A SYSTEMATIC REVIEW OF THE CLUSTERING AND CORRELATES OF PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOR AMOSN BOYS AND GIRL

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A systematic review of the clustering and correlates of physical activity and sedentary behavior among boys and girls

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Abstract

Identifying the clustering and correlates of physical activity (PA) and sedentary behavior (SB) is very important for developing appropriate lifestyle interventions for children and adolescents. This systematic review (Prospero CRD42018094826) aimed to identify PA and SB cluster patterns and their correlates among boys and girls (0-19 years). The search was carried out in five electronic databases. Cluster characteristics were extracted in accordance with authors' descriptions by two independent reviewers and a third resolved any disagreements. Seventeen studies met the inclusion criteria and the population age ranged from six to 18 years old. Nine, twelve, and ten cluster types were identified for mixed-sex samples, boys, and girls, respectively. While girls were in clusters characterized by "Low PA Low SB" and "Low PA High SB", the majority of boys were in clusters defined by "High PA High SB" and "High PA Low SB". Few associations were found between sociodemographic variables and all cluster types. Boys and girls in "High PA High SB" clusters had higher BMI and obesity in most of the tested associations. In contrast, those in the "High PA Low SB" clusters presented lower BMI, waist circumference, and overweight and obesity. Different cluster patterns of PA and SB were observed in boys and girls. However, in both sexes, a better adiposity profile was found among children and adolescents in "High PA Low SB" clusters. Our results suggest that it is not enough to increase PA to manage the adiposity correlates, it is also necessary to reduce SB in this population.
Keywords: Cluster analysis; Adolescent; Children.

Introduction

Clustering among physical activity (PA) and sedentary behavior (SB) have been linked to important health outcomes (e.g. cardio-metabolic biomarkers, adiposity, self-esteem and psychological distress)[11,37,56,105]. PA and SB are coexisting behaviors

and form part of the human movement spectrum[12]. Thus, an increase in PA may not be associated with a decrease in SB and vice versa, suggesting that this behavioral pattern coexists in different ways[2,3,119].

Recent studies have shown that low levels of PA combined with excessive time spent in SB occur repeatedly in children and adolescents[120–122]. Previous reviews have noted that clusters characterized by "High levels of PA and High time in SB"[3], "High PA and Low SB" and "Low PA and High SB"[2,3] occurred most frequently in children and adolescents. Additionally, one review has identified a tendency for older children/adolescents to comprise clusters defined by low PA[41]. Considering characteristics of the clusters, in relation to sex, girls tend to be in clusters characterized by low PA and high time spent in socializing activities, whereas boys tend be in clusters characterized by high PA and high time spent watching television and playing videogame[28–30,32,33,123]. These findings suggest that both age and sex are important factors to consider when examining PA and SB cluster patterns. This is further supported by evidence showing the prevalence of compliance with PA and SB guidelines decreases and increases with increasing age, respectively[124,125] and the widening of differences in PA levels and time spent in SB between boys and girls between childhood and adolescence[126].

These clusters with distinct characteristics may also correspond to correlates in different ways. Thus, the association between clusters and different sociodemographic, mental and physical health have been explored in children and adolescents[29,30,41,56]. Studies suggest that better cardiometabolic health, self-esteem, body image and weight status are found in youth with the healthiest behavioral clusters[56,127,128]. For example, adolescents in "uses recreation center" and "active in school" clusters had higher self-esteem[128]. The opposite has also been observed for children and adolescents in less healthy cluster. For example, boys and girls in clusters characterized by "low PA and SB" and "high PA and SB" higher adiposity levels adiposity[31,34,129].

Given the complex inter-relationships summarized above, there is a need to (i) map the characteristics of PA and SB cluster patterns among boys and girls according to the methodological quality of studies; (ii) describe which clusters are most prevalent by sex; and (iii) examine the range of correlates that have been explored. This is necessary because previous reviews on cluster patterns were either not systematic[41], employed limited search strategies (i.e., limited combination of descriptors for PA and

SB)[2,29,41] and/or limited the publications reviewed up to 2018[2]. To identify different patterns and their correlates will help to inform the development of appropriate strategies for modifying and improving the lifestyles of different population subgroups[130–132].

The aim of the present study is therefore to review systematically the literature that has investigated the clustering patterns of PA and SB in children and adolescents. In particular, we aimed to verify if clusters differ according to sex, and to identify their potential correlates.

Methods

Protocol

This systematic review used Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)[133,134] and the extension Synthesis Without Meta-analysis (SWiM)[135]. PRISMA and SWiM checklist is included in Supplementary material (see Appendix C Table S1 and Table S2). This study was registered in PROSPERO (CRD42018094826) and formed part of a comprehensive evidence synthesis project[3]. The PI(E)COS strategy was used for the development of the research question.

Eligibility criteria

Studies were included if they met the following eligibility criteria: (a) included children and/or adolescents (aged 0–19 years, or reported means between these ages); (b) analyzed simultaneously PA and SB); c) applied exploratory data-based statistical procedures, considering cluster analysis (i.e., k-means), latent Class/Profile Analysis, and dimensionality reduction techniques (i.e., Principal Component Analysis and Factor Analysis); and (d) be published in English, Portuguese, or Spanish. All correlates reported in the included studies were extracted. Studies were excluded if they involved clinical populations (e.g., disabilities, metabolic and/or cardiovascular diseases, hospitalized or institutionalized populations), or included other behaviors or variables (e.g., tobacco use, unhealthy eating, socioeconomic status) as part of the cluster patterns. Reviews, letters to editor, and conference abstracts were excluded.

All studies designs were considered for inclusion. More information about the eligibility criteria can be observed in Supplementary material Appendix C Table S3.

Search strategies and selection process

The search strategies used five electronic databases (PubMed, Scopus, Web of Science, LILACS and PsycINFO) and were carried out in December 2019. Particularities strategy and Boolean operators and truncation symbols ($, * or "") were considered and no restrictions of publication year and study design were applied. The search string can be observed in Supplementary material (see Appendix C Table S4).

Firstly, the titles and abstracts were screened independently by the authors of the first review (GTM/RMC and GTM/MVVL). If the relevance of an article was unclear, it was retained for full text screening by the same peers. Reference lists of included studies and previous reviews were examined as additional searches (RMC and MVVL).

Methodological quality assessment of included studies

The methodological quality of the included studies was assessed by the 17-point adapted version of the Quality Assessment Tool for Quantitative Studies of Effective Public Health Practice Project (EPHPP)[63], in four methodological domains, as shown in supplementary material Appendix C Table S5. The risk of bias classification (low [strong], moderate [moderate] and high [weak]) for each domain was determined on the basis of the study distribution (see Table S6 supplementary material). The risk of bias was assessed by two independent reviewer (GTM and GM) and a third reviewer was consulted for the consensus of disagreements (CB).

Data extraction and synthesis

Data were extracted by (GTM/CB) and discrepancies were resolved by a third person (GM). Extraction elements included: (1) article description (e.g., publication year; country; study design; sample size and age); (2) instruments used to measure PA and SB; behaviors domain and components (e.g., leisure-time PA, habitual PA, daily time spent on TV, videogames); (3) variables used to determine clusters (i.e.

cluster input variables) and the resulting cluster types according to mixed-sex samples, boys, girls, children, and adolescents; and (4) all correlates examined and their direction of association.

Instruments used to measure PA and SB were classified as: (1) Defined (with validation process); (2) Undefined (reported question and/or response option and instrument reference); (3) Undefined-Reproducible (reported question and response options but did not mention the reference); (4) Objective measurement (e.g., accelerometer); (see Table 2 and Figure S1a and S1b in supplementary material).

The descriptions reported by the authors of the studies were used to extract cluster characteristics according to mixed-sex, boys and girls. For example, authors characterized a cluster with low values for watching TV and high values for playing games and low PA levels; the cluster type was classified as “Low PA and High/Low SB”. Where authors did not provide a text description, quantitative data presented in figures and/or tables were used to classify cluster types. Thus, labels of PA and SB components were categorized as “Low” or “High”.

Paper characteristics included in this review were described in the light of the total number of studies, thus, articles reporting on the same data set were represented by the most recently published paper. All other sections of the results were described taking into account the total number of articles included in the review. For the cluster descriptions, similar clusters derived from the same population, and presented in different articles, were therefore reported only once. A meta-analysis was not performed due to the heterogeneity observed between studies in the following aspects 1) Distinctions in measurements and indicator types of PA and SB; 2) Variability of algorithms used in distinct data-based cluster statistical procedures; and, 3) The different clusters types identified.

The results were organized according to the SWiM as follow: a) study characteristics and its risk of bias (Table 1 and Figure 7); b) instruments used to evaluated PA and SB, and variables used in clusters procedures (Table 2 and Table 3); c) cluster types identified and their correlates (Table 4 and 5). Excel was used to make the figures and tables. Correlates were categorized as sociodemographic, adiposity, healthy risk behaviors and others.

Results

The searches resulted in 11,912 potentially relevant titles, of which 17 (11 from different data set) were identified and included in the review (Figure 6). Table 1 summarizes each article included in the review. The year of publication varied from 2002 to 2017 and three studies were published in the last five years[129,136,137]. Four studies used data from two or more countries[28,123,138,139] and a large number of studies were conducted in the United States[31,128,129,136,140]. All articles included were provide from high income countries. Exception for four studies[32,139,141,142] all provided from macro-project data, and the exploratory data-based methods were applied cross-sectionally across all studies. Sample sizes ranged from 495 to 21,811 participants and most included a relatively equal distribution of boys and girls. Five studies identified cluster types in mixed-sex samples[128,140,142–144], and twelve studies according to sex[28,31–34,123,129,136–139,141]. The age range was from six to 18 years old, with three studies involving children and adolescents[28,32,137], one only children[136], nine only adolescents[33,34,123,129,138,141–144], and four with an average age in the adolescent range[31,128,139,140]. More instruments and behaviors outcomes information can be found elsewhere (see Appendix C Table S7).

Risk of bias assessment

The percentage of disagreement among the risk of bias evaluators was 34.7% (kappa = -0.25; 1.0), ranging from 5.9% to 64.7%. Only three studies[28,128,140] were considered to have a low risk of bias for all evaluated criteria and another study[138] showed moderate and low risk. The other studies showed a high risk of bias in at least one evaluated criterion (see Appendix C Table S6). Half of the included studies failed to achieve at least 60% of the eligible response (response rate), and a quarter of them had ≥80% of participants who completed the study. Almost all studies provided information that would allow researchers to replicate the PA and SB tool. According to Figure 7, a high-risk selection bias was observed among studies.

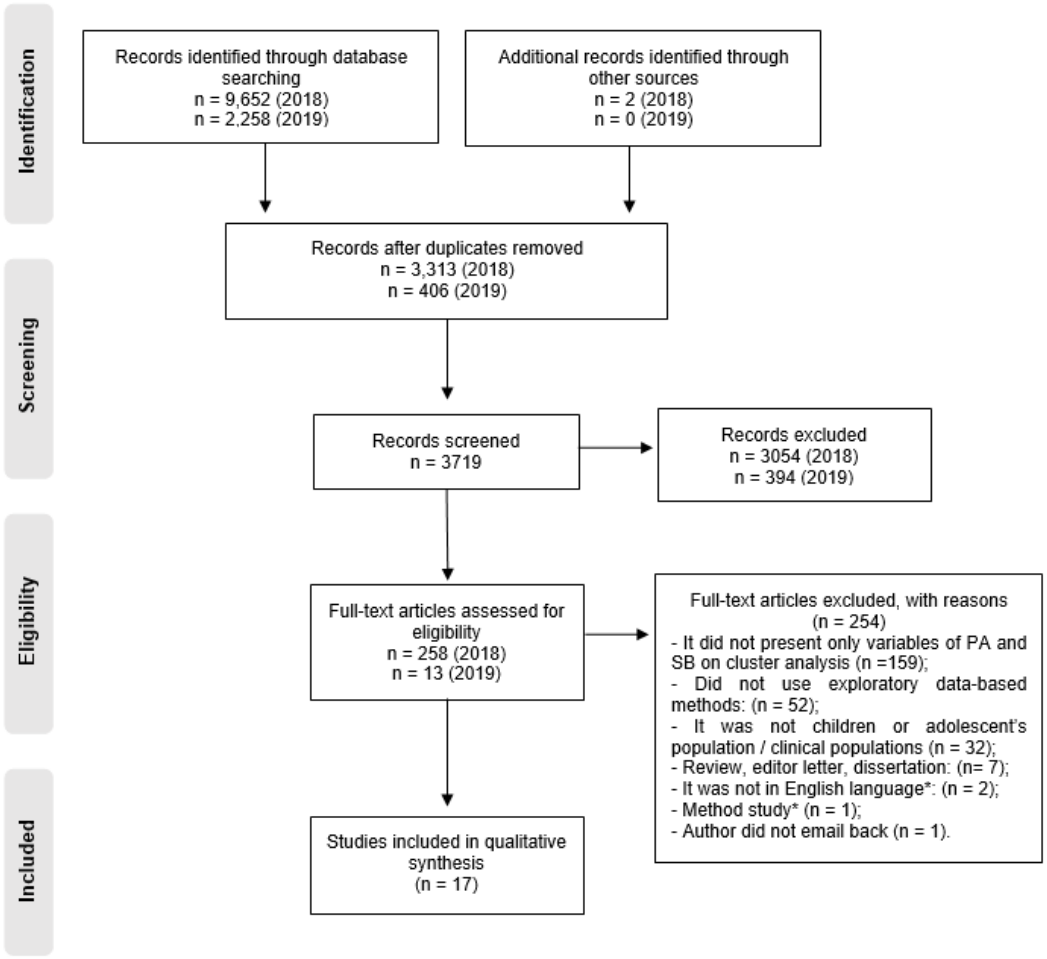

Figure 6 – Flow of study inclusion for the review.

Note: * Polach idiom; Explained how to use cluster analysis – did not present results

Table 1 – Characteristics of studies included in the systematic review (n=17).

First author (publication year)	Country	Original project	Sample size (girls %)	Age group (mean age)	Method used to derive clusters	Number of clusters	Correlates associated with clusters
De Bourdeaudhuij (2013)	European countries[a]	ENERGY	766 (52.9%)	10 – 12 years (11.5 girls /11.7 boys)	Two step cluster analysis (hierarchical and non-hierarchical methods)	Boys 4 Girls 4	BMI and waist circumference
Gorely (2007)	UK[b]	STIL	1,371 (62.0%)	Mean 14.7 years (sd= 0.92, range 12.5–17.6 years)	Cluster analysis (Ward's method and k-means)	Boys 5 Girls 5	None
Huang (2015)	China[c]	Not reported	951 (50.5%)	9 – 13 years (11.0)	Cluster analysis (hierarchical)	Boys 5 Girls 5	Sociodemographic factors and sports team participation
Kim (2016)	USA	YRBS	12,081 (49.4%)	9th – 12th grades (adolescents)	Latent class analysis	Boys 4 Girls 4	Obesity
Lazarou (2009)	Cyprus	CYKIDS	1,140 (53.4%)	10 – 13 years (10.7)	Principal component analysis	8	None
Marshall (2002)	USA and UK	Not reported	USA: 1,750 (59.0%) UK: 744 (85.0%)	USA: mean 12.9 years (sd=0.92) UK: mean 13.0 years (sd=0.94)	Cluster analysis	Boys 3 Girls 3	Age, nationality, ethnicity, and BMI
Melkevik (2010)	Norway	HBSC	4,848 (48.0%)	13, 15, and 16 years	Latent profile analysis	Boys 6 Girls 6	Overweight
Nelson (2005)	USA	Add Health	1,1957 (50.0%)	Mean age (wave I) 14.9 years (sd=0.12)	Cluster analysis*	7	Meet PA guidelines
Nelson (2006)	USA	Add Health	1,1957 (50.0%)	Mean age (wave II) 15.8 years (sd=11.6)	Cluster analysis*	7	Health risk behaviors and other weekly activities, and self-esteem
O'Neill (2016)	Ireland	GUI	8,568 (48.9%)	9 – 13 years	Two step cluster analysis	Boys 4 Girls (no coherent cluster type found)	Weight status
Patnode (2011)	USA	IDEA and ECHO	720 (51.1%)	Mean age 14.7 years (sd=1.8)	Latent class analysis	Boys 3 Girls 3	Grade, race, parent education, live with 2 parents, overweight, weight status, free or reduced-price lunch
Ramos (2012)	Spain	HBSC	21,811 (53.1%)	11 – 18 years	Cluster analysis (general linear models)	3	Biopsychosocial health
Spengler (2015)	Germany	MoMo	2,083 (50.5%)	11 – 13 years 14 – 17 years	Cluster K-means	Boys 8 Girls 7	Age and socioeconomic status
Taverno Ross (2016)	USA	TRACK	495 (55.4%)	5th (baseline) and 7th grades (children)	Latent class analysis	Boys 3 Girls 3	Socio-demographics, Individual-level factors and Interpersonal-level factors; School-level factors[#]

Table 1 – Continued

First author (publication year)	Country	Original project	Sample size (girls %)	Age group (mean age)	Method used to derive clusters	Number of clusters	Correlates associated with clusters
te Velde (2007)	European countries[d]	CSS	12,538 (50.1%)	8.8 – 13.8 years (11.4)	Cluster K-means	Boys 5 Girls 5	Overweight
Wang (2006)	Singapore	Not reported	780 (61.8%)	11 – 14 years	Cluster analysis (hierarchical methods)	Boys 3 Girls 3	None
Wang (2012)	Singapore	Not reported	847 (61.0%)	10 – 16 years	Latent profile analysis	5	None

[a] Belgium, Greece, Hungary, the Netherlands, and Switzerland. [b] England, Northern Ireland, Scotland, and Wales. [c] Hong Kong Island, Kowloon, and the New Territories in Hong Kong. [d] Austria, Belgium, Denmark, Iceland, the Netherlands, Norway, Portugal, Spain, and Sweden. USA: United States. UK: United Kingdom. ENERGY: European energy balance research to prevent excessive weight Gain among youth. NHANES: National health and nutrition examination survey. STIL: Project sedentary teenagers and inactive lifestyles. YRBS: Youth risk behavior survey. CYKIDS: Cyprus kids study. HBSC: Health behavior in school-aged children. Add Health: National longitudinal study of adolescent health. GUI: Growing Up in Ireland. IDEA: Eating and activity in adolescents. ECHO: Etiology of childhood obesity. MoMo: Motorik-modul study. TRACK: Transitions and activity changes in kids. BMI: body mass index. BMI: body mass index. [#] race, Parent education, SES, Weight status, Self-efficacy, enjoyment, Perceived PA barriers, Perceived parent support for PA, Parent support for PA, Sports/physically active lessons in past year, Screen devices in bedroom, Home PA equipment, Neighborhood safety. *Did not specify which cluster analysis.

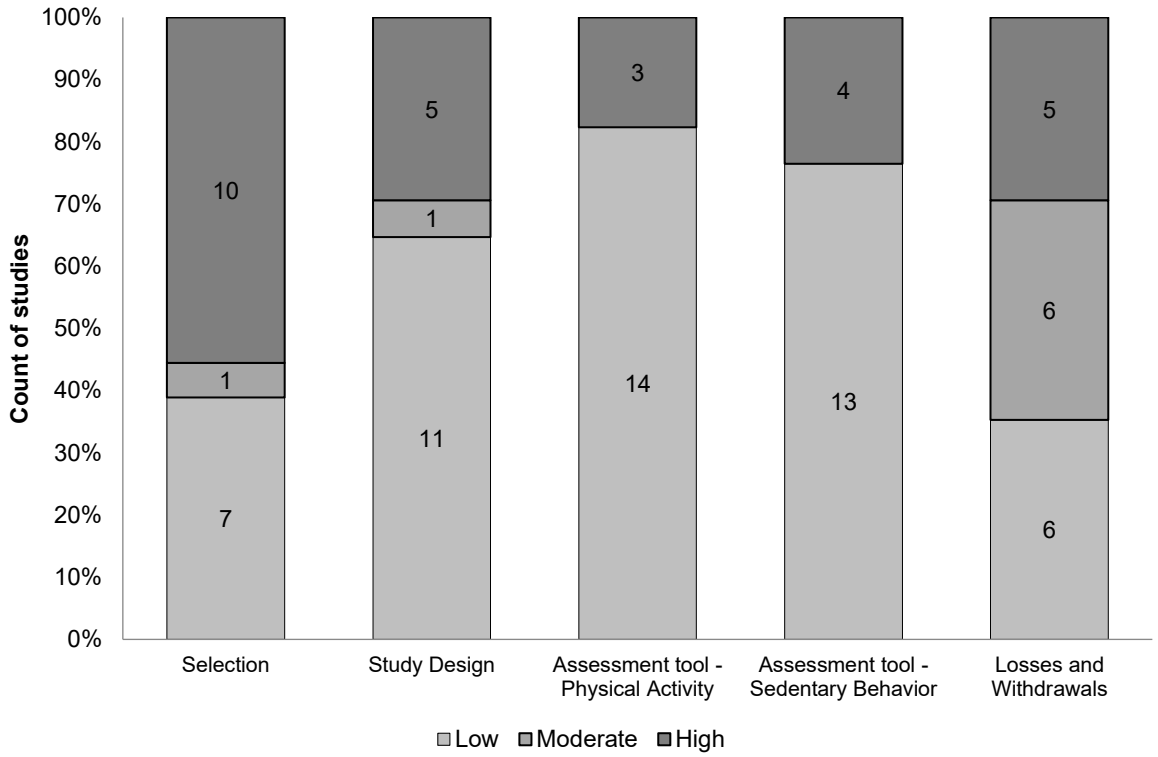

Figure 7 – Assessment of the risk of bias of studies.

Behavior measurement and clusters variables

The classification of the instruments used to measure PA and SB is available in Table 2 and Appendix C (Figure S1a and S1b). Objective measures were used in three studies[31,136,138] and one study[138], to evaluate PA and SB, respectively. Questionnaire was the most prevalent instrument used to measure PA (n=11)[28,32–34,129,137,139,141–144], and SB (n=13)[28,31–34,129,136,137,139,141–144]. All questionnaires applied[28,31–34,129,136,137,139,141–144] were consolidated or previously validated, and one[123] study used a diary, and two studies[128,140] used recalls.

The most used variables for PA were Weekly PA (n = 11 articles[31,33,34,129,136,137,139,141–144]), followed by Weekly leisure-time PA (n = 6 articles)[28,32–34,123,143] and Accelerometer Measured PA (n = 3 articles)[31,136,138]. PA in Physical Education classes and Daily PA were used by four[33,128,140,143] and two[128,140] articles, respectively. Five[28,32,34,123,144] articles used Leisure-time PA (i.e., yes or no) and one[129] used Muscle strengthening exercise (days/week) and Active sports team participation (number of modalities) as PA indicators (Table 3).

For SB, Weekly Computer Time was the most used variable (n = 10 studies)[31,32,34,123,128,139–143] followed by Weekly Videogame Time (n = 9 studies)[31,32,34,128,139–143], Weekly TV Time (n = 9 studies)[31,32,34,123,128,140–143], and Weekly Non-screen Activities (n = 7 studies)[31,32,123,136,139,141,142]. Other studies used Weekly Phone Time (n = 4)[31,139,141,142], Daily Stationary Time (n = 1)[138], Daily TV Time (n = 3)[28,33,129], Daily Computer Time (n = 3)[28,33,129] and Weekly Screen Time (n = 2)[31,136]. Finally, indicators Weekly SB (screen and sit time[143]), Daily SB[137], Daily Videogame Time[33], and Daily Screen Time[144] were also used (Table 3).

Table 2 – Classification of Instruments used to measure PA and SB

Author (publication year)	**Instruments classification**	
	Physical Activity	**Sedentary Behavior**
De Bourdeaudhuij (2013)	Accelerometer (Defined)	Accelerometer (Defined)
Gorely (2007)	Defined	Defined
Huang (2015)	Validated	Validated
Kim (2016)	Undefined-Reproducible	Undefined-Reproducible
Lazarou (2009)	Undefined-Reproducible	Undefined-Reproducible
Marshall (2002)	Defined	Defined
Melkevik (2010)	Defined	Defined
Nelson (2005)	Defined	Undefined
Nelson (2006)	Defined	Undefined
O'Neill (2016)	Undefined-Reproducible	Undefined-Reproducible
Patnode (2011)	Accelerometer (Defined)*	Defined
Ramos (2012)	Defined	Defined
Spengler (2015)	Defined	Defined
Taverno Ross (2016)	Accelerometer (Defined)*	Defined
Te velde (2007)	Defined	Defined
Wang (2006)	Defined	Defined
Wang (2011)	Defined	Defined

* Used two instruments (accelerometer and questionnaire). (1) Defined (reported the validation process); (2) Undefined (reported question and/or response option and instrument reference); (3) Undefined-Reproducible (reported question and response options but no instrument reference); (4) Objective measurement (e.g., accelerometer).

Table 3 – PA and SB variables used to determine the behavioral clusters in each study

First author (year)	Physical activity (PA)								Sedentary behavior												
	Daily PA	Muscle exercise (days/week)	Sports team participation*	Physical Education/PA at school	Accelerometer Measure PA	Leisure PA (yes/no)	Weekly Leisure PA	Weekly PA	Daily Screen Time	Daily Videogame Time	Daily Sedentary Behavior	Weekly Sedentary Behavior	Weekly Screen time	Daily Computer Time	Daily TV Time	Daily Stationary Time**	Weekly Phone Time	Weekly Non-Screen Activities	Weekly Non-Screen Activities	Weekly TV Time	Weekly Videogame Time	Weekly Computer Time
De Bourdeaudhuij (2013)					■											■						
Gorely (2007)						■	■											■		■		■
Huang (2015)						■	■											■		■	■	■
Kim (2016)		■	■					■						■	■							
Lazarou (2009)				■			■	■				■								■	■	■
Marshall (2002)								■									■	■			■	■
Melkevik (2010)						■	■	■												■	■	■
Nelson (2005)	■			■																■	■	■
Nelson (2006)	■			■																■	■	■
O'Neill (2016)								■			■											
Patnode (2011)					■			■					■				■	■		■	■	■
Ramos (2012)						■		■	■													
Spengler (2015)				■			■	■		■				■	■							
Taverno (2016)					■			■					■					■				
Te Velde (2007)						■	■							■	■							
Wang (2006)								■									■	■		■	■	■
Wang (2012)								■									■	■		■	■	■

*Number of modalities; ** Note: *Stationary time refers to accelerometer measured movement behaviors.

Description of the derived clusters

Studies included up to 16 input summary variables in cluster analysis. As presented in Table 1, cluster analysis (n=11)[28,32,33,123,128,137–141,144] was most commonly used approach to derive clusters, followed by latent class analysis (n=3)[31,129,136], latent profile analysis (n=2)[34,142] and, principal component analysis (n=1)[143]. A description of the cluster types defined by the reviewers and authors can be found in Appendix C Table S8, and the prevalence and frequency of each cluster type identified in Table 4. The most prevalent clusters found in studies with the lowest risk of bias included “Low PA Low SB” and “High SB” for whole sample[128,140], “Low SB” and “Low PA High/Low SB” for boys[28], and “Low PA Low SB”, “Low PA High SB” and “High PA Low SB” for girls[28].

Nine cluster types were identified for whole samples (i.e. boys and girls combined) (n=5 studies)[128,140,142–144], these studies involved only adolescents and average adolescents’ age. The most frequently clusters identified in whole sample was “Low PA Low SB” (n=4 studies) and “High PA High SB” (n=3 studies). Otherwise, the most prevalent cluster types for whole samples were “Low PA Low SB” and “Low PA High/Low SB” and, highlighting that these was the clusters most prevalent in adolescents.

From studies that evaluated clusters according to sex (n=12), twelve clusters were identified for boys and ten for girls. The most frequently cluster identified in boys was “High PA High SB” (n=8 studies) and “Low PA Low SB” (n=8 studies). Most prevalent cluster among boys were “High PA High SB”, “High PA Low SB”, and Low PA and Low SB. Girls’ most frequently clusters were “Low PA Low SB” (n=8 studies), “Low PA High SB” (n=6 studies), and ‘High PA Low SB” (n=6 studies). Otherwise, the most prevalent clusters were “Low PA Low SB”, “Low PA High SB” and “High PA High SB”. Only one study was realized in children and procedure cluster analysis according to sex, the most prevalent cluster in both sexes were characterized by “Low PA Low SB”.

Correlates and its association with clusters types

From the included studies a total of 31 correlates were investigated. The cluster correlates were sociodemographic factors[31–33,136,139]; adiposity

indicators[28,31,32,34,129,136–139]; health risk behaviors[128]; and others factors, such as work and sleeping hours[32,128,140]; meeting PA guidelines[140]; and correlates of behavior at the individual[128,136], interpersonal[136], and school level[136]. Table 5 presents all the correlates associated with cluster types.

The only study identified in children found null associations between school level, interpersonal and individual outcomes and cluster[136]. All information presented below, in subsequent paragraphs, refer to adolescents. Considering overweigh girls in the cluster “Low PA High/Low SB” presented negative[31] and positive[28] associations. Otherwise, at BMI outcome adolescents in cluster “High PA High SB” presented negative[138] and positive[137] associations.

Adolescents in “Low PA Low SB” clusters had higher odds of consuming alcohol[128], working[128] and lower odds of delinquency, wearing a seatbelt[128], sleeping ≥ 8 hours[128] and meeting PA guidelines in adolescence[140]. These results were found in studies with a low risk of bias. Boys in this cluster presented high odds to be overweight[31,34] or obesity[129], low self-eficacy[136] and differences between age[33]. Girls in this cluster were older[33,139], from North America[139], and are more likely to be obese[129].

Boys and girls in “High PA High SB” clusters, had higher BMI and were more likely to be obese in most of the tested associations[129,137], whereas those in the “High PA Low SB” clusters had lower BMI and waist circumference and were less likely to be overweight or obese[31,138].

Adolescents in "High PA" clusters had higher odds to work, sleeping ≥ 8 hours[128] and meeting PA guidelines in adolescence[140] and were less exposed to all health risk behaviors[128] and self-steem[128].

In the “Low SB” cluster, the results were similar, except for self-steem[128]. The associations found for "High PA" and “Low SB” were present in studies with low risk of bias.

In general, the correlates associated with clusters differed by sex. The similarities found, for the variables and the association direction, were: “High/Low PA Low SB cluster” vs age (differs); “High PA High SB cluster” vs obesity (positive); “High PA Low SB cluster” vs BMI and waist circumference (negative); “Low PA High SB cluster” vs obesity/overweight (positive); vs age and socioeconomic status/poverty (differs); “Low PA Low SB cluster” vs obesity (positive); vs age (differs); and “Low PA

High/Low SB cluster" vs overweight (positive); vs age and socioeconomic status/poverty (differs).

Table 4 – Description of the derived clusters and the prevalence of children and adolescents within each cluster. Results are presented as n(%).

		Cluster Types												
	Author (year)	**High PA**	**High/Low PA**	**High/Low PA Low SB**	**High PA High SB**	**High PA Low SB**	**High PA High/Low SB**	**Low PA**	**Low PA High SB**	**Low PA Low SB**	**Low PA High/Low SB**	**High SB**	**High/Low SB**	**Low SB**
Mixed-sex samples	Lazarou (2009)[b]	id										id		
	Nelson (2005)#[b]	1681 (14.1%) 1309 (10.9%) 935 (7.8%)			1119 (9.4%)					2897 (24.2%)		2494 (20.9%)		1522 (12.7%)
	Nelson (2006)#[b]	1681 (14.1%) 1309 (10.9%) 935 (7.8%)			1119 (9.4%)					2897 (24.2%)		2494 (20.9%)		1522 (12.7%)
	Ramos (2012)[b]					5042 (25.4%)			4404 (22.1%)	10889 (52.5%)				
	Wang (2012)[b]				122 (14.5%) 98 (11.6%)					107 (12.6%)	386 (45.6%)		134 (15.8%)	

continued

Table 4 – Continued

	Author (year)	High PA	High/Low PA	High/Low PA Low SB	High PA High SB	High PA Low SB	High PA High/Low SB	Low PA	Low PA High SB	Low PA Low SB	Low PA High/Low SB	High SB	High/Low SB	Low SB
		Cluster Types												
Boys	De Bourdeaudhuij (2013) [b]				82 (22.7%)	72 (19.9%)			100 (27.8%)	107 (29.6%)				
	Gorely (2007)[b]					75 (15.4%)					93 (19.2%) 97 (20%) 144 (30.1%) 75 (15.4%)			
	Huang (2015)[a]				78 (16.6%)	43 (9.1%)				280 (59.4%)		48 (10.2%)	22 (4.7%)	
	Kim (2016)[b]				1239 (20.3%)	2356 (38.6%)			470 (7.7%)	2044 (33.5%)				
	Marshall (2002)[b]				333 (40%)	383 (47%)				103 (13%)				
	Melkevik (2010)[b]	605 (24%) 630 (25%)							353 (14%) 50 (2%)	302 (12%)				
	O'Neill (2016)[a]				1924 (43.9 %) 807 (18.4%)				578 (13.2%) 989 (22.6%)					
	Patnode (2011)[b]					148 (42.1%)				116 (33%)	88 (24.9%)			
	Spengler (2015)[b]		53 (5.1%) 65 (6.3%) 50 (4.8%)	197 (19.1%)					50 (4.8%)	343 (33.3%)	126 (12.2%) 147 (14.3%)			
	Taverno Ross (2016)[c]				31 (14%)					156 (70.6%)		34 (15.4%)		
	Te velde (2007)[a]				1100 (17.6%)				436 (7.0%)		1494 (23.9%) 601 (9.6)			2624 (42.0%)
	Wang (2006)[b]				102 (35.8%)		75 (26.3%) 108 (37.9%)							

Table 4 – Continued

		Cluster Types												
	Author (year)	**High PA**	**High/Low PA**	**High/Low PA Low SB**	**High PA High SB**	**High PA Low SB**	**High PA High/Low SB**	**Low PA**	**Low PA High SB**	**Low PA Low SB**	**Low PA High/Low SB**	**High SB**	**High/Low SB**	**Low SB**
Girls	De Bourdeaudhuij (2013)[b]					85 (21%)			97 (24%)	119 (29.3%)		104 (25.7%)		
	Gorely (2007)[b]					144 (14.5%)					198 (25.2%) 206 (26.4%) 181 (23.1%) 86 (11%)			
	Huang (2015)[a]				54 (11.3%)	57 (11.9%)			138 (28.8%)	190 (39.6%)		41 (8.5%)		
	Kim (2016)[b]				1050 (17.6%)	1378 (23.1%)			1575 (26.4%)	1969 (33%)				
	Marshall (2002)[b]				243 (15%)	562 (36%)				765 (49%)				
	Melkevik (2010)[b]	303 (13%) 466 (20%)						256 (11%) 419 (18%)				256 (11%)		
	Patnode (2011)[b]						69 (18.7%)		175 (47.6%)		124 (33.7%)			
	Spengler (2015)[b]			54 (5.1%) 105 (10.0%)					65 (6.2%)	443 (42.1%) 124 (11.8%)	97 (9.2%) 164 (15.6%)			
	Taverno Ross (2016)[c]	35 (12.8%)								149 (54.4%)		90 (32.8%)		
	Te velde (2007)[a]				229 (3.6%)	1337 (21.3%)			1339 (21.3%)	2794 (44.5%)	584 (9.3%)			
	Wang (2006)[b]				276 (57.3%)					72 (15%)	134 (27.8%)			

PA: Physical activity. SB: Sedentary behavior. #Same cluster. Id: Impossible to identify. In each column, the darker the gray, the greater number of children and adolescents in each cluster type. N and prevalence should be interpreted according to n sample present in each study (line of each study). More than one prevalence included in a little square means that more than one cluster were identified with this characteristic. [a] involved children and adolescent. [b] involved adolescents and average adolescents' age. [c] involved children.

Table 5 – Summary of correlates examined and their associations with cluster types.

Cluster Types													
Correlates	**High PA**	**High/Low PA**	**High/Low PA Low SB**	**High PA High SB**	**High PA Low SB**	**High PA High/Low SB**	**Low PA**	**Low PA High SB**	**Low PA Low SB**	**Low PA High/Low SB**	**High SB**	**High/Low SB**	**Low SB**
Sociodemographic Factors													
Age		0 ♂[33] ≠ ♂[33]	0 ♂[33] ≠ ♂[33] 0 ♀[33] ≠ ♀[33]	0 ♂[32,139] 0 ♀[32] - ♀ older[139]	0 ♂[32,139] 0 ♀[32] - ♀ older[139]			0 ♂[33] ≠ ♂[33] 0 ♀[32,33] ≠ ♀[33]	0 ♂[32,33,139] ≠ ♂[33] 0 ♀[32] + ♀ older[33,139] ≠ ♀[33]	0 ♂[33] ≠ ♂[33] 0 ♀[33] ≠ ♀[33]	0 ♂[32] 0 ♀[32]	0 ♂[32]	
Race/Ethnicy	0 ♀[136]			0 ♂[136,139] 0 ♀[139]	0 ♂[31,139] 0 ♀[139]	0 ♀[31]		- ♀ white[31]	0 ♂[31,136,139] 0 ♀[136,139]	0 ♂[31] + ♀ white[31]	0 ♂[136] 0 ♀[136]		
Parental Education	0 ♀[136]			0 ♂[32,136] 0 ♀[32]	0 ♂[31,32] 0 ♀[32]	0 ♀[31]		0 ♀[31,32]	0 ♂[31,32,136] 0 ♀[32,136]	0 ♂[31] 0 ♀[31]	0 ♂[136] - ♂[32] 0 ♀[32,136]	0 ♂[32]	
Socio economic status/poverty	0 ♀[136]	0 ♂[33]	0 ♂[33] ≠ ♂[33] 0 ♀[33]	0 ♂[136]				0 ♂[33] ≠ ♂[33] 0 ♀[33] ≠ ♀[33]	0 ♂[33,136] 0 ♀[33,136] ≠ ♀[33]	0 ♂[33] ≠ ♂[33] 0 ♀[33] ≠ ♀[33]	0 ♂[136] 0 ♀[136]		
Live with 2 parents					0 ♂[31]	+ ♀[31]		- ♀[31]	0 ♂[31]	0 ♂[31] + ♀[31]			
Marital status				0 ♂[32] 0 ♀[32]	0 ♂[32] 0 ♀[32]			0 ♀[32]	0 ♂[32] 0 ♀[32]		0 ♂[32] 0 ♀[32]	0 ♂[32]	
Occupation				0 ♂[32] 0 ♀[32]	0 ♂[32] 0 ♀[32]			0 ♀[32]	0 ♂[32] 0 ♀[32]		0 ♂[32] 0 ♀[32]	0 ♂[32]	
Work	+[128]			0[128] +[128]					0[128] +[128]				0[128] +[128]
Nationality				0 ♂[139] - ♀ North America [139]	0 ♂[139] - ♀ North America[139]				0 ♂[139] + ♀ North America [139]				

Table 5 – Continued

Cluster Types													
Correlates	**High PA**	**High/Low PA**	**High/Low PA Low SB**	**High PA High SB**	**High PA Low SB**	**High PA High/Low SB**	**Low PA**	**Low PA High SB**	**Low PA Low SB**	**Low PA High/Low SB**	**High SB**	**High/Low SB**	**Low SB**
Sociodemographic Factors													
Grade					+ ♂ high 6th to 8th[31]	0 ♀[31]		0 ♀[31]	- ♂ less 6th to 8th[31]	- ♂ (less 6th to 8th)[31] 0 ♀[31]			
Academic grades	+[128]			0[128]					0[128]				0[128]
Free or reduced-price lunch					0 ♂[31]	0 ♀[31]		0 ♀[31]	0 ♂[31]	0 ♂[31] 0 ♀[31]			
Adiposity variables													
BMI	0 ♀[136]			0 ♂[136,139] 0 ♂ age 9[137] - ♂[138] + ♂ age 13[137] 0 ♀[139]	0 ♂[139] - ♂[138] 0 ♀[139] - ♀[138]			0 ♂[138] + ♂ age 9 and 13[137] 0 ♀[138]	0 ♂[136,138,139] 0 ♀[136,138,139]		0 ♂[136] 0 ♀[136,138]		
Waist circumference				- ♂[138]	- ♂[138] - ♀[138]			0 ♂[138] 0 ♀[138]	0 ♂[138] 0 ♀[138] - ♀[138]		0 ♀[138] + ♀[138]		
Weight status				0 ♂[32,136] 0 ♀[32]	0 ♂[31,32] 0 ♀[32]			0 ♀[32]	0 ♂[31,32,136] 0 ♀[32]	0 ♂[31]	0 ♂[32,136] 0 ♀[32]	0 ♂[32]	
Obesity				+ ♂[129] + ♀[129]				+ ♂[129] + ♀[129]	+ ♂[129] + ♀[129]				
Overweight	0 ♂[34] 0 ♀[34]			0 ♂[28] 0 ♀[28]	- ♂[31]	- ♀[31]	0 ♀[34]	+ ♂[28,34] + ♀[28,31]	+ ♂[31,34] 0 ♀[28]	+ ♂[28,31] - ♀[31] + ♀[28]	+ ♀[34]		
Overweight + Obesity	0 ♀[136]			0 ♂[136]					0 ♂[136] 0 ♀[136]		0 ♂[136] 0 ♀[136]		

Table 5 – Continued

Cluster Types													
Correlates	**High PA**	**High/Low PA**	**High/Low PA Low SB**	**High PA High SB**	**High PA Low SB**	**High PA High/Low SB**	**Low PA**	**Low PA High SB**	**Low PA Low SB**	**Low PA High/Low SB**	**High SB**	**High/Low SB**	**Low SB**
Health risk behaviors													
Delinquency	-[128]			0[128]					-[128]				-[128]
Smoke	-[128]			-[128]					0[128]				-[128]
Alcohol	-[128]			-[128]					+[128]				-[128]
Drugs	-[128]			0[128]					0[128]				-[128]
Wear seatbelt	-[128]			-[128]					-[128]				-[128]
Sexual intercourse	-[128]			-[128]					0[128]				-[128]
Truant	-[128]			-[128]					0[128]				-[128]
Others factors													
Sleeps ≥ 8 hours	+[128]			+[128]					-[128]				+[128]
Siblings and sports team participation				0 ♂[32] 0 ♀[32]	0 ♂[32] 0 ♀[32]			0 ♀[32]	0 ♂[32] 0 ♀[32]		0 ♂[32] 0 ♀[32]	0 ♂[32]	
Meeting PA guidelines in adolescence	+[140]			+[140]					-[140]				+[140]
Individual-level factors[1]	- self-steem[128] 0 ♀ self-eficacy[136]			- self-steem[128] + ♂ self-eficacy[136]					0 self-steem[128] - ♂ self-eficacy[136] 0 ♀ self-eficacy[136]		- ♂ self-eficacy[136] 0 ♀ self-eficacy[136]		0 self-steem[128]
Interpersonal-level factors[2]	0 ♀[136]			0 ♂[136]					0 ♂[136] 0 ♀[136]		0 ♂[136] 0 ♀[136]		
School-level factors[3]	0 ♀[136]			0 ♂[136]					0 ♂[136] 0 ♀[136]		0 ♂[136] 0 ♀[136]		

PA: physical activity. SB: sedentary behavior. ♂ indicates male only. ♀ indicates female only. + indicates positive association (higher average values or greater exposure). − indicates negative association (lower average values or lower exposure). 0 indicates no association. ≠ indicate difference. *There was little variation in the relationship between PA patterns and self-esteem by gender; [1]Self-efficacy, Enjoyment, Perceived PA barriers, Perceived parent support for PA; [2]Parent support for PA, Sports/physically active lessons in past year, Screen devices in bedroom, Home PA equipment, Neighborhood safety; [3]School index; ≠differences in the comparison between clusters, without the possibility of identifying the direction of the association.

Discussion

This systematic review sought to provide comprehensive and up to date evidence on the clustering of SB and PA according to sex (identified using exploratory data-based methods) and their potential correlates. Nine, twelve and ten cluster types were identified for whole samples, boys, and girls, respectively. Boys were mostly allocated to the “High PA/High SB” clusters and girls to the “Low PA Low SB” clusters. Moreover, boys were more likely to accumulate time watching television time, using computer, and playing videogame and girls dedicate more time to paid work or housework[31,32,123,139,141]. Cluster types were associated with more than thirty different health-related correlates.

The risk of bias assessment identified methodological weaknesses in the studies, especially for the domains of sample selection and for withdrawal and dropouts. Few studies included samples representative of the target population, or were impacted by participant dropouts. Further, the number of participants who completed the study was often poorly reported across the studies. Having information on study response and dropout rates, as well as their reasons and the participant characteristics, allows a better interpretation of the results and the potential impact of selection bias. Future studies on clustering should therefore report the process of selection of participants, withdrawals and dropouts in a more comprehensive way.

Several cluster types with distinct combinations were identified for children and adolescents, and more than 70% of clusters included one negative behavior, corroborating with previous literature[2,3,41,48]. In our review, girls were in clusters characterized by “Low PA High/Low SB” and “Low PA/Low SB”, while cluster types labelled “High PA Low SB”, followed by “High PA Low SB”, “High PA High SB” and “High PA” comprised more boys. Similar results from previous reviews showed that SB was inversely related to PA[66,145] and high levels of PA coexisted with high and low levels of SB[2,41,48].

The predominance of unhealthy profiles in youths have been constantly reported in the literature[29,41,48] and, girls report lower levels of PA compared to boys[28,29]. These differences can be explained by the way in which adolescents spend their time; boys spend more time being physically active PA and girls prefer to spend their time in socializing activities and in domestic tasks[146]. Moreover, motivational aspects such as the unwillingness[147] or discomfort from sweat and dirt[148] caused by

PA contribute to girls being less physically active. Still, our results also demonstrated that girls were more often allocated to clusters characterized by large amounts of time in SB related to socializing components[31,32,123,139,141]. In contrast, boys were more likely to be in clusters characterized by large amounts of time using the computer and playing videogames,[31–34,123,139,141] consistent with literature[123,146,149]. Studies have shown that different SB components have different effects on youths physical and mental health[150,151]. For example, TV viewing was associated with worse physical health, quality of life and emotional problems, whereas interactive screen time (e.g. video game, social media and internet) showed negative psychological effects[150,151]. These results suggest that policymakers, professionals, and parents should consider the type of youths' screen time rather than only use-time. Also, is important to considered questionnaires to evaluated PA and SB once they are useful in collect data about variables context, whereas accelerometers provide more accurate info on time and intensity in each behavior.

In relation to the correlates of clusters, most studies included in this review evaluated adiposity indicators[28,31,32,34,129,136–139] followed by sociodemographic factors[31–33,136,139]. Few studies examined health risk behaviors[128]; sleeping hours[32,128,140], and individual[128,136], interpersonal[136], and school level[136] correlates. Few associations were observed and most positive associations were found for at Health risk Behavior's correlates provided from studies with low risk of bias. Briefly, clusters characterized by Low PA/Low SB presented lower probability to delinquency, wear seatbelt[128], sleeps ≥ 8 hours[128] and low self-eficacy[136], and cluster characterized by "High PA" presented less exposure for health risk behaviors[128] and self-steem[128]. However, further evidence is needed to clarify these relationships. Boys[31,34,129,137] and girls[129,137] in "Low PA Low SB" and "High PA High SB" clusters were more likely to have a higher BMI, or be overweight or obese. In contrast, better adiposity profiles were found when boys or girls were allocated to the "High PA Low SB" clusters[31,138]. Physical inactivity and high time spent in SB are potential risks factors for increased adiposity[2,41,152] and their coexistence is linked to cumulative harmful effects to health[41,153]. These findings emphasize the needed for the development of public policies strategies to promote PA and reduce SB simultaneously.

This was the first study to systematically review the clustering of PA and SB, and their associations with a comprehensive range of health correlates, in mixed-sex samples, and in boys and girls, separately. The search strategies were developed

based on suggestion of experts on the theme which enabled the identification of many potential studies. This study also was able to identify and describe the behavior variables used to determine clusters. All these points advance the evidence base on clustering because previous reviews on cluster patterns were either not systematic[41], employed limited search strategies (i.e., limited combination of descriptors for PA and SB)[2,29,41] or limited the publications reviewed up to 2018[2]. However, caution is needed when generalizing results: 1) the cluster type identified in this review were based on the authors' interpretation based on descriptions reported by the studies' authors. However, during the data extraction, a sequence of criteria and agreement between researchers was used to ensure that parsimonious information was obtained; 2) the wide range of PA and SB outcomes/variables made the synthesis of results challenging, however, the agreement process during the data extraction provided suitable information of the clusters types characterization; 3) we synthesized the direction of association and not the magnitude, which is important to understand for health-related variables.

The findings of this review have implications for future research examining the clustering of PA and SB. First, we emphasize that more studies examining clustering of PA and SB using data-driven exploratory methods should be conducted in children and adolescent populations from lower income countries, as none were found in this review and cluster types have been shown to differ according to socioeconomics variables[41,58]. Second, more studies that employ and compare different exploratory data-based methods using the same data are needed to understand how different methods may yield different cluster patterns. Third, few studies provide sufficient detail regarding the analytic decisions taken to determine the optimal number of clusters and the reliability of the resulting cluster solution is rarely reported. Fourth, longitudinal studies are needed to identify how cluster patterns vary over time and to evaluate the effect of interventions on changing both PA and SB. Many large multi-component interventions have been implemented to change multiple behaviors simultaneously; however most studies are still using traditional methods approach of reporting changes in individual risk behaviors[154]. Fifth, studies that assess PA and SB using both device-based and self-report methods are needed to provide a richer understanding of behavior patterns and the contexts in which they occur. Further to this, analysis is needed to determine if cluster characterization (i.e., high/low PA, or high/low SB) varies according to whether behaviors are assessed using objective or questionnaire

measurement tools. Finally, future cross-sectional and longitudinal studies examining the clustering of PA and SB should consider incorporating a wider range of modifiable correlates to better inform intervention strategies for behavior change.

We highlight that meta-analysis was not performed due to heterogeneity in measurements, analysis used and clusters types observed between studies. In order to conduct a meta-analysis, the cluster indicators and algorithms used in clusters procedures would need to be standardized.

Conclusion

In summary, the majority of cluster types had at least one unhealthy behavior in PA or SB indicators. Clusters differ in SB components in the profiles between boys and girls and high proportion of boys were allocated in cluster characterized by high PA. These demonstrate that different preventive approaches, tailored to boys and girls, need to be considered to improve children and adolescent lifestyles. Predominantly, clusters were associated with sociodemographic and adiposity correlates. Therefore, a better understanding of the modifiable correlates associated with PA and SB cluster types is needed to plan effective policies and interventions to improve youth lifestyles and subsequent health and wellbeing, and to develop guidelines considering simultaneously between behaviors once they together contribute to unhealthier health correlates.

2.3 CLUSTERS OF DIET AND 24-HOUR MOVIMENT BEHAVIORS AND THEIR RELATIONSHIP WITH HEALTH INDICATORS AMONG YOUTH: A SYSTEMATIC REVIEW

This article are under review in the International Journal BMC Public Health.

Mello GT, Minatto G, Costa RM, Leech RM, Cao Y, Lee R, Silva KS. Clustering od 24-hour movement behavior and diet and their relationship with health indicators among youth: a systematic review.

Clusters of 24-hour movement behavior and diet and their relationship with health indicators among youth: a systematic review

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Abstract

Movement-related behaviors (physical activity [PA], sedentary behavior [SB], and sleep) and diet interact with each other and play important roles in health indicators in youth. This systematic review aimed to investigate how PA, SB, sleep, and diet cluster in youth by biological sex; and to examine which cluster are associated with health indicators. This study was registered in PROSPERO (number: CRD42018094826). Five electronic databases were assessed. Eligibility criteria allowed studies that included youth (aged 19 years and younger), and only the four behaviors combined {PA, SB, sleep, and diet (ultra-processed foods [UPF]; fruits and vegetables [FV])} analyzed by applying data-based cluster procedures. Out of 12,719 articles screened; 23 were included. Of these, four investigated children, and ten identified clusters by biological sex. Sixty-six mixed cluster were identified including, 34 in mixed-sex samples, 10 in boys and 11 in girls. The most frequent clusters in mixed-sex samples were “High SB UPF Low Sleep”, “Low PA High SB Satisfactory Sleep”, and “High PA”. The main difference in profiles according to sex was that girls’ clusters were characterized by high sleep duration, whereas boys’ clusters by high PA. There were a few associations found between cluster types and health indicators, highlighting that youth assigned to cluster types with low PA exhibited higher adiposity. In conclusion, the youth presented a range of clusters of behaviors, typically exhibiting at least one

unhealthy behavior. Similar patterns were observed in both sexes with the biggest difference in time of sleep for girls and PA for boys. These findings underscore the importance of intervention strategies targeting multiple behaviors simultaneously to enhance health risk profiles and indicators in children and adolescents.

Keywords: Adolescent health; Child Health; Clustering; Diet, Food, and Nutrition; Exercise; Sleep.

Introduction

The 24-hour movement behaviors (i.e., physical activity - PA, sedentary behavior - SB, and sleep) and diet are referred to as energy balance-related behaviors (EBRBs) and mutually moderate each other's health impacts[6,155]. For instance, the positive effects of engaging in PA or consuming fruit and vegetables might be compromised if individuals engage in prolonged periods of SB, exhibit short sleep duration, or consume ultra-processed foods. These four behaviors interact and play an important role in indicators of physical and mental health[10–12,37,38,56] and wellbeing[2,3,11] in children and adolescents. Youth engage in multiple risk behaviors simultaneously[3,23,156], which increases the risk of chronic diseases and all-cause mortality over and above the addictive effects of individual behaviors[9]. Thus, understanding how these interactions occur or how these behaviors cluster in the pediatric population may be promising for guiding future behavior change strategies that support healthy development[57]. Initiatives to support healthy lifestyles for children and adolescents are crucial once risk behaviors emerge during youth and could interrupt the trajectory toward poor adult health[47].

Systematic reviews have identified a range of clusters types, usually presenting at least one unhealthy behavior in children and adolescents[2,3,11,29,156]. The profiles most frequently identified among youth were “high SB and consumption of ultra-processed foods”, “high PA”, “low PA and SB”, “low PA high/low SB”, and “low PA high SB”[3,29,156]. Studies also demonstrated that the intrapersonal characteristic, biological sex, may influence the adoption of behaviors[3,24,25]. For example, there are differences between boys and girls in the adoption of specific behaviors that may be explained by biological factors, such as hormonal and maturation differences, psychosocial factors, also by expectations, and social norms regarding behavior[157,158]. Indeed, boys have

presented in clusters characterized by high PA[28–30,156] and tend to be in clusters with high amounts of screen time (e.g., watching television, using computers, and playing video games), whereas girls spend more time in social activities such as sitting and talking with their friends[31–34,123,139,141,149,156] as well as had better diet quality (e.g., higher fruit and vegetables and lower ultra-processed foods) when compared to boys[35,36]. No difference has been observed in sleep time and clusters types between boys and girls[37–39].

Profiles of clusters have been associated with different health indicators[29,156]. For example, children exhibiting unhealthy patterns—defined by at least two behaviors among poor diet quality, PA, high SB, and inadequate sleep—were more likely to have higher adiposity compared to their peers following healthy or mixed patterns[29]. In addition, children and adolescents in high PA and high SB clusters had higher body mass index and obesity[156]. Also, adolescents in clusters with more screen time, shorter sleep duration, and higher consumption of ultra-processed foods had higher insulin resistance, and girls in clusters with high screen time and an unhealthy lifestyle were at increased risk for being overweight[43]. In contrast, youths in clusters with more time spent in moderate and vigorous PA had lower insulin resistance, total high-density lipoprotein, and low-density lipoprotein cholesterol[44,45].

Exploring how 24-hour movement behaviors and diet cluster together and their association with diverse health indicators holds the potential to offer insights into the etiology of mental, physical, and overall health and wellbeing in children and adolescents[50]. This study advances previous investigations[2,3,29,159] by conducting a systematic review designed to explore the clustering profiles of PA, SB, sleep, and diet in children and adolescents. Additionally, this study aims to explore these clusters according to biological sex and to examine which cluster types are associated with a variety of mental and physical health indicators. The results of this research have the capacity to underscore the importance of promoting PA, SB, sleep, and diet behaviors among youths[51], contributing to the development of interventions targeting more than one of these behaviors at the same time[40].

Methods

This systematic review was registered in PROSPERO (registration number: CRD42018094826) and forms part of a large project on a global panorama of research

examining the clustering of behaviors in children and adolescents. This article synthesized the evidence on clusters of PA, SB, sleep, and diet in youth and was reported considering the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines[133,134] and the extension Synthesis Without Meta-analysis (SWiM)[135] (see supplementary material table S1 and S2). The research question was formulated using the PI(E)COS framework, encompassing the Population (children and adolescents aged 19 years or younger), Intervention/Exposure (PA, SB, sleep and diet cluster types), Comparison/Control (not applicable), Outcome (physical and mental health outcomes), and Study design (any). The PI(E)COS question focused on identifying the types of behavioral clusters related to PA, SB, sleep, and diet, as well as exploring their relationships with physical and mental health outcomes in children and adolescents.

Eligibility criteria

The criteria used to determine eligibility of each article for inclusion were 1. included children and/or adolescents aged 19 years and younger or mean age between this range; 2. had undertaken a person-oriented statistical approach to identify clustering behaviors; 3. included only the combination of the four behaviors (PA, SB, sleep, and diet) in the analyzes; and 4. were written in English, Portuguese, or Spanish language. Original articles provided by any designs were included. Studies exclusively targeting clinical populations (e.g., disabilities, metabolic and/or cardiovascular diseases, population reached in hospitals) or derived clusters that included other behaviors or variables (e.g., tobacco use, unprotected sex, body mass index) were excluded.

Search strategies and screening

This study involved a wide behavior search strategy with no restrictions of publication year, including studies published in English, Portuguese and Spanish. Papers published up to and including May 2018 were identified through five electronic databases: PubMed, Scopus, Web of Science, LILACS, and PsycINFO. This search was then updated at the begin of April 2023. The search was independently conducted by two authors (GTM/RMC). When the articles matched, the metadata were exported

and inserted into the Rayyan tool, where duplicates were removed before the screening process. The search encompassed sets of descriptors associated with behaviors (e.g., diet), person-oriented statistical approaches (e.g., 'cluster analysis'), and specific populations (e.g., adolescents*) (see supplementary material Table S3). Terms within each search string were separated by the OR operator considering particularities from each database and Boolean operators and truncation symbols ($, * or ""). The search terms were based on pre-existing systematic reviews and then expanded with a Medical Subject Headings (MeSH) Browser search (https://meshb.nlm.nih.gov/). Reference lists of included studies and previous reviews were examined to identify any additional relevant articles.

The searches and screening were conducted to encompass the presence of at least two behaviors of PA, SB, and/or diet. Titles and abstracts were screened using the Rayyan tool, followed by independent full-text assessments using PDF reader software by two authors (GTM/RMC). During the thorough reading stage, articles were selected if they included only PA, SB, diet, and sleep behaviors for the cluster analysis, per the inclusion criteria. Discrepancies were resolved by GM.

Quality assessment

Risk of bias and methodological quality of included studies was assessed using a 17-point adapted version of the Quality Assessment Tool for Quantitative Studies of Effective Public Health Practice Project (EPHPP)[63]. This tool considers the following four methodological domains:

1) Selection bias, measured by the question “Are the individuals selected to participate in the study likely to be representative of the target population?”. Response possibilities were ≥80% = *strong* or 1; 79 - 60% = *moderate* or 0; ≤60% = *weak* or -1;

2) Study design, measured by the questions “Is there a description of the representativeness of the sample?”, with answer options: yes = 1; no = 0; “Was the sampling method described?”, with answer options: yes = 1; no = 0; “Was the method appropriate?”, with answer options: random = 1; not described = 0; convenience = -1. The *strong* classification was assigned for 1 in all three items, *moderate* for combinations: 1-1-0, 1-0-1, 1-0-0, and 0-0-1, and *weak* for all other combinations.

3) Information about instruments to evaluate PA, SB, sleep, and diet (Is there a prior validation report of the tool? yes = 1; no = 0); and information that would enable

reproducing PA, SB, sleep, and diet assessment (Is there information that makes it possible to replicate the tool? yes = 1; no = 0). Studies using accelerometer to measure PA and/or SB and/or sleep were assigned a score of "1", that is, it was considered that there was a previous validation report of the instrument (*strong* for 1 in both outcome items, and *weak* for all other combinations); and

4) Flow of people throughout the study (Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group? yes = 1; no = 0) and percentage of participants completing the study (Indicate the percentage of participants completing the study? ≥80% = 1 or strong; 60–79% = 0 or moderate; ≤59%= -1 or weak). The classification *strong* was applied for 1 in both items or 0 and 1, *moderate* for combinations 1 and 0 or 0 and 0, and *weak* for all other combinations.

The risk of bias classification (low [strong], moderate [moderate] and high [weak]) for each domain was performed based on study distribution (see Appendix D Table S4). Two independent reviewers (GTM and GM) assessed the quality of all studies, and a third reviewer (RMC) was consulted for the discrepancies.

Data extraction and synthesis

Data were extracted and input it into a tailored spreadsheet by the same peers of the aforementioned full-text process. Data extracted from each study (Table 6) included publication year, study name, sample country; design; sample size and age, data driven analytic method, and number of clusters identified. Also, information of the instruments used to measure PA, SB, sleep, and diet behaviors domain and components (e.g., leisure/habitual PA, time spent watching TV/computer use), variables included in cluster procedures and, cluster types according to mixed-sex samples, boys and girls were extracted. Also, association between clusters types and physical and mental health indicators were extracted as positive (+), negative (-), and no association (0).

Instruments used to measure PA, SB, sleep, and diet were classified as (1) Defined (validated instruments), (2) Undefined (reported question and/or response option and instrument reference), (3) Undefined-Reproducible (reported question and response options and not mention the reference), (4) Objective measurement (e.g., accelerometer), (see Appendix D Table S5 and Table S6).

Cluster sex characteristics were extracted as mixed-sex when clusters were identified as total samples considering boys and girls together, and according to biological sex when studies identified clusters of boys and girls separately. The study authors' descriptions of the cluster types were used for the clusters data extraction. For example, if authors characterized a cluster with low time watching TV, low PA levels, and high sleep time, the cluster type was classified as "Low PA SB and High sleep". When authors did not describe the cluster in the article text, quantitative data present in figures and tables were used to identify the cluster types.

Sleep was classified as High (>13 hours – 3-4 years old; >11 hours – 5-13 years old; >10 hours – 14-17 years old); Sufficient (10-13 hours – 3-4 years old; 9-11 hours – 5-13 years old; 8-10 hours – 14-17 years old); and Low (<10 hours – 3-4 years old; <9 hours - 5-13 years old; <8 hours – 14-17 years old)[49,160]. Diet characteristics were named as ultra-processed foods (UPF) (i.e., snacks, sweetened beverages, excessive salty foods, candies, and fried meals), and fruits and vegetables (FV) (i.e., fruits, vegetables, fiber consumption, green salads). Variables that did not fit in UPF and FV parameters were defined as "Specific Diet" (e.g., milk and meat consumption). For instance, a cluster described as low consumption of snacks and soft drinks, high consumption of fruits and vegetables, and high time spent in PA and SB was labeled as "High PA SB FV and Low UPF".

Results

Studies using the same sample data were considered once, using the most recent publication. These cases can be observed in Table 1. The authors of one study[161] did not respond to an email request to clarify the cluster results of their study, so that study was not included in the analysis of cluster characteristics and associations.

Studies description

A total of 12,719 articles were identified, of which 23 were included in this review following the exclusion of duplicates and through the screening process (Figure 1). The majority of the studies were conducted in high-income European countries (70%)[24,39,43,44,46,74,82,106,108,162,163]. Two articles included data from an upper-middle

country (Brazil)[24,164] and all other studies were from high-income countries. The study sample sizes varied from 235[46] to 5759[37] participants, and most studies investigated adolescents, whereas only four investigated children[39,42,162,165]. The analysis mostly used to identify clusters was k-means (n = 9), followed by principal components analysis (PCA) (n = 7), latent class analysis (LCA) (n = 2), and two-step cluster analysis (n = 2). Ten studies identified clusters according to biological sex. The number of clusters identified ranged from two[43,106] to ten[24] in studies that analyzed mixed-sex samples; from two[46] to five[105] in boys, and from one[46] to five[88,105] in girls (Table 6).

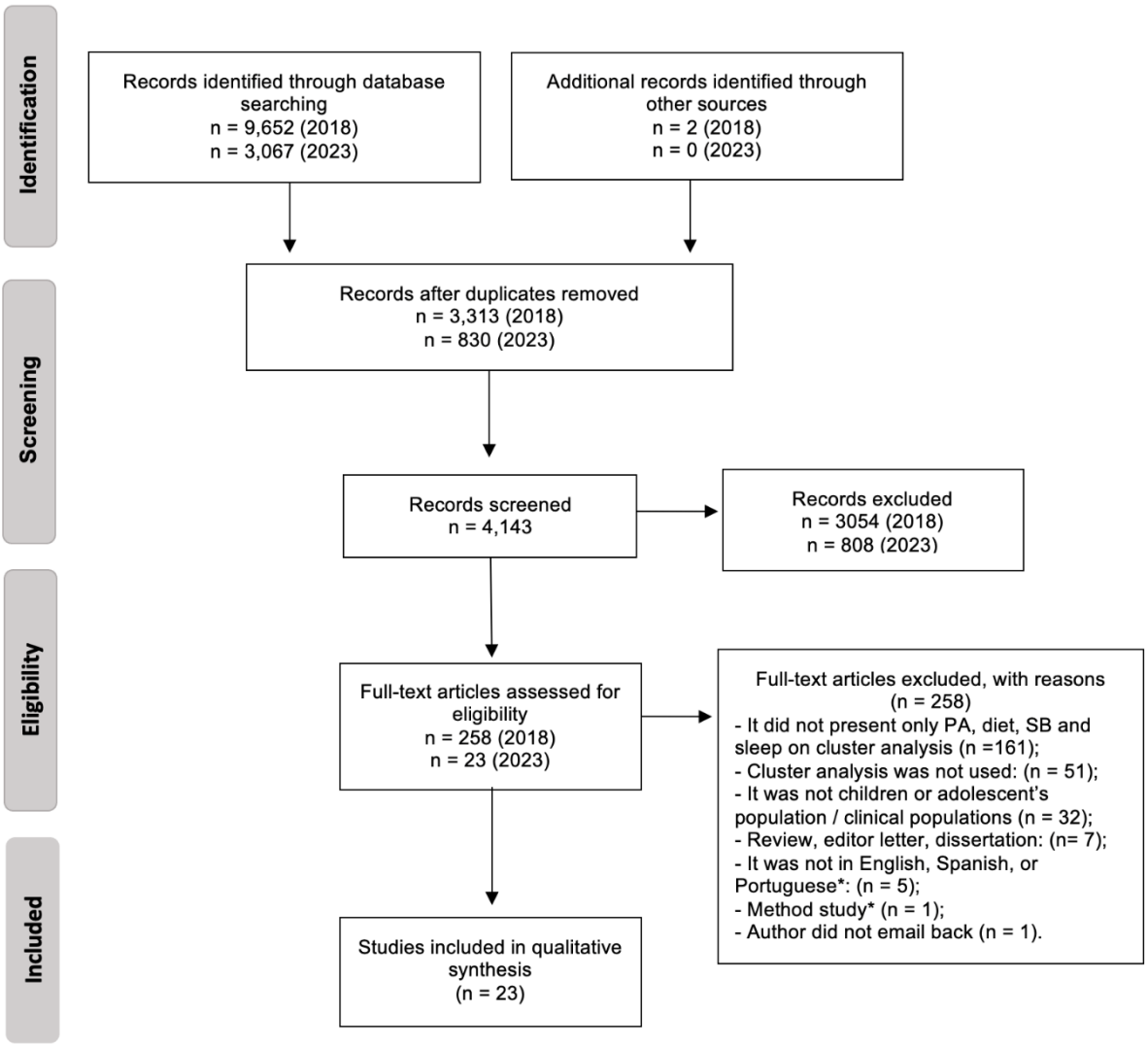

Figure 8 – Flowchart of study inclusion for the review.

PA: physical activity; SB: sedentary behavior.

Note: * Polach idiom; Explained how to use cluster analysis – did not present results.

Risk of bias assssment is presented in Figure 9 and in Appendix D Table S4. The percentage of disagreement among the risk of bias evaluators was 18.9% (kappa = -0.15; 1.0), ranging from 4.3% to 43.5%. Only one study[43] was classified with a low risk of bias for all evaluated criteria and three studies[39,105,164] showed moderate and low risk. The other studies showed a high risk of bias in at least one evaluated criterion and one study[42] presented a high risk of bias for all evaluated criteria (see Appendix D Table S4). Six[24,38,42,80,165,166] of the 23 included studies failed to achieve at least 60% of the eligible response (response rate – selection bias) and 10[24,37,38,42,82,106,161,162,165–167] had ≤59% of participants who completed the study (participation rate – losses and withdrawals). The risk of bias for the study design was mostly low[43,46,82,88,105,106,161–164,167] and moderate[37,39,44,45,74,108]. Almost all studies presented information that would allow researchers to replicate the applied tool; however, a high risk of bias was found for the assessment of sedentary behavior[37,38,42,44,74,161–163,167] and sleep[42,44–46,82,88,108,161–163,167].

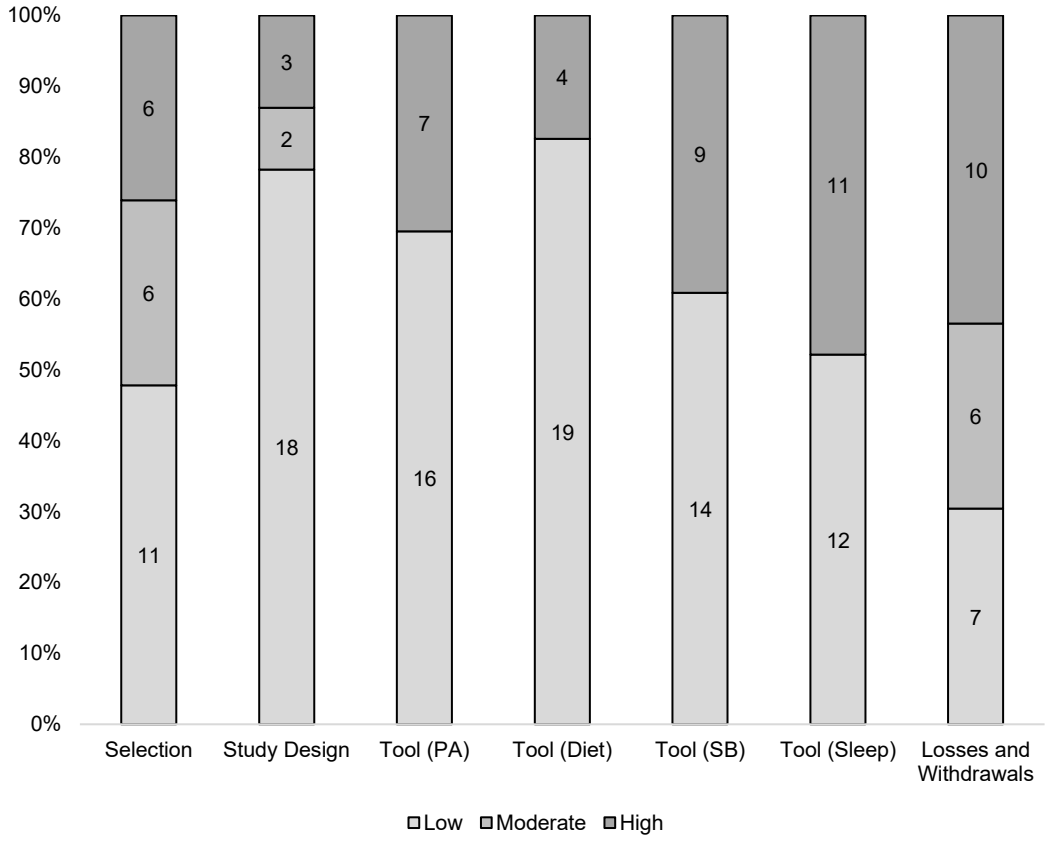

Figure 9 – Assessment of the risk of bias of studies.

PA: physical activity. SB: sedentary behavior. Low: low risk of bias. Moderate: moderate risk of bias. High: high risk of bias.

Table 6 – Characteristics of studies included in the systematic review (n = 23).

Author (publication year)	Study name	Sample Country	Study Design	Sample n (% of girls)	Age (years; range or mean)	Data driven analytic method	Nº of clusters
Androutsos (2014)[44]	Healthy Growth Study	Greece	CS	2656 (50.1)	9-13	PCA	5
Collese (2018)[24] #	HELENA BRACAH	European study[d] Brazil	CS CS	1252 (52.7) 682 (54.2)	12.5–17.5 14.0-17.5	K-means*	10
Descarpentrie (2021)[167] §	EDEN	France	Longitudinal	978 (46.9)	5	PCA	Boys 3 / Girls 3
Descarpentrie (2022)[46]	ENFAMS	France	CS	235 (48.5)	6-12	PCA	Boys 2 / Girls 1
Descarpentrie (2023)[162] §	EDEN	France	Longitudinal	876 (47.6)	5	PCA	Boys 3 / Girls 3
D' Souza (2021)[166] £	HAPPY	Australia	Longitudinal (CS analysis)	432 (43.5)	5.4-9.1 (7.6±0.7)	K-means*, LPA, PCA	K-means* 3, LPA 3, PCA 4
D' Souza (2022)[165] £	HAPPY	Australia	Longitudinal (CS analysis)	432 (43.5)	5.4-9.1 (7.6±0.7)	K-means*, LPA, PCA	K-means* 3, LPA 3, PCA 4
Dumuid (2017)[38]	ISCOLE	Australia	CS	284 (53.9)	9-11	K-means*	4
Dumuid (2017)[37]	ISCOLE	Intercontinental study[a]	CS	5759 (55.0)	9-11	K-means*	Boys 4 / Girls 4
Dumuid (2016)[105]	ISCOLE	Intercontinental study[a]	CS	5710 (NR)	9-11	K-means*	Boys 5 / Girls 5
Fernández-Alvira (2013)[74]	ENERGY-project	European study[b]	CS	5284 (54.0)	10-12	K-means*	Boys 4 / Girls 4
Ferrar and Golley (2015)[88]	NCNPAS	Australia	CS	1853 (49.8)	9-16	Two-steps	Boys 4 /Girls 5
Knebel (2022)[164]	*Movimente*	Brazil	CRCT (CS analysis)	750 (52.8%)	10-16 (13.1±1.0)	Two-steps	3
Magee (2013)[42]	LSAC	Australia	Longitudinal (CS analysis)	1833 (48.4)	6-9	LCA	6
Miguel-Berges (2017)[39]	ToyBox	European study[c]	RCT (CS analysis)	5387 (49.0)	3.5-5.5	K-means*	Boys 3 / Girls 4
Moraes (2016)[80] #	HELENA BRACAH	HELENA European study[d] BRACAH Brazil	CS CS	1252 (52.7) 682 (54.2)	12.5–17.5 14 to 17.5	K-means*	5
Moschonis (2013)[45] &	Healthy Growth Study	Greece	CS	2043 (50.2)	9-13	PCA	5
Moschonis (2014)[108] &	Healthy Growth Study	Greece	CS	2073 (50.2)	9-13	PCA	Boys 3 / Girls 3
Nuutinen (2017)[43]	HBSC	Finland	CS	13 years: 2152 15 years: 2110	13 and 15	K-means	2
Pereira (2015)[106]	ISCOLE	Portugal	CS	686 (55.5)	9.5-10.5	LCA	2
Pérez-Rodrigo (2015)[82]	ANIBES Study	Spain	CS	415 (37.8)	9-17	K-means*	Boys 3 / Girls 4

Table 6 – Continued

Author (publication year)	Study name	Sample Country	Study Design	Sample n (% of girls)	Age (years; range or mean)	Data driven analytic method	Nº of clusters
Saldanha-Gomes (2020)[161]	EDEN	France	Longitudinal	2 years – 1436 (47.8%) / 5 years - 1195 (47%)	2 and 5	LCA	2 years (Boys 2 / Girls 2). 5 years (Boys 2 / Girls 4).
Wiersma (2022)[163]	GECKO	Netherlands	Longitudinal	1792	3-11	PCA	3

£ # § &: clusters identified in same sample. [a] Australia, Brazil, Canada, China, Colombia, England, Finland, India, Kenya, Portugal, South Africa, and USA. [b] Belgium, Greece, Hungary, Netherlands, Norway, Slovenia, and Spain. [c] Belgium, Bulgaria, Germany, Greece, Poland, and Spain. [d] Austria, Belgium, France, Greece, Germany, Hungary, Italy, Spain, and Sweden. NR: not reported; *: With Wald's method; LSAC: Longitudinal Study of Australian Children; BRACAH: Brazilian Cardiovascular Adolescent Health; EDEN: EDEN mother-child cohort study; ENERGY: European Energy balance Research to prevent excessive weight Gain among Youth; ENFAMS: *Enfants et familles sans logement*; HAPPY: Healthy Active Preschool and Primary Years study; HBSC: Health Behavior in School-aged Children; HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; *Movimente*: Promotion of healthy lifestyles in adolescents and their relation to school performance - *Movimente* Study; NCNPAS: National Children's Nutrition and Physical Activity Survey; YRBSS: Youth Risk Behavior Surveillance System. GECKO: Groningen Expert Center for Kids with Obesity; LCA: Latent class analysis; PCA: Principal component analysis. RCT: randomized controlled trial; CRCT: Cluster-randomized controlled trial; CS: Cross-sectional.

Data synthesis

Instruments and Clusters Outcomes

The most frequent instruments used to measure PA, SB, sleep, and diet were questionnaires with validation process (see Appendix D Table S5). Diet also included three studies evaluated by a face-to-face 24 hour dietary recall collected over two consecutive week days and one weekend day[44,45,82,108]. Ten studies evaluated youth diet using food frequency questionnaires[24,37–39,46,105,106,162,163,165].

A wide range of variables were included in data-driven cluster procedures (see Appendix D Table S6). Most frequent PA outcomes involved minutes per day in moderate and vigorous PA[106,108,165,166], and moderate[37,38,82,105], and vigorous[37,38,82,105] PA only. Most studies included screen time defined by hours per day spent on television, computer and videogame[24,37,38,44–46,106,108,162,167]. Sleep outcomes mainly involved self-reported hours of sleep duration per day[24,39,42–44,46,74,82,108,162,164], and only one study assessed sleep quality and discrepancy (time sleeping on weekend vs. week nights)[43], and regular bedtime and wake-up time[161]. The most frequent outcomes of diet used were intakes of fruit and vegetables measured separately[44–46,88,108,162,165–167] and sweet/sugary beverages[24,39,42,44–46,74,80,106,108,162,167]. Five studies also used PCA[37,38,105,164] and factor analysis[82] to determine dietary patterns based on 5 to 38 different food groups. Outcomes of eating habits included breakfast and meal frequency[44,45,108].

Clusters Types

Information about the types of cluster identified from this review are presented in Figure 10 and in Appendix D Table S7. Sixty-six mixed cluster types, characterized by both healthy and unhealthy behaviors were identified. More than two thirds of the clusters were identified by one study (n = 53). Thirty-four clusters were identified in mixed-sex samples only and the most frequent clusters were “High SB UPF Low Sleep” (n=4), “Low PA High SB Satisfactory Sleep” (n=3), and “High PA” (n=3). Ten clusters’ types were identified in boys and eleven in girls and each profile were identified by one study. The biggest difference found was that most of the girls’ cluster types were

characterized by high sleep time, whereas for boys, clusters tended to be characterized by high PA.

Indicators associated with cluster types

Of the 23 studies included in this review, 16 examined the relationship between cluster types and health indicators. Adiposity indicators were the most investigated (n=13 studies)[39,42,43,82,88,105,106,108,161–163,165]. Other indicators were investigated to a lesser extent: systolic and diastolic blood pressure[80], insulin resistance[44], quality of life[37,165], cholesterol and triglycerides[45], and mental health (depression, hyperactivity/inattention, emotional and relationship problems, phobia, anxiety)[46,162]. In general, null associations were found between cluster types and all health indicators (see Supplementary Material Table S8). However, both positive and negative associations were observed, as shown in Table 2 and below.

Adiposity indicators - Adolescents allocated to clusters “Low PA High SB Satisfactory Sleep” and “High UPF Satisfactory Sleep” had a higher odds of obesity compared with their peers in the healthiest cluster (“High PA FV Sleep Low SB UPF”)[42]. In addition, adolescents allocated in the cluster “Low SB High FV Sleep” had lower probability to be overweight at 10-11 years[163]. Positive associations with BMI z-score and waist circumference were found among young people for the "High SB UPF Low Sleep" cluster[165]. Girls in the “Low PA FV Sleep High SB UPF” cluster had higher odds of being overweight/obese compared to girls with “High PA FV Low SB UPF Satisfactory Sleep”[43].

Other studies found negative associations (Table 2); youths in clusters characterized by “Specific diet”[108], “High FV”[108], “Low PA High SB Sleep”[165], “Low SB High FV Sleep”[163], and **“**High PA”[108] had lower body mass index[108,163,165], fat mass[108], the sum of skinfold thicknesses[108], waist circumference[108], and trunk fat[108]. A lower frequency of overweight/obesity was found in girls and boys in the “High PA SB Satisfactory Sleep” cluster[88]. One study showed significant differences in weight status and adiposity for both boys’ and girls’ clusters[105], while null associations with overweight/obesity were found[39,82,106].

Metabolic risk factors - Adolescents in “High SB UPF Low sleep” cluster had higher insulin resistance and in “High PA” cluster had lower insulin resistance[44]. Boys in the “Low PA FV Sleep” cluster had higher systolic blood pressure, and girls in “High

UPF Low FV" and "Low SB UPF High FV Sleep" profiles had higher and lower diastolic blood pressure, respectively, compared with their peers in "High SB UPF" cluster[80]. In terms of cholesterol indicators, adolescents in "High SB UPF Low Sleep" cluster had lower HDL cholesterol, and in "High PA" cluster had lower total, HDL and LDL cholesterol[45].

Quality of life and Social-emotional indicators - Adolescents in "Low SB High FV" cluster had a better overall quality of life[37,165] and those in "High PA sleep Low SB FV" cluster had a better quality of life and higher emotional, social, and psychosocial functioning. Positive associations were found with prosocial behaviors for the "Low SB High FV Specific diet" clusters among boys and the among girls[46,162] in "High FV UPF Sleep Specific diet"[46] and "High PA SB UPF Low sleep"[162] clusters. Negative associations were also observed between the "Low SB High FV Specific diet" cluster and hyperactivity/inattention symptoms among boys[162], and between the "High FV UPF Sleep Specific diet" cluster and the variable peer relationship problems among girls[46]. Other negative associations were also observed, for boys only between the "High PA FV UPF Sleep Specific diet"[46] cluster and the following mental health indicators: specific phobia symptoms, separation anxiety symptoms, generalized anxiety symptoms, hyperactivity-inattention symptoms; and between the cluster "High PA UPF Specific diet"[46] and emotional symptoms.

	Mixed*	♂	♀
High PA FV Low SB UPF Satisfactory Sleep (2)	39	43	43
High SB UPF (3)	74,164	24,80	24,80
High PA (3)	44,45,108		24,80
High PA SB UPF Low sleep (2)	37		162,167
High PA FV Sleep Low SB UPF (2)	42	24,80	
High SB UPF Low Sleep (4)	37,44,45,108	162,167	
High PA FV (2)	165,166	24,80	
Low PA FV Sleep High SB UPF (1)		43	43
Low PA SB UPF Sleep (1)		74	74
Low PA SB UPF Satisfactory Sleep (1)		74	74
High SB FV Satisfactory Sleep (1)		88	88

Mixed*	
High PA Low FV Satisfactory Sleep (1)	39
High PA SB Low Sleep (1)	37
High PA Low SB Sleep (1)	37
High PA Low Sleep (1)	37
High PA Low SB Satisfactory Sleep (2)	38,105
High PA FV Low SB UPF (2)	82,165,166
High PA Low SB UPF (1)	74
Low PA SBB FV Sleep (1)	106
Low PA FV High UPF (1)	82
Low PA FV Satisfactory Sleep (1)	39
Low PA High FV Satisfactory Sleep (1)	39
Low PA Sleep High SB (1)	37
Low PA High SB Satisfactory Sleep (3)	38,42,105
Low PA FV Sleep High SB (1)	37
Low PA FV Sleep High SB UPF (2)	106,165,166
Low PA FV High SB UPF Satisfactory Sleep (1)	39
High SB UPF Satisfactory Sleep (2)	38,105
Low SB High FV (1)	37
Low SB UPF High FV Satisfactory Sleep (2)	38,105
High FV (2)	44,45,108
High UPF Satisfactory Sleep (1)	42
Specific Diet (1)	45,108
High PA Low FV (1)	163
High PA UPF Low SB FV (1)	165,166
High PA UPF Low SB Satisfactory Sleep (1)	165,166
High PA Low SB (1)	163
High PA FV Low SB (1)	164
High PA sleep Low SB FV (1)	165,166
Low PA SB (1)	164
Low PA High SB sleep (1)	165,166
Low PA FV High SB (1)	165,166
High SB UPF Low Sleep (1)	165,166
Low SB High FV Sleep (1)	163
Low SB High FV Specific Diet (1)	162,167

♂	
High PA FV UPF Sleep Specific diet (1)	46
High PA UPF Specific diet (1)	46
High PA SB Sleep Specific diet (1)	162,167
High PA SB Satisfactory Sleep (1)	88
High PA SB FV Satisfactory Sleep (1)	88
Low PA FV High UPF Sleep (1)	24,80
Low PA FV High SB UPF (1)	24,80
Low PA SB UPF High FV (1)	24,80
High SB (1)	74
High SB UPF Low FV Satisfactory Sleep (1)	88

♀	
High PA SB Sleep (1)	88
High PA SB FV UPF Satisfactory Sleep (1)	88
High FV Low UPF (1)	24,80
Low FV Sleep (1)	24,80
High SB Satisfactory Sleep (1)	43
High SB Sleep (1)	24,80
High SB UPF Sleep (1)	88
Low SB and UPF High FV Sleep (1)	24,80
High UPF Low FV (1)	24,80
High SB and UPF Low FV (1)	162,167
High FV UPF sleep Specific diet (1)	46

Information order
Cluster type (number of studies that identified the cluster) | Studies reference.
References highlighted in gray identified clusters in same sample and was counted once.
***** Involve general sample with the presence of boys and girls together.

Figure 10 – Cluster types (n=67) by sample strata and respective studies references.

PA: physical activity. SB: sedentary behavior. UPF: ultra-processed foods. FV: fruit and vegetables. Specific Diet" involve consumption of foods that do not frame on FV and UPF (e.g., milk and meat consumption).

Table 7 – Positive and negative associations between types of clusters and health indicators with their respective study references (n = 16).

Indicators	High PA	High PA SB Satisfactory Sleep	High PA SB UPF Low sleep	High PA sleep Low SB FV:	High PA FV UPF Sleep Specific diet	High PA UPF Low SB Satisfactory Sleep	High PA UPF Specific diet	Low PA SB UPF High FV	Low PA SB Satisfactory Sleep	Low PA High SB Satisfactory Sleep	Low PA High SB Sleep	Low PA FV Sleep	Low PA FV Sleep High SB UPF*	Low SB High FV	Low SB High FV Specific diet	Low SB High FV Sleep	Low SB UPF High FV Sleep	High SB FV Satisfactory Sleep	High SB UPF Low Sleep	Specific diet	High UPF Low FV	High UPF Satisfactory Sleep	High FV UPF Sleep Specific diet
Adiposity variables																							
Trunk fat	(-)[108]																						
Fat Mass	(-)[108]								(+)♀♂[105]											(-)[108]			
BMI	(-)[108]								(+)♀♂[105]		(+)[165]					(-)[163]			(+)[165]	(-)[108]			
Waist circumference	(-)[108]								(+)♀♂[105]										(+)[165]	(-)[108]			
Weight status Overweight																(-)[163]							
Overweight + Obesity		(-)[88]							(+)♀♂[105]	(+)[42]			(+)♀[43]					(-)[88]				(+)[42]	
Metabolic risk factors																							
SBP								(-)♂[80]				(+)♂[80]									(+)♀[80]		
DBP																	(-)♀[80]						
HDL cholesterol																			(-)[45]				
Total/HDL cholesterol ratio	(-)[45]																		(+)[45]				
Total cholesterol	(-)[45]																						
Insulin resistance	(-)[44]																		(+)[44]				

PA: physical activity. SB: sedentary behavior. ***** The cluster is also characterized by high discrepancy and quality of sleep. ♂ indicates male only. ♀ indicates female only. (+) indicates positive association (higher average values or greater exposure). (−) indicates negative association (lower average values or lower exposure). 0 indicates no association. SBP: systolic blood pressure. DBP: diastolic blood pressure. HDL: high-density lipoprotein.

Table 7 – Continued

Indicators	High PA	High PA SB Satisfactory Sleep	High PA SB UPF Low sleep	High PA sleep Low SB FV:	High PA FV UPF Sleep Specific diet	High PA UPF Low SB Satisfactory Sleep	High PA UPF Specific diet	Low PA SB UPF High FV	Low PA SB Satisfactory Sleep	Low PA High SB Satisfactory Sleep	Low PA High SB Sleep	Low PA FV Sleep	Low PA FV Sleep High SB UPF*	Low SB High FV	Low SB High FV Specific diet	Low SB High FV Sleep	Low SB UPF High FV Sleep	High SB FV Satisfactory Sleep	High SB UPF Low Sleep	Specific diet	High UPF Low FV	High UPF Satisfactory Sleep	High FV UPF Sleep Specific diet
Socio-emotional																							
Prosocial Behaviors			(+)♀[162]												(+)♂[162]								(+)♀[46]
Hyperactivity/inattention symptoms					(-)♂[46]										(-)♂[162]								
Specific phobia symptoms					(-)♂[46]																		
Separation anxiety symptoms					(-)♂[46]																		
Generalized anxiety symptoms					(-)♂[46]																		
Peer relationship problems																							(-)♀[46]
Emotional symptoms							(-)♂[46]																
Quality of life																							
Social functioning				(+)[165]		(+)[165]																	
Emotional functioning				(+)[165]																			
Psychosocial functioning				(+)[165]																			
Score														(+)[37]									

PA: physical activity. SB: sedentary behavior. ***** The cluster is also characterized by high discrepancy and quality of sleep. ♂ indicates male only. ♀ indicates female only. (+) indicates positive association (higher average values or greater exposure). (−) indicates negative association (lower average values or lower exposure). 0 indicates no association. SBP: systolic blood pressure. DBP: diastolic blood pressure. HDL: high-density lipoprotein.

Discussion

This study systematically reviewed clustering of 24-hour movement behaviors and dietary intake and their relationship with health indicators among youth. Overall, sixty-six cluster types were identified for mixed-sex samples, of which, 10 were for boys, and 11 were for girls. Most cluster types comprised healthy and unhealthy behaviors (i.e., mixed cluster types). The majority were identified in youth from high-income countries. Adiposity indicators were the most commonly investigated health outcome. A few associations between cluster types and health indicators were found.

The presence of mixed behavior profiles with the coexistence of unhealthy and healthy behaviors was frequently observed in this review, corroborating existing literature[2,3,156]. For example, previous reviews and studies have found that high levels of PA coexisted with high time spent in SB and high consumption of ultra-processed foods and FV in children and adolescents[2,3]; low levels practicing PA occur with lower time in SB[2,3,29]; and high sleep hours coexisted with low quality of diet and low SB and PA[29]. The compensatory health beliefs theory can explain the coexistence of behaviors, which explains that negative effects of unhealthy behaviors (e.g., consuming sweet beverages) can be compensated or neutralized by a healthy behavior (e.g., doing PA)[1]. In contrast, the problem behavior theory[5] posits that engaging in an unhealthy behavior (e.g., watching excess screen time) increases the likelihood of participating in another unhealthy behavior (e.g., consuming UPF) and vice versa. Both theories may help us to understand why certain behaviors cluster together and may result in the coexistence of healthy and unhealthy behaviors.

The main difference in profiles according to sex was that girls' clusters were characterized by high sleep duration, whereas boys' clusters by high PA. Previous literature has also identified the presence of mixed lifestyle profiles in boys and girls[30,43], and studies have demonstrated that girls consistently sleep longer than boys[168,169]. A possible explanation can be that sleep characteristics are genetically and environmentally determined, although their respective contributions are unknown[169,170]. What is known is that this sex difference is usually attributed to external influences, such as light and time exposure via use of the screens, academic obligations, and consumption of healthy foods[169,171,172]. Boys being more physical active than girls can be explained by points such as sweat, dirt and unwillingness that doing PA can cause[147,148]. Moreover, girls tend to spend time in domestic tasks and in

social activities such as sitting and talking with friends, compared to boys in tasks that involve body movement[146]. In addition, studies have shown that sleeping more or fewer hours than recommended (9-11 hours for those aged 5-13 years, and 8-10 for those aged 14-17 years) is associated with increased depressive symptoms, adiposity, blood pressure, and insulin resistance in children and adolescents[173,174]. Systematic reviews found that children and adolescents with low sleep and PA, and high SB (unhealthiest behavior combination) had unfavorable adiposity, cardiometabolic and mental health[150,175]. Thus, intervention strategies focused on multiple behaviors at the same time may be important to improve health risk profiles in youth. Additionally, distinct strategies focusing on improving sleep behavior and PA in girls may be an important next step given our finding of girl-specific clusters characterized by excessive sleep duration (above the recommended levels).

Most studies in this review analyzed adiposity indicators in youth[39,42,43,82,88,105,106,108,161–163,165]. Clusters with unhealthy behaviors (e.g., “High UPF Satisfactory Sleep”[42], “Low PA SB Satisfactory Sleep”[105], “Low PA High SB Satisfactory Sleep”[42], “Low PA FV Sleep High SB UPF”[43], Low PA High SB Sleep[165], and "High SB UPF Low Sleep"[165]) were associated with overweight/obesity and increase in adiposity. Interventions based on traditional theories and methodological approaches focusing on a single risk behavior might be insufficient to address complex diseases such as obesity[176]. Although few studies examined indicators such as blood pressure, insulin resistance, cholesterol levels, and mental health indicators, evidence suggested that clusters characterized by unhealthy combination of 24-hour movement behaviors and diet are associated with higher insulin resistance[44], blood pressure[80], and prosocial behavior[46,162]. However, not all associations observed were in the expected direction. For instance, one study found that those in the “High SB UPF Low Sleep” cluster had lower LDL cholesterol[45]. Another study found higher quality of life in adolescents’ at “Low SB High FV” cluster[37]. These findings suggest that future studies should investigate health indicators other than adiposity, and public policy should develop approaching multicomponent strategies to improve health indicators in youth.

One of the strengths of this study is that it is the first study to systematically review the clustering of 24-hours movement behavior and diet in mixed-sex samples, and in boys and girls, separately. Boys and girls presented different clusters of behaviors[28–30]; therefore, the most important implication of this study is to develop

strategies to improve multiple behaviors considering their sex-specific profiles. The search strategies were developed in consultation with topic experts and enabled us to identify many potential studies. We also were able to identify and describe the behavior variables used to determine the clusters and the health indicators associated with clusters. Also, our inclusion criteria and authors' language expertise permitted us to review studies written in multiple languages.

Caution is warranted when generalizing results: 1) the cluster types were based on the classifications presented by the authors of each paper that met the inclusion criteria. However, during the process of describing the clusters, a sequence of criteria and agreement between the researchers was used to ensure parsimonious information was obtained; 2) the wide range of PA, SB, sleep, and diet outcomes/variables made the synthesis of results challenging; however, extraction of behavior frequency, behavior types, intensity, and volumes provided suitable information for characterizing cluster types; 3) we synthesized the direction of the association rather than the magnitude, which is important to understand certain impact/relevance of such behaviors for health-related variables; 4) most of the studies included in this research did not consider maturation as a confounding factor when analyzing associations between clusters types and BMI/adiposity measures; 5) the frequent high risk of bias found mainly for the instruments for assessing sedentary behavior and sleep suggests caution in interpreting the results. It also indicates the need to advance research validating instruments for these behaviors.

We suggest that future studies assess time spent in different types of screen time (e.g., television, cellphone) and include this information as separate input variables in the data-driven clustering analyses. Previous research has shown that different screen-time behaviors may influence health differently[150,151]. Most studies reported that the time spent sleeping does not differ between clusters, suggesting that future studies should explore sleep behaviors other than sleep duration, such as variables related to quality of sleep (number of awakenings, wake after sleep onset, and sleep efficiency), and sleep stages, enable a more sensitive panorama. Most studies in this review evaluated diet based on consumption of limited food groups, namely FV and UPF. A more detailed assessment of dietary intake is needed. Future studies would benefit from examining dietary patterns that account for interactions between foods, nutrients, and other bioactive components consumed as part of a whole diet and their potential synergistic effects on health. Studies that utilize

longitudinal/prospective study designs and employ causal inference analysis are also needed to identify changes in cluster behaviors and their associated factors, in order to examine the effect of intervention strategies. Future cross-sectional and longitudinal studies are needed to examine the association between the clustering of 24-hour movement behaviors and diet and other health indicators in addition to adiposity. Few studies provided sufficient detail regarding the analytic decisions made to determine the optimal number of clusters, and the reliability of the resulting cluster solution was rarely reported. Future interventions should test multiple behaviors strategies to promote children and adolescent's health.

Conclusion

Sixty-six types of PA, SB, sleep, and diet clusters were identified among children and adolescents. These clusters were mainly characterized by the presence of both healthy and unhealthy behaviors. The main difference in profiles according to biological sex was that girls' clusters were characterized by high sleep duration, whereas boys' clusters were characterized by high PA. There were few associations found between cluster types and health indicators. Nevertheless, it was observed that youth assigned to cluster types with low PA exhibited higher indicators related to body adiposity. These results highlighted that intervention strategies focused on multiple behaviors at the same time may be important to improve health risk profiles and health indicators in children and adolescents.

3 FINAL CONSIDERATIONS

3.1 STRENGHTS AND LIMITATIONS

This compilation of studies systematically reviewed the types of PA, SB, sleep, and diet among children and adolescents based on determinants of these behaviors, including income countries and biological sex. The search strategies were developed based on suggestion of experts on the theme which enabled the identification of many potential studies. All these points advance the evidence base on clustering because previous reviews on cluster patterns were either not systematic[159], employed limited search strategies (i.e., limited combination of behaviors descriptors)[2,29,159] or limited

the publications reviewed up to 2018[2]. Another strong point is the identification of a comprehensive range of correlates associated with cluster types, which is crucial to understanding, preventing, and promoting healthy behaviors, enabling more targeted and effective interventions.

Aspects should be considered when generalizing the results of this thesis. First, the subjectivity of the clusters type extractions, based on the classifications presented by the authors of each paper that met the inclusion criteria. Also, the wide range of PA, SB, sleep, and diet variables on the studies analyses made the synthesis of results challenging. However, during the extraction process a sequence of criteria and agreement between the researchers was used to ensure parsimonious information was obtained. Second, only the direction of the association between correlates and cluster types were extracted, rather than the magnitude. Understanding the magnitude is important to assess the impact or relevance of such behaviors for health-related variables. Third, the frequently identified high risk of bias among the instruments used to assess behaviors suggests caution in interpreting the results. It also underscores the need for further research to validate instruments for these behaviors. Fourth, studies published in Portuguese and Spanish were included, in addition to those in English.

3.2 CONCLUSION

The present thesis aimed to estimate the prevalence of three combinations of energy balance-related behaviors (1. PA, SB and diet; 2. PA and SB; 3. PA, SB, sleep and diet); and examine which correlates have been associated with these cluster types.

The first study investigated the combination of PA, SB, and diet. Our findings revealed 55 cluster types among children and adolescents. The clusters most prevalent among youth were the ones labeled “High SB and consumption of SSB” and “High PA” in all income countries. The healthiest profile, “*High PA and fruit and vegetables (FV); Low SB and SSB*”, was present in upper-middle and high-income countries, while the unhealthiest “*Low PA and FV; High SB and SSB*” was present only in high-income countries. A greater variety of cluster types was observed in high-income countries compared to lower-income countries, however, a low number of studies were found in countries with lower income strata. These results support the

need for multi-component actions targeting more than one behavior simultaneously, as the unhealthy behaviors present in each cluster type vary.

Our second study examined the clustering of PA and SB among youth, and associated correlates. Most girls were in clusters characterized by “Low PA Low SB” and “Low PA High SB”. In contrast, most of boys were in clusters defined by “High PA High SB” and “High PA Low SB”. Cluster differ in SB components being boy more in cluster types characterized by time watching television, using computer, and playing videogame and girls dedicate more time to socializing activities (e.g., siting and talking with their friends). These findings demonstrate that different preventive approaches, tailored to boys and girls, need to be considered to improve behaviors among children and adolescents. Furthermore, boys and girls in the 'High PA High SB' clusters had higher BMI and obesity in most of the tested associations. In contrast, those in the 'High PA Low SB' clusters presented lower BMI, waist circumference, and overweight and obesity. A better understanding of the simultaneous impact of these behaviors is needed to understand as they contribute together to unhealthier health correlates.

The last study investigated the clustering of PA, SB, sleep, and diet among children and adolescents, and associated correlates. Sixty-six types of PA, SB, sleep, and diet clusters were identified among children and adolescents. These clusters were mainly characterized by the presence of both healthy and unhealthy behaviors. We observed that the most frequents clusters in mixed-sex samples were “High SB UPF Low Sleep”, “Low PA High SB Satisfactory Sleep”, and “High PA”. Girls’ clusters were characterized by high sleep duration, whereas boys’ clusters were characterized by high PA. It was observed that youth assigned to cluster types with low PA exhibited higher indicators related to body adiposity. These results highlighted that intervention strategies focused on multiple behaviors at the same time may be important to improve health indicators in children and adolescents.

In summary, boys and girls presented cluster types characterized by at least one unhealthy behavior independently of the energy-balance behaviors investigated. It was possible to identify differences in clustering behavior types according to income countries only in the first study; in the other articles, all the studies involved samples from high-income countries. Differences among cluster types were identified according to sex. The predominance of null associations between cluster types, socioeconomic factors, and health outcomes was found.

3.3 IMPLICATIONS

Considering the results of the present thesis, it is essential to highlight some possible implications:

a) Interventions aimed at improving energy balance-related behaviors among youth may focus strategies to address more than one behavior simultaneously. Our results support that regardless of the number of behaviors observed simultaneously, the cluster types were characterized by at least one unhealthy behavior.
b) We need to identify specific social and cultural factors influencing behavior adoption. Our results found differences in cluster types among income countries, highlighting the importance of addressing context-specific factors to promote change behaviors.
c) Specific strategies should be designed to promote behavioral changes in boys and girls. Our results showed differences in cluster types for boys and girls, suggesting the need to improve PA for girls and reduce SB for boys.

3.4 DISSEMINATION

Several results of this thesis were presented to the scientific community at the International Society for Physical Activity and Heath 2021, at the International Society of Behavioral Nutrition and Physical Activity 2022, and the Arizona State University 2023. Articles have been published in high-impact journals to share these findings. Announcements of the results will be posted on the *Núcleo de Pesquisa e Atividade Física* e Saúde (NUPAF) website and social media, ensuring that the community has access to this knowledge. The results of this thesis extend beyond the academic sphere and do not stop here. My future intention is to use the information from this thesis to conduct interventions on these behaviors to promote health.

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APPENDIX A – SYSTEMATIC REVIEWS METHODS

1. SYSTEMATIC REVIEWS

A systematic review was developed to answer the first, second and third specific purposes of the present project. The systematic review was registered at the International Prospective Register of Systematic Reviews (PROSPERO; register number CRD42018094826) (ANNEX A). This is a larger collaborative comprehensive evidence synthesis project on a global panorama of researches that involved clustering behaviors considering at least two behaviors [diet, physical activity (PA), and/or sedentary behavior (SB)] in children and adolescents.

Briefly, the search strategy included five electronic databases: PubMed, Web of Science, LILACS, Scopus, PsycINFO. And, the inclusion criteria were that the articles must: (1) include children and/or adolescents (aged 0–19 years); (2) simultaneously analyze at least two behaviors between diet, PA, and SB by applying data-based cluster statistical procedures (studies could also include additional behaviors); and (3) be published in English, Portuguese, or Spanish. Exclusion criteria was that articles must not include clinical populations (e.g., disabilities, metabolic and/or cardiovascular diseases).

Considering the aspects aforementioned more than 271 studies met the inclusion criteria. Thus, three studies were developed considering the clusters behaviors combination most published: 1. Clusters involving diet, PA and SB; 2. Clusters involving PA and SB; and 3. Clusters involving diet, PA, SB and sleep. Undermentioned more information about particularities of each study can be observed at item 3.2, 3.3, and 3.4.

APPENDIX B – SUPLEMENTARRY MATERIAL TOPIC 2.1

Table S1. PRISMA-ScR checklist

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	Page 1. Title.
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	Page 3
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	Page 4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	Page 4. Topic Protocol.
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	Page 4. Topic Eligibility Criteria.
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	Page 4. Topic Protocol.
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Page 5. Supplementary material Table S2.
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	Page 6. Topic Data extraction and Synthesis.
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	Page 6. Topic Data extraction and Synthesis.

Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Page 6. Topic Data extraction and Synthesis.
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Page 7. Topic Critical appraisal of individual sources of evidence.
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	Page 6. Topic Data extraction and Synthesis.
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	Page 9
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Page 9
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	Page 10
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Page 6 to 14
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Page 10 to 14
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	Page 14
Limitations	20	Discuss the limitations of the scoping review process.	Page 18
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	Page 19
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Page 20

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

Table S2. Search of all strategy

PUBMED

Search Group	Search Terms
Physical Activity	sport* OR sports[mesh] OR sports OR "motor activity"[mesh] OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise[mesh] OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness"[mesh] OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR "physical inactivity")
Sedentary Behavior	sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle"[mesh] OR "sedentary lifestyle" OR television[mesh] OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers[mesh] OR computers OR "computer time" OR "computer use" OR "video game*"
Diet Behavior	diet[mesh] OR diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet"[mesh] OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior"[mesh] OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences"[mesh] OR "food preferences" OR "unhealthy food" OR "nutritional quality"
Analysis	"cluster analysis"[mesh] OR "cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity
Population	youth OR adolesce* OR adolescent[mesh] OR adolescent OR adolescent* OR adolescence OR student* OR students[mesh] OR students OR teen* OR teenage* OR schoolchildren OR child* OR child[mesh] OR child OR children[mesh] OR children

Web of Science

Search Group	Search Terms
Physical Activity	TS=(sport* OR sports OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	TS=(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle" OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game*")
Diet Behavior	TS=(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Analysis	TS=("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	TS=(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

SCOPUS

Search Group	Search Terms
Physical Activity	TITLE-ABS-KEY(sport* OR sports OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	TITLE-ABS-KEY(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle" OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game*")
Diet Behavior	TITLE-ABS-KEY(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Analysis	TITLE-ABS-KEY("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	TITLE-ABS-KEY(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

LILACS, MEDLINE AND PSYCINFO

Search Group	Search Terms
Physical Activity	(sport OR sports OR "motor activity" OR "physical activity" OR "physical activities" OR exercise OR exercises OR "physical exercise" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activity" OR "leisure activities" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyles" OR "sedentary lifestyle" OR television OR "television time" OR "television watch" OR "television watches" OR "TV watch" OR "TV watching" OR "TC watches" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game" OR "video games")
Diet Behavior	(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Clustering	("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

Table S3. Behaviors included in clustering procedures along with physical activity, diet, and sedentary behavior.

Author (year)	Behaviors included
Androutsos et al. (2014)	Sleep.
Azeredo et al. (2016)	Aggression (intimidated and involved in a fight last 30d); Alcohol (frequency and glasses last 30d); Smoking (days last 30d); Drugs (use on last 30d); Unsafe sex (different people, use condom).
Bel-Serrat (2013)	None.
Berlin (2017)	Lose/gain weight.
Boone-Heinonen (2008)	Use of a community recreation center; Alcohol use; Smoking; Dieting or exercising to lose weight.
Busch (2013)	Alcohol use; Drug use; Smoking; Sexual behavior; Peer bullying.
Cameron (2011)	None.
Collese (2018)	Sleep time.
Cuenca-Garcia (2013)	None.
de Moraes (2016)	Sleep time.
Dantas (2018)	None.
Dumuid (2017)	None.
Dumuid (2017)	None.
Dumuid (2018)	Sleep.
Fernandez-Alvira (2013)	Sleep duration.
Ferrar (2015)	Sleep; Grooming; School activities.
Fleary (2017)	Unhealthy weight control; Sleep; Substance use (smoking, alcohol, binge drinking and marijuana)
Gubbels (2012)	None.
Gubbels (2012)	None.
Hartz (2018)	None.
Huh (2011)	Weight perception; Attitudes towards weight.
Iannotti (2013)	None.
Juresa (2012)	Family structure; Socio economic; Demographic characteristics; Alcohol and smoking; Teeth hygiene; Traffic safety; Physical conflicts; Health problems; Status and symptoms; Family medical history.
Kontogianni (2010)	None.
Lazzeri (2018)	Smoking; Alcohol; Violent behavior.
Laxer (2017)	Smoking; Alcohol; Marijuana.
Laxer (2018)	Smoking; Alcohol; Marijuana.
Leech (2014)	None.
Leech (2015)	None.
Lioret (2008)	None.
Magee et al. (2013)	Sleep duration; Sleeping/napping.
Maia et al. (2018)	Eating with the parents/guardians; Eating in front of the TV or studying; Having breakfast.
Mandic et al. (2017)	Body Weight.
Marttila-Tornio (2019)	Alcohol use; Smoking
Matias (2018)	None.
Matias (2018)	None.
Miguel-Berges (2017)	Sleep.
Moreira (2018)	None.
Moschonis (2013)	Sleep
Moschonis (2012)	Sleep
Nuutinen (2017)	Sleep quality
Ottevaere (2011)	None.
Pereira (2015)	Sleep
Perez-Rodrigo (2015)	Sleep
Platat (2006)	None.
Riggs (2012)	Weight consciousness; Weight loss attempts; Exercising to lose weight.
Rodrigues (2017)	Father and mother PA level; Father and mother excess weight.
Santaliestra-Pasias (2015)	None.

Seghers (2010)	None.

Table S3. Continued

Author (year)	Behaviors included
Sena (2017)	Consumption of alcoholic beverages; Tobacco experimentation.
Spengler (2012)	None.
Spengler (2014)	None.
Turner (2011)	Alcohol.
Van der Sluis (2010)	None.
Veloso (2012)	None.
Yen (2006)	Smoking; Drinking alcohol; Chewing betel nut were; Brushing teeth before bed; Staying up late; Hitting others; Swearing; Breaking things when angry; Vandalism; Stealing; Cheating on an examination; Washing hands before eating.

Table S4. Methodological Characteristics of included studies.

First Author	Study (year)	Sample Country	Sample (% of girls)	Age (range or mean)	PA (instrument)	Diet (instrument)	SB (instrument)	N. of behaviors	Cluster analysis
High-Income Countries									
Androutsos (2014)	Healthy Growth Study (2007)	Greece	2.656 (50.1)	9-13	Questionnaire (Undefined)	24 hours recall	Questionnaire (Undefined)	12	PCA
Bel-Serrat (2013)	IDEFICS (2007–2008)	Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden.	4.619 (48.4)	2-9	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	4	K-means*
Berlin (2017)	ECLS-K (1998-1999)	U.S.A.	9.295 (49)	13-15	Questionnaire (Undefined)	Questionnaire (Undefined)	Questionnaire (Undefined)	21	LPA
Boone-Heinonen (2008)	National Longitudinal Study of Adolescent Health (1995 and 1996)	U.S.A.	8.840 (50.7)	11-21	Questionnaire (Sallis et al., 1999)	Questionnaire (Sallis et al., 1999)	Questionnaire (Sallis et al., 1999)	37	K-means
Busch (2013)	Not informed (2012)	Netherlands	2.690 (55.0)	11-18	Questionnaire (adapted from the Dutch version of HBSC)	Questionnaire (adapted from the Dutch version of HBSC)	Questionnaire (adapted from the Dutch version of HBSC)	15	PCA & Two-steps
Cameron (2012)	READI (2007-2008)	Australia	352	5-12	Objective Measure (Accelerometer)	Questionnaire (Undefined)	Questionnaire (Undefined)	4	Ward
Cuenca-García (2013)	HELENA (2006-2007)	Austria, Belgium, France, Greece, Germany, Hungary, Italy, Spain, and Sweden.	2.084 (54.0)	12-14	Questionnaire (IPAQ-A)	24 hours recall	Questionnaire (Undefined-Reproductible)	4	K-means*
Dumuid (2017)	ISCOLE (2011-2012)	Australia	284 (53.9)	9-11	Objective Measure (Accelerometer)	Questionnaire (FFQ)	Questionnaire (Undefined)	7	K-means*
Fernández-Alvira (2013)	ENERGY-project (2010)	Belgium, Greece, Hungary, Netherlands, Norway, Slovenia, and Spain.	5.284 (54.0)	10-12	Questionnaire (ENERGY-child)	Questionnaire (ENERGY-child)	Questionnaire (ENERGY-child)	4	K-means*
Ferrar and Golley (2015)	National Children's Nutrition and Physical Activity Survey (2007)	Australia	1.853 (49.8)	9-16	Questionnaire (Multimedia Activity Recall for Children and Adults)	Questionnaire (Food Model Booklet)	Questionnaire (Multimedia Activity Recall for Children and Adults)	24	Two-steps

Table S4. Continued

First Author	Study (year)	Sample Country	Sample (% of girls)	Age (range or mean)	PA (instrument)	Diet (instrument)	SB (instrument)	N. of behaviors	Cluster analysis
High-Income Countries									
Fleary (2017)	YRBSS (2011)	U.S.A.	14.815 (49.0)	NR	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	15	LCA
Gubbels (2011)	The KOALA Birth Cohort Study (2000)	Netherlands	2.074 (48.6)	5	Questionnaire (Standard Questionnaire for measuring Physical Activity)	Questionnaire (FFQ)	Questionnaire (Standard Questionnaire for measuring Physical Activity)	30	PCA
Gubbels (2012)	The KOALA Birth Cohort Study (2000)	Netherlands	2.074 (48.6)	5	Questionnaire (Standard Questionnaire for measuring Physical Activity)	Questionnaire (FFQ)	Questionnaire (Standard Questionnaire for measuring Physical Activity)	13	PCA
Hartz (2018)	NHANES (2003-2004)	U.S.A.	1.233 (48.5)	12-19	Objective Measure (Accelerometer)	24 hours recall	Objective Measure (Accelerometer)	3	LCA
Huh et al (2011)	Pathways Study (Not informed)	U.S.A.	997 (48.1)	Mean: 9.6	Questionnaire (Undefined)	Questionnaire (Undefined)	Questionnaire (Undefined)	11	LCA
Iannotti and Wang (2013)	Not informed (Not informed)	U.S.A.	9.206 (51.6)	Mean: 13.9	Questionnaire (Undefined-Reproductible)	Questionnaire (FFQ)	Questionnaire (Undefined-Reproductible)	10	LCA
Kontogianni (2010)	Not informed (2007)	Greece	Children: 751 (49.0) Adolescents: 554 (56.0)	Children: 3-12 Adolescents: 13-18	Questionnaire (Undefined)	24 hours recall	Questionnaire (Undefined)	9	PCA
Landsberg (2010)	KOPS (1996-2006)	Germany	1.894 (51.5)	Mean: 14.7	Questionnaire (Undefined)	Questionnaire (FFQ)	Questionnaire (Undefined)	7	Two-steps
Laxer (2017)[1]	COMPASS (2012-2013)	Canada	18.587 (48.9)	9-12	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	15	LCA
Laxer (2018)	COMPASS (2012-2013)	Canada	5.084 (52.1)	Mean: 14.7	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	15	LCA
Lazzeri (2018)	HBSC (2010)	Italy	3.291	11, 13 and 15	Questionnaire (HBSC)	Questionnaire (HBSC)	Questionnaire (HBSC)	22	EFA & K-means
Leech (2014)	HEAPS (2002-2003)	Australia	Younger children: 362 (50.0) Older children: 610 (56.0)	Younger children: 5-6 Older children: 10-12	Objective Measure (Accelerometer)	Questionnaire (FFQ)	Objective Measure (Accelerometer)	5	K-means
Leech (2015)	HEAPS (2002-2003)	Australia	Younger children: 123 (46.0) Older children: 87 (43.0)	Younger children: 5-6 Older children: 10, 12 & 14	Objective Measure (Accelerometer)	Questionnaire (FFQ)	Objective Measure (Accelerometer)	5	K-means
Lioret (2008)	French INCA1 (1998-1999)	France	748	3-11	Questionnaire (Modifiable Activity Questionnaire)	7 days recall	Questionnaire (Modifiable Activity Questionnaire)	34	PCA
Magee (2013)	LSAC (2006-2008)	Australia	1.833 (48.4)	6-9	Diares	Diares	Diares	6	LCA
Mandic (2017)	BEATS (2014-2015)	New Zeland	1.300 (51.0)	13-18	Questionnaire (HBSC)	Questionnaire (HBSC)	Questionnaire (HBSC)	4	Two-steps
Marttila-Tornio (2019)	Northen Finland Birth Cohort 1986	Finland	4.305 (53.0)	15-16	Questionnaire (NFBC1986)	Questionnaire (NFBC1986)	Questionnaire (NFBC1986)	7	K-means

Table S4. Continued.

First Author	Study (year)	Sample Country	Sample (% of girls)	Age (range or mean)	PA (instrument)	Diet (instrument)	SB (instrument)	N. of behaviors	Cluster analysis
High-Income Countries									
Miguel-Berges (2017)	ToyBox (2012)	Belgium, Bulgaria, Germany, Greece, Poland, and Spain	5.387 (49.0)	3.5-5.5	Objective Measure (Pedometer) & Questionnaire (Primary Caregivers Questionnaire)	Questionnaire (Primary Caregivers Questionnaire)	Questionnaire (Primary Caregivers Questionnaire)	6	K-means*
Moschonis (2013)	Healthy Growth Study (2007)	Greece	2.043 (50.2)	9-13	Questionnaire (Manios, Kafatos & Markakis, 1998)	24 hours recall	Questionnaire (Undefined)	12	PCA
Moschonis (2014)	Healthy Growth Study (2007)	Greece	2.073 (50.2)	9-13	Questionnaire (Manios, Kafatos & Markakis, 1998)	24 hours recall	Questionnaire (Undefined)	12	PCA
Nuutinen (2017)	HBSC (2010)	Finland	13 years: 2.152 15 years: 2.110	13 and 15	Questionnaire (HBSC)	Questionnaire (HBSC)	Questionnaire (HBSC)	9	K-means
Ottevaere (2011)	HELENA (2006-2007)	Belgium, France, Greece, Germany, Italy, Spain, and Sweden.	2.084 (54.4)	Youngers: 12.5-14.9 Olders: 15-17.5	Questionnaire (IPAQ-A)	24 hours recall	Questionnaire (HELENA questionnaire)	3	K-means
Pereira (2015)	ISCOLE (2011-2012)	Portugal	686 (55.5)	9.5-10.5	Objective Measure (Accelerometer)	Questionnaire (FFQ)	Questionnaire (YRBSS)	5	LCA
Pérez-Rodrigo (2015)	ANIBES Study (2012)	Spain	415 (37.8)	9-17	Questionnaire (IPAQ-A)	24 hours recall	Questionnaire (HELENA questionnaire)	4	K-means*
Platat (2006)	Not informed (2001)	France	2.724	12	Questionnaire (Modifiable Activity Questionnaire)	Questionnaire (Undefined)	Questionnaire (Modifiable Activity Questionnaire)	6	MCA
Riggs (2012)	Pathways (Not informed)	U.S.A.	997 (51.9)	Mean: 9.3	Questionnaire (Undefined)	Questionnaire (Undefined)	Questionnaire (Undefined)	12	LCA
Rodrigues (2017)	PPSOC (2009-2010)	Portugal	10.258 (51.0)	6-9	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	Questionnaire (Undefined-Reproductible)	15	PCA
Santaliestra-Pasías (2015)	IDEFICS (2007-2008)	Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden.	11.674 (49.2)	2-9	Questionnaire (Undefined-Reproductible)	Questionnaire (CEHQ-FFQ)	Questionnaire (Undefined-Reproductible)	4	K-means*
Seghers and Rutten (2010)	Not informed (2007)	Belgium	317 (56.8)	Mean: 11.7	Questionnaire (Flemish Physical Activity Questionnaire)	Questionnaire (FFQ)	Questionnaire (Undefined)	5	K-means
Spengler (2012)	KIGGS MoMo (2003-2006)	Germany	1.643 (49.4)	11-17	Questionnaire (MoMo-PAQ overall activity index)	Questionnaire (Adapted FFQ)	Questionnaire (Undefined)	3	K-means*
Spengler (2014)	KIGGS MoMo (2003-2006)	Germany	1.642 (49.4)	11-17	Questionnaire (MoMo-PAQ overall activity index)	Questionnaire (Adapted FFQ)	Questionnaire (Undefined)	3	K-means*

Table S4. Continued.

First Author	Study (year)	Sample Country	Sample (% of girls)	Age (range or mean)	PA (instrument)	Diet (instrument)	SB (instrument)	N. of behaviors	Cluster analysis
High-Income Countries									
Turner (2011)	Not informed (2005)	Canada	445 (60.2)	14-17	Questionnaire (SAPAC)	Questionnaire (adapted from the WHO Steps instrument)	Questionnaire (SAPAC)	7	Two-step
Van der Sluis (2010)	Fruits and Vegetables Make the Marks (2001-2005)	Norway	713 (53.0)	Not reported	Questionnaire (Undefined-Reproductible)	Questionnaire (Andersen et al., 2004)	Questionnaire (Undefined-Reproductible)	4	K-means
Veloso (2012)	HBSC (2010)	Portugal	3.069 (54.1)	13-16.9	Questionnaire (HBSC)	Questionnaire (HBSC)	Questionnaire (HBSC)	8	K-means
Yen (2006)	CABLE (2001)	Taiwan	2.075 (48.0)	Not reported	Questionnaire (CABLE)	Questionnaire (CABLE)	Questionnaire (CABLE)	18	PCA
Upper-Middle Income Countries									
Azeredo (2016)	National Survey of School Health (2015)	Brazil	104.109 (52.2)	13-16	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	18	FA
Collese (2018)	HELENA (2006-2007) BRACAH (2007)	Brazil	HELENA study: 1,252 (52.7) BRACAH study: 682 (54.2)	HELENA: 12.5–17.5 years (14.7) BRACAH: 14 to 17.5 years (16.3)	Questionnaire (IPAQ-A)	Questionnaire (FFQ)	Questionnaire (HELENA questionnaire)	5	K-means*
Dantas (2018)	Health Education Program through Dietary Interventions and Physical Activity (2017)	Brazil	578 (67.8)	12–18	Questionnaire (IPAQ-A)	Questionnaire (YRBSS)	Questionnaire (Undefined-Reproductible)	4	K-means*
Juresa (2012)	School Health Survey (2003-2004)	Croatia	960 (48.6)	Mean: 7.5	Questionnaire (School Health Survey)	Questionnaire (School Health Survey)	Questionnaire (School Health Survey)	41	EFA
Maia (2018)	PeNSE (2012)	Brazil	109.104 (52.2)	Younger than 13 and older tha 16	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	17	K-means
Matias (2018)	PeNSE (2012)	Brazil	102.072	11-19	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	4	Two-steps
Matias (2018)	PeNSE (2012)	Brazil	102.072 (51.3)	11-9 (14.3)	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	Questionnaire (PeNSE Questionnaire)	4	Two-steps
Sena (2017)	Not informed (2009-2011)	Brazil	1.716 (49.3)	10-17	Questionnaire (Undefined)	Questionnaire (FFQ)	Questionnaire (Undefined)	6	PCA

Table S4. Continued.

First Author	Study (year)	Sample Country	Sample (% of girls)	Age (range or mean)	PA (instrument)	Diet (instrument)	SB (instrument)	N. of behaviors	Cluster analysis
Intercontinental Studies with Different Income Countries									
Dumuid (2016)	ISCOLE (2011-2012)	Australia, Brazil, Canada, China, Colombia, England, Finland, India, Kenya, Portugal, South Africa, and USA	5.710	9-11	Objective Measure (Accelerometer)	Questionnaire (FFQ)	Objective Measure (Accelerometer)	9	K-means*
Dumuid (2017)	ISCOLE (2011-2012)	Australia, Brazil, Canada, China, Colombia, England, Finland, India, Kenya, Portugal, South Africa, and USA.	5.759 (55.0)	9-11	Objective Measure (Accelerometer)	Questionnaire (FFQ)	Questionnaire (Undefined)	8	K-means*
Moraes (2016)	HELENA (2006-2007) BRACAH (2007)	HELENA: Austria, Belgium, France, Greece, Germany, Hungary, Italy, Spain, and Sweden. BRACAH: Brazil.	HELENA study: 1.252 (52.7) BRACAH study: 682 (54.3)	HELENA: 12-17.5 BRACAH: 14-17.5	Questionnaire (IPAQ-A)	Questionnaire (HBSC)	Questionnaire (Undefined)	5	K-means*

Table S4. Continued.

First Author	Study (year)	Sample Country	Sample (% of girls)	Age (range or mean)	PA (instrument)	Diet (instrument)	SB (instrument)	N. of behaviors	Cluster analysis
Intercontinental Studies with Different Income Countries									
Moreira (2018)	HELENA (2006-2007) BRACAH (2007)	HELENA: Austria, Belgium, France, Greece, Germany, Hungary, Italy, Spain, and Sweden. BRACAH: Brazil.	HELENA study: 2.057 (53.8) ELANA study: 968 (53.2)	HELENA: 12.5-17.7 ELANA: 13.5-19	HELENA: Questionnaire (IPAQ-A) ELANA: Questionnaire (IPAQ short version)	HELENA: 24 hours recall ELANA: Questionnaire (FFQ)	HELENA: Questionnaire (HELENA questionnaire) ELANA: Questionnaire (Undefined)	4	K-means*

PA: physical activity; SB: sedentary behavior; NA: not applicable; NR: not reported; *: With Wald's method; IDEFICS: Identification and prevention of Dietary and lifestyle-induced health Effects in children and InfantS; ECLS-K: Early Childhood Longitudinal Study Cohort; READI: Resilience for Eating and Activity Despite Inequality; HEAPS: Health, Eating and Play study; LSAC: Longitudinal Study of Australian Children; BEATS: Built Environment and Active Transport to School; Pathways: Pathways to Health; PPSOC: Portuguese Prevalence Study of Obesity in Childhood; BRACAH: Brazilian Cardiovascular Adolescent Health; CABLE: Child and Adolescent Behaviors in Long-term Evolution; ELANA: Adolescent Nutritional Assessment Longitudinal; ENERGY: EuropeaN Energy balance Research to prevent excessive weight Gain among Youth; FFQ: Food Frequency Questionnaire; HBSC: Health Behavior in School-aged Children; HELENA: Healthy Lifestyle in Europe by Nutrition in Adolescence; IPAQ-A: International Physical Activity Questionnaire for Adolescents; MoMo: Motorik-Modul; PeNSE: National School-based Health Survey; SAPAC: Self-Administered Physical Activity Checklist YRBSS: Youth Risk Behavior Surveillance System.

EFA: Exploratory factor analysis; FA: Factor analysis; LCA: Latent class analysis; LPA: Latent profile analysis; MCA: Multiple correspondence analysis; PCA: Principal component analysis.

Equal superscript black letters indicate common samples.

Table S5. Assessment of the bias risk of studies.

Study	Selection bias		Study design				Assessment tool											
							PA			Diet			SB			Withdrawals and drop-outs		
	Q1	Bias	Q2	Q3	Q4	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q7	Q8	Bias
Androutsos (2014) [a]	0	Moderate	1	1	1	Strong	0	0	Weak	1	1	Strong	0	1	Weak	1	1	Strong
Azeredo (2016) [b]	1	Strong	1	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Weak	1	1	Strong
Bel-Serrat (2013) [a]	-1	Weak	1	1	0	Moderate	1	1	Strong	1	1	Strong	0	1	Weak	1	1	Strong
Berlin (2017) [a]	?	Weak	1	0	0	Moderate	0	1	Weak	0	1	Weak	0	1	Weak	0	1	Strong
Boone-Heinonen (2008) [a]	0	Moderate	1	1	0	Moderate	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Busch (2013) [a]	0	Moderate	0	1	-1	Weak	?	1	Weak	?	1	Weak	?	1	Weak	1	1	Strong
Cameron (2012) [a]	-1	Weak	0	1	1	Moderate	1	1	Strong	0	1	Weak	0	1	Weak	1	-1	Weak
Collese (2018) [b]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	0/?	Weak
Cuenca-García (2013) [a]	-1	Weak	0	0	0	Weak	1	1	Strong	1	1	Strong	1	1	Strong	0	-1	Weak
Dantas (2018) [b]	-1	Weak	0	1	1	Moderate	1	1	Strong	1	1	Strong	0	1	Weak	0	0	Weak
Dumuid (2017)	0	Moderate	0	1	*	Weak	1	1	Strong	1	1	Strong	0	1	Weak	1	1	Strong
Dumuid (2017) [c]	-1	Weak	0	1	1	Moderate	1	1	Strong	1	1	Strong	0	1	Weak	1	-1	Weak
Dumuid (2016) [c]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Fernández-Alvira (2013) [a]	0	Moderate	1	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Weak	0	1	Strong
Ferrar and Golley (2015) [a]	1	Strong	0	-1	1	Weak	1	1	Strong	0	1	Weak	1	1	Strong	0	1	Strong
Fleary (2017) [a]	?	Weak	1	0	0	Moderate	0	1	Weak	0	1	Weak	0	1	Weak	1	1	Strong
Gubbels (2011) [a]	0	Moderate	0	1	-1	Weak	0	1	Weak	1	1	Strong	0	1	Weak	0	0	Moderate
Gubbels (2012) [a]	0	Moderate	0	1	-1	Weak	0	1	Weak	1	1	Strong	0	1	Weak	0	0	Moderate
Hartz (2018) [a]	-1	Weak	1	1	1	Strong	1	1	Strong	0	1	Weak	1	1	Strong	1	0	Moderate
Huh et al (2011) [a]	?	Weak	0	-1	1	Weak	0	0	Weak	0	1	Weak	0	0	Weak	1	0	Moderate
Iannotti and Wang (2013) [a]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong
Juresa (2012) [b]	1	Strong	1	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Weak	0	-1	Weak
Kontogianni (2010) [a]	1	Strong	1	1	1	Strong	0	1	Weak	1	1	Strong	0	1	Weak	0	1	Strong
Landsberg (2010) [a]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Laxer (2017) [a]	-1	Weak	0	1	-1	Weak	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong
Laxer (2018) [a]	-1	Weak	0	1	-1	Weak	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Lazzeri (2018) [a]	1	Strong	1	1	1	Strong	0	1	Weak	1	1	Strong	0	0	Weak	0	?	Weak
Leech (2014) [a]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Leech (2015) [a]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Lioret (2008) [a]	-1	Weak	1	1	1	Strong	1	1	Strong	0	1	Weak	1	1	Strong	1	1	Strong
Magee (2013) [a]	?	Weak	0	-1	1	Weak	0	1	Weak	0	1	Weak	0	1	Weak	0	?	Weak
Maia (2018) [b]	1	Strong	1	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Weak	1	1	Strong
Mandic (2017) [a]	-1	Weak	0	1	0	Weak	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Marttila-Tornio (2019) [a]	-1	Weak	1	1	-1	Weak	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak

Table S5. Continued.

Study	Selection bias		Study design				Assessment tool											
							PA			Diet			SB			Withdrawals and drop-outs		
	Q1	Bias	Q2	Q3	Q4	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q7	Q8	Bias
Matias (2018) [b]	1	Strong	1	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Weak	1	1	Strong
Matias (2018) [b]	1	Strong	1	1	1	Strong	1	1	Strong	0	1	Weak	0	1	Weak	1	1	Strong
Miguel-Berges (2017) [a]	0	Moderate	0	1	1	Moderate	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Moraes (2016) [c]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Moreira (2018) [c]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Moschonis (2013) [a]	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Moschonis (2014) [a]	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Nuutinen (2017) [a]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Strong
Ottevaere (2011) [a]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Pereira (2015) [a]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	?	Weak
Pérez-Rodrigo (2015) [a]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Platat (2006) [a]	0	Moderate	1	1	1	Strong	1	1	Strong	0	1	Weak	1	1	Strong	1	0	Moderate
Riggs (2012) [a]	?	Weak	1	1	1	Strong	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Strong
Rodrigues (2017) [a]	-1	Weak	1	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Weak	1	1	Strong
Santaliestra-Pasías (2015) [a]	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Weak	1	0	Moderate
Seghers and Rutten (2010) [a]	?	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong
Sena (2017) [b]	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Weak	1	0	Moderate
Spengler (2012) [a]	?	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong
Spengler (2014) [a]	?	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Turner (2011) [a]	?	Weak	0	1	-1	Weak	1	1	Strong	0	1	Weak	0	1	Weak	1	1	Strong
Van der Sluis (2010) [a]	1	Strong	1	1	1	Strong	0	1	Weak	1	1	Strong	0	1	Weak	1	1	Strong
Veloso (2012) [a]	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	0	Moderate
Yen (2006) [a]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong

PA: physical activity; SB: sedentary behavior; Q1: Are the individuals selected to participate in the study likely to be representative of the target population?; Q2: Is there a description of the representativeness of the sample?; Q3: Was the sampling method described?; Q4: Was the method appropriate?; Q5: Is there a prior validation report of the tool?; Q6: Is there information that makes it possible to replicate the tool?; Q7: Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?; Q8: Indicate the percentage of participants completing the study; ?: impossible to determine; *The selection method differed among study countries. [a]High-Income Countries; [b]Upper-Middle Income Countries; [c]Involves samples from more than one country and with different income classification (Intercontinental Studies with Different Income Countries).

Table S6. Articles from their respective studies.

1. ISCOLE (1)
    - Dumuid (2016)
    - Dumuid (2017)
    - **Dumuid (2017) – Intercontinental – 5.759 – 9-11 – Children & Adolescents (C&A) – Australia, Brazil, Canada, China, Colombia, Finland, India, Kenya, Portugal, South Africa, England, USA.**
    - Pereira (2015)
2. HBSC – 11, 13, 15 – Adolescents (A)
    - **Lazzeri (2018) - Italy**
    - **Nuutinen (2017) - Finland**
    - **Veloso (2012) - Portugal**
3. HELENA
    - **Cuenca-García (2013) – European Countries – 2.084 – 12-14 – A**
    - Moraes (2016)
    - Moreira (2018)
    - Ottevaere (2011)
    - Collese (2018)
4. Healthy Growth Study (2007)
    - **Androutsos (2014) – Greece – 2.656 – 9-13 – C&A**
    - Moschonis (2012)
    - Moschonis (2013)
5. HEAPS
    - **Leech (2014) – Australia – 972 – 5-6 & 10-12 – C&A**
    - Leech (2015)
6. IDEFICS
    - Bel-Serrat (2013)
    - **Santaliestra-Pasías (2015) – European Countries – 11.674 – 2-9 – Children (C)**
7. KIGGS/MoMo
    - **Spengler (2012) – Germany – 1.643 – 11-17 - A**
    - Spengler (2014)
8. KOALA Birth Cohort
    - **Gubbels (2011) – Netherlands – 2.074 – 5 – C**
    - Gubbels (2012)
9. Pathways to Health
    - **Huh (2011) – USA – 997 – 9.6 - C**
    - Riggs (2012)
10. PeNSE 2015
    - **Azeredo (2016) – Brazil – 104.109 – 13-16 or more - A**
    - Matias (2018)
    - Matias (2018) – Body Image
11. 2011 YRBSS
    - Fleary (2017) – USA – 14.815 – Not reported (NR)
12. ANIBES
    - Pérez-Rodrigo (2016) – Spain – 415 – 9-17 – C&A
13. BEATS
    - Mandic (2017) – New Zeland – 1.300 – 13-18 - A
14. BRACAH
    - **Moraes (2016) – Brazil – 682 – 14-17.5 – A**
    - Collese (2018)
15. CABLE
    - Yen (2006) – Taiwan – 2.075 - NR
16. COMPASS
    - **Laxer (2017) – Canada – 18.587 – 9-12 – C&A**
    - Laxer (2018)

Table S6. Continue.

17. ECLS-K
    - Berlin (2015) – USA – 9.295 – 13-15 - A
18. ELANA
    - Moreira (2018) – Brazil – 968 – 13.5-19 - A
19. ENERGY
    - Fernández-Alvira (2013) – European Countries – 5.284 – 10-12 - A
20. French INCA1
    - Lioret (2008) – France – 748 – 3-11 – C&A
21. Fruits & Vegetables Make the Marks
    - Van Der Sluis (2010) – Norway – 713 - NR
22. KOPS
    - Landsberg (2010) – Germany – 1.894 – 14.7 - A
23. LSAC
    - Magee (2013) – Australia – 1.833 – 6-9 - C
24. National Children's Nutrition and PA Survey
    - Ferrar (2015) – Australia – 1.853 – 9-16 – C&A
25. National Longitudinal Study of Adolescent Health
    - Boone-Heinonen – USA – 8.840 – 11-21 - A
26. NHANES
    - Hartz (2018) – USA – 1.233 – 12-19 - A
27. PeNSE 2012
    - Maia (2017) – Brazil – 109.104 - <13 & >16 - A
28. PPSOC
    - Rodrigues (2017) – Portugal – 10.258 – 6-9 - C
29. READI
    - Cameron (2011) – Australia – 352 – 5-12 – C&A
30. School Health Survey
    - Juresa (2012) – Croatia – 960 – 7.5 - C
31. ToyBox
    - Miguel-Berges (2017) – European Countries – 5.387 – 3.5-5.5 - C
32. Article that did not presented the study name: 1
    - Busch (2013) – Netherlands – 2.690 – 11-18 - A
33. Article that did not presented the study name: 2
    - Iannotti (2013) – USA – 9.206 – 13.9 - A
34. Article that did not presented the study name: 3
    - Kontogianni (2010) – Greece – 1.305 – 3-18 – C&A
35. Article that did not presented the study name: 4
    - Platat (2006) – France – 2.724 – 12 - A
36. Article that did not presented the study name: 5
    - Seghers (2010) – Belgium – 317 – 11.7 - A
37. Article that did not presented the study name: 6
    - Sena (2017) – Brazil – 1.716 – 10-17 - A
38. Article that did not presented the study name: 7
    - Turner (2011) – Canada – 445 – 14-17 – A
39. Health Education Program through Dietary Interventions and Physical Activity
    - Dantas (2018) – Brazil – 578 – 12-18 – A
40. Northen Finland Birth Cohort 1986 (NFBC1986)
    - Marttila-Tornio (2019) – Finland – 4.305 – 15-16 – A

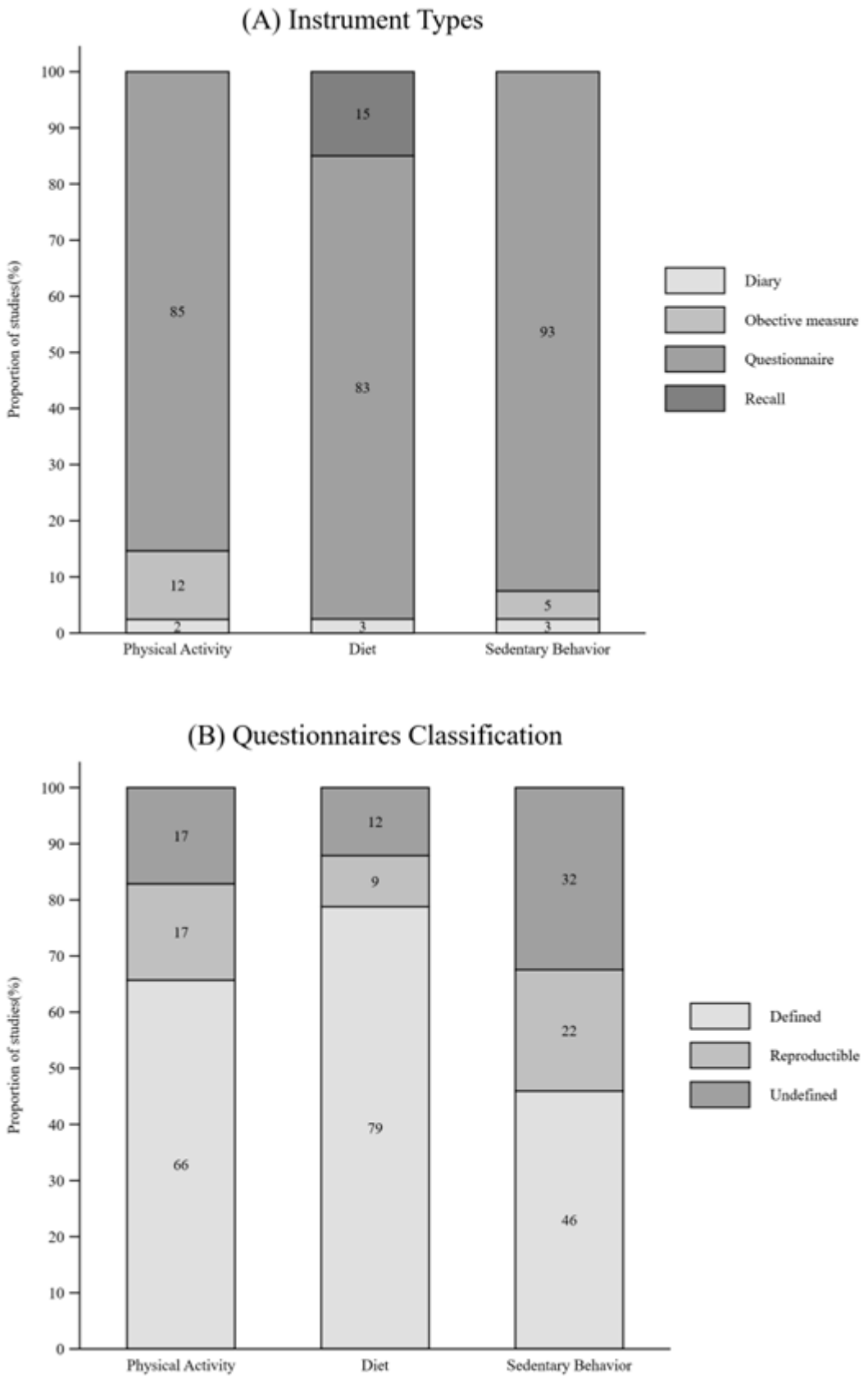


Figure S1. Instruments used and questionnaires classification according to each behavior.

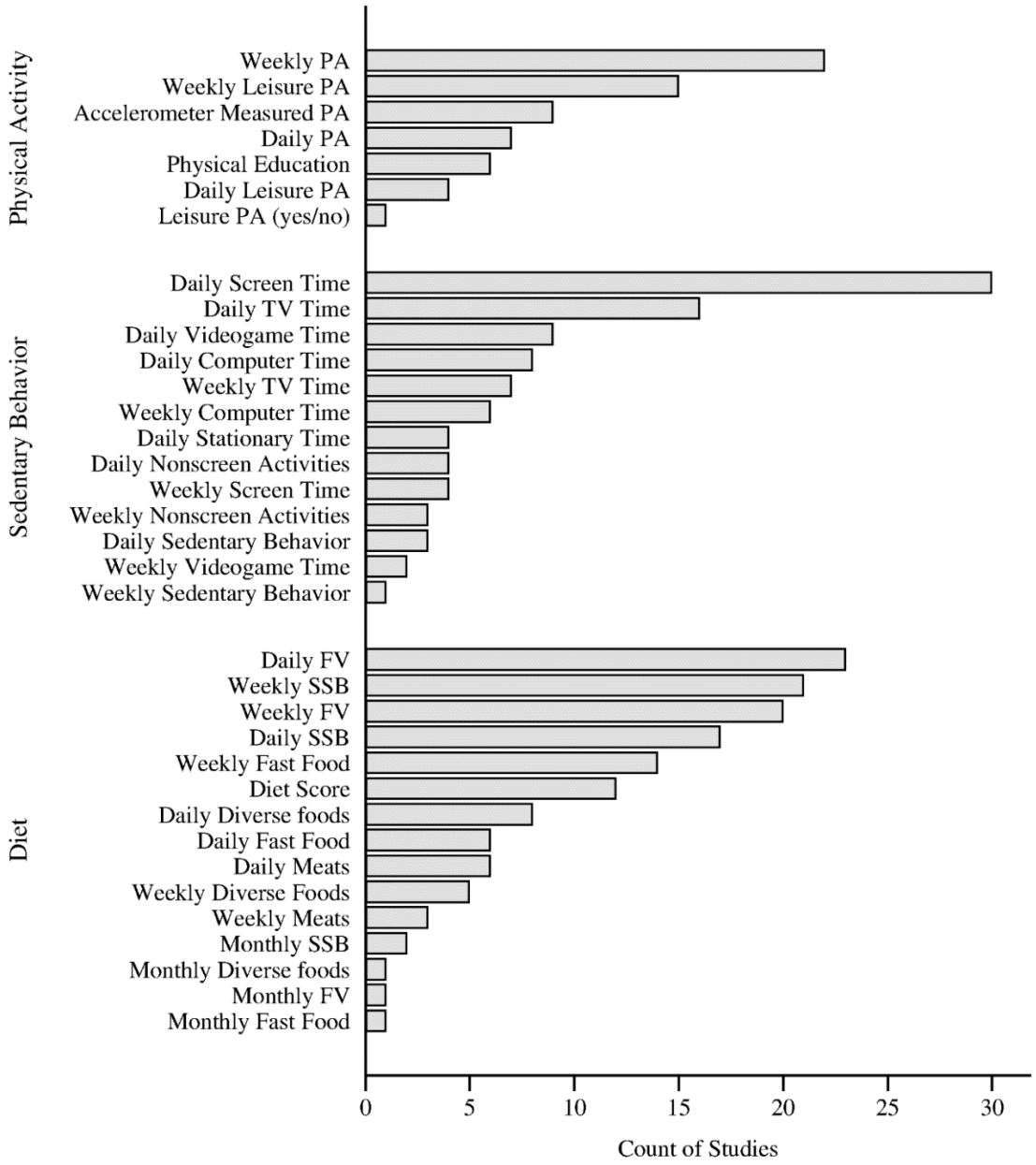


Figure S2. Behavioral outcomes used to define PA, diet, and sedentary behavior in clustering procedures.
Note: FV: fruits and/or vegetables; SSB: salty and sugary snacks, and/or sweetened beverages. *Stationary time refers to accelerometer measured movement behaviors.

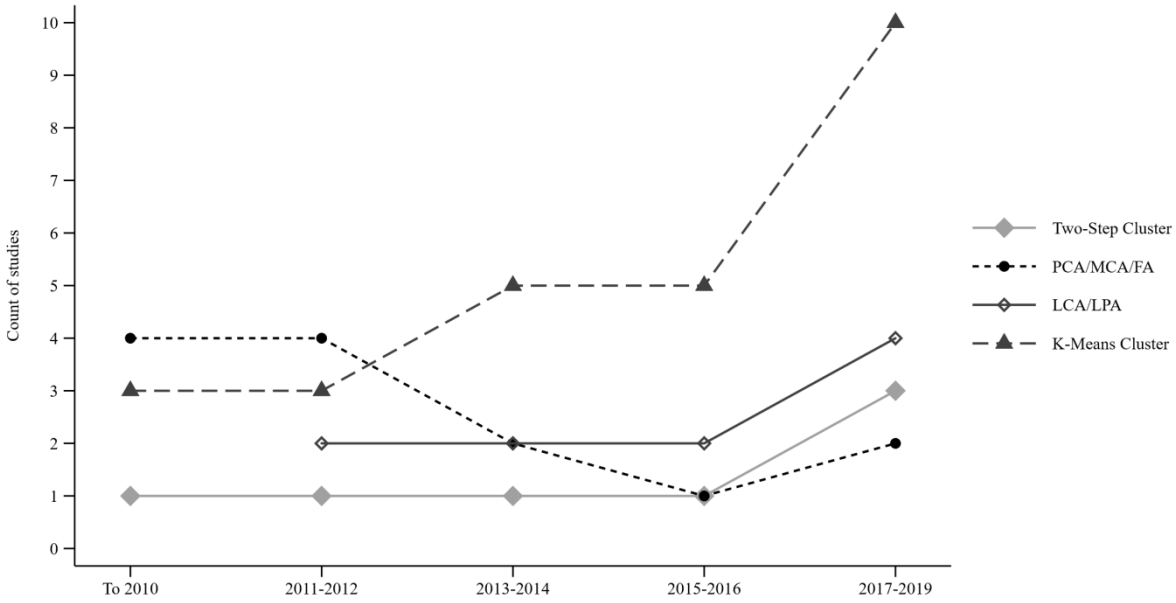


Figure S3. Use of statistical procedures to evaluate the clustering between physical activity, diet and sedentary behavior among children and adolescents.
Note: LCA: Latent Class Analysis; LPA: Latent Profile Analysis; PCA: Principal Component Analysis; MCA: Multiple corresponding analysis; FA: Factorial Analysis.

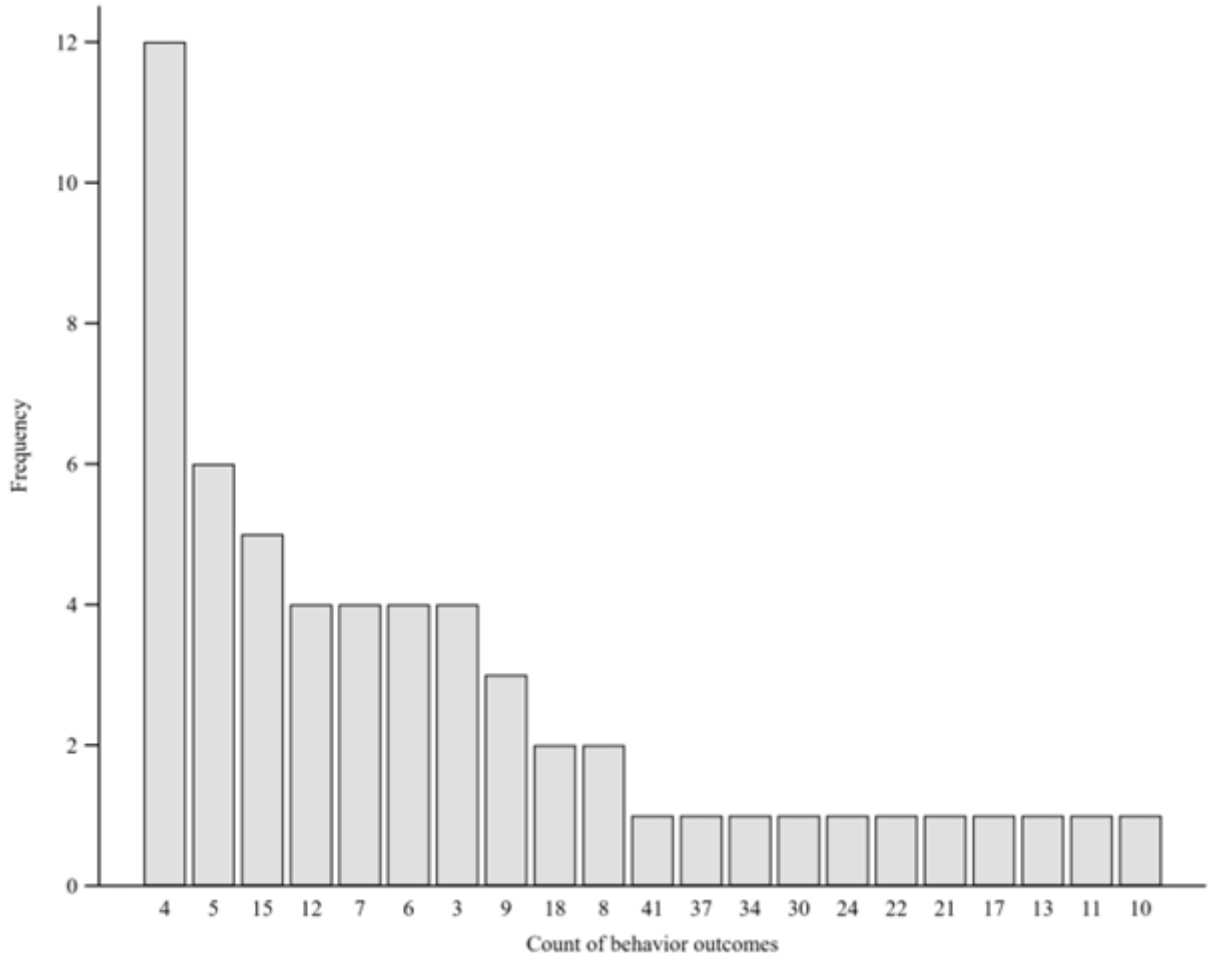


Figure S4. Quantity of outcomes used in clusters procedures.

APPENDIX C – SUPLEMENTARRY MATERIAL TOPIC 2.2

Table S1. Prisma Checklist

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1. Title
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 3 and 4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 4 and 5
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 5. Topic eligibility criteria
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 5 and 6. Topic Protocol and Search strategies and selection process
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 6. And, supplementary material Table S4
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6. Topic Search strategies and selection process
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 6 and 7. Topic Data extraction and synthesis.
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 7. Topic Data extraction and synthesis.
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 7. Topic Data extraction and synthesis.
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6. Topic methodological quality assessment of include studies
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Not applicable

Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 7. Topic Data extraction and synthesis.
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 7. Topic Data extraction and synthesis.
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 7. Topic Data extraction and synthesis.
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 7. Topic Data extraction and synthesis.
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 7 and 8. Topic Data extraction and synthesis.
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page 7 and 8. Topic Data extraction and synthesis
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 6. Topic methodological quality assessment of include studies
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 7 and 8. Topic Data extraction and synthesis.

Section and Topic	Item #	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 8. Topic results.
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 8. Topic results and Figure 1.
Study characteristics	17	Cite each included study and present its characteristics.	Page 8. Topic results.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 9. Topic risk of bias assessment and Figure 2.
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Page 8.
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 9. Topic risk of bias assessment.
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 8 to 13. Topic results.
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page 7 and 8. Topic data extraction and synthesis.

	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 7 and 8. Topic Data extraction and synthesis
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page 9. Risk of bias assessment.
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page 7 and 8. Topic Data extraction and synthesis
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 13.
	23b	Discuss any limitations of the evidence included in the review.	Page 15 and 16.
	23c	Discuss any limitations of the review processes used.	Page 15 and 16.
	23d	Discuss implications of the results for practice, policy, and future research.	Page 16.
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 5. Topic Protocol.
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 5. Topic Protocol.
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Page 5. Topic Protocol.
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 17. Topic Funding..
Competing interests	26	Declare any competing interests of review authors.	Page 17. Topic competing interest.
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Supplementary material.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71
For more information, visit: http://www.prisma-statement.org/

Table S2. SWiM checklist

The citation for the Synthesis Without Meta-analysis explanation and elaboration article is: Campbell M, McKenzie JE, Sowden A, Katikireddi SV, Brennan SE, Ellis S, Hartmann-Boyce J, Ryan R, Shepperd S, Thomas J, Welch V, Thomson H. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline BMJ 2020;368:l6890 http://dx.doi.org/10.1136/bmj.l6890

SWiM is intended to complement and be used as an extension to PRISMA			
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
Methods			
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (e.g., groupings of populations, interventions, outcomes, study design)	Page 5. Topic Protocol.	
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	Page 5. Topic Protocol.	
2 Describe the standardised metric and transformation methods used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen, and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance consulted	Page 6 and 7. Topic Data extraction and synthesis.	
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates	Page 7 and 8. Topic Data extraction and synthesis.	
4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select the particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (e.g., based on study design, risk of bias assessments, directness in relation to the review question)	Page 7 and 8. Topic Data extraction and synthesis.	
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it was not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity	Page 7 and 8. Topic Data extraction and synthesis.	
6 Certainty of evidence	Describe the methods used to assess certainty of the synthesis findings	Page 7 and 8. Topic Data extraction and synthesis.	
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (e.g., tables, forest plots, harvest plots). Specify key study characteristics (e.g., study design, risk of bias) used to order the studies, in the text and any tables or graphs, clearly referencing the studies included	Page 7 and 8. Topic Data extraction and synthesis.	
Results			
8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings, and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis	Page 8 to 13.	
Discussion			

9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis, and how these affect the conclusions that can be drawn in relation to the original review question	Page 16.	

PRISMA=Preferred Reporting Items for Systematic Reviews and Meta-Analyses.
*If the information is not provided in the systematic review, give details of where this information is available (e.g., protocol, other published papers (provide citation details), or website (provide the URL)).

Table S3. Eligibility criteria.

Items	Inclusion	Exclusion
Study	All studies design that applied exploratory data-based statistical procedures, considering cluster analysis (i.e., k-means), latent Class/Profile Analysis, and dimensionality reduction techniques (i.e., Principal Component Analysis and Factor Analysis);	Reviews, letters to editor, and conference abstracts
Outcome	analyzed simultaneously physical activity and sedentary behavior	other behaviors or variables (e.g., tobacco use, unhealthy eating, socioeconomic status) as part of the cluster patterns
Population	children and/or adolescents (aged 0–19 years, or reported means between these ages)	clinical populations (e.g., disabilities, metabolic and/or cardiovascular diseases, hospitalized or institutionalized populations)
Language	English, Portuguese, or Spanish	-

Table S4. Search of all strategy

PUBMED

Search Group	Search Terms
Physical Activity	sport* OR sports[mesh] OR sports OR "motor activity"[mesh] OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise[mesh] OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness"[mesh] OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR "physical inactivity")
Sedentary Behavior	sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle"[mesh] OR "sedentary lifestyle" OR television[mesh] OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers[mesh] OR computers OR "computer time" OR "computer use" OR "video game*"
Diet Behavior	diet[mesh] OR diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet"[mesh] OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior"[mesh] OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences"[mesh] OR "food preferences" OR "unhealthy food" OR "nutritional quality"
Analysis	"cluster analysis"[mesh] OR "cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity
Population	youth OR adolesce* OR adolescent[mesh] OR adolescent OR adolescent* OR adolescence OR student* OR students[mesh] OR students OR teen* OR teenage* OR schoolchildren OR child* OR child[mesh] OR child OR children[mesh] OR children

Web of Science

Search Group	Search Terms
Physical Activity	TS=(sport* OR sports OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	TS=(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle" OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game*")
Diet Behavior	TS=(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Analysis	TS=("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	TS=(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

SCOPUS

Search Group	Search Terms
Physical Activity	TITLE-ABS-KEY(sport* OR sports OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	TITLE-ABS-KEY(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle" OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game*")
Diet Behavior	TITLE-ABS-KEY(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Analysis	TITLE-ABS-KEY("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	TITLE-ABS-KEY(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

LILACS, MEDLINE AND PSYCINFO

Search Group	Search Terms
Physical Activity	(sport OR sports OR "motor activity" OR "physical activity" OR "physical activities" OR exercise OR exercises OR "physical exercise" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activity" OR "leisure activities" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyles" OR "sedentary lifestyle" OR television OR "television time" OR "television watch" OR "television watches" OR "TV watch" OR "TV watching" OR "TC watches" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game" OR "video games")
Diet Behavior	(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Clustering	("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

Table S5. Adapted version of the Quality Assessment Tool for Quantitative Studies of Effective Public Health Practice Project (EPHPP).

Domain	Question	Classification	
1) Selection bias	Are the individuals selected to participate in the study likely to be representative of the target population?	≥80% = *strong* or 1 79 - 60% = *moderate* or 0 ≤60% = *weak* or -1	
2) Study design	Is there a description of the representativeness of the sample?	Yes = 1 No = 0	*Strong:* 1 in all three items. *Moderate:* for combinations: 1-1-0, 1-0-1, 1-0-0, and 0-0-1. *Weak:* for all other combinations.
	Was the sampling method described?	Yes = 1 No = 0	
	Was the method appropriate?	Random = 1 Not described = 0 Convenience = -1	
3) information about instruments to evaluate PA and SB and information that would enable reproducing PA and SB assessment	Is there a prior validation report of the tool?	Yes = 1 No = 0	*Studies using accelerometer to measure PA and/or SB were assigned score "1", that is, it was considered that there was a previous validation report of the instrument. *Strong:* for 1 in both outcome items. *Weak:* for all other combinations.
	Is there information that makes it possible to replicate the tool?	Yes = 1 No = 0	
4) Flow of people throughout the study and percentage of participants completing the study	Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?	Yes = 1 No = 0	*Strong:* was applied for 1 in both items or 0 and 1. M*oderate:* for combinations 1 and 0 or 0 and 0. *Weak:* for all other combinations.
	Indicate the percentage of participants completing the study?	≥80% = 1 or *strong;* 60–79% = 0 or *moderate*; ≤59%= -1 or *weak*.	

Table S6. Assessment of the bias risk of studies.

Study	Selection bias		Study design				Assessment tool						Withdrawals and drop-outs		
							PA			SB					
	Q1	Bias	Q2	Q3	Q4	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q7	Q8	Bias
De Bourdeaudhuij (2013)	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Gorely (2007)	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Huang (2015)	-1	Weak	1	1	1	Strong	0	1	Weak	1	1	Strong	1	1	Strong
Kim (2016)	1	Strong	1	1	1	Strong	0	1	Weak	0	1	Weak	1	1	Strong
Lazarou (2009)	?	Weak	0	-1	0	Weak	1	1	Strong	1	1	Strong	1	-1	Weak
Marshall (2002)	1	Strong	1	-1	1	Weak	1	1	Strong	0	1	Weak	1	1	Strong
Melkevik (2010)	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Nelson (2005)	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong
Nelson (2006)	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong
O'Neill (2016)	1	Strong	1	1	1	Strong	0	1	Weak	0	1	Weak	1	-1	Weak
Patnode (2011)	1/?*	Strong/Weak	1	1	-1	Weak	1	1	Strong	1	1	Strong	0	0	Moderate
Ramos (2012)	?	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	0	0	Moderate
Spengler (2015)	-1	Weak	1	1	1	Strong	1	1	Strong	0	1	Weak	1	-1	Weak
Taverno (2016)	-1	Weak	1	1	0	Moderate	1	1	Strong	1	1	Strong	1	-1	Weak
Te Velde (2007)	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong
Wang (2006)	?	Weak	0	0	0	Weak	1	1	Strong	1	1	Strong	0	0	Moderate
Wang (2012)	?	Weak	-1	0	1	Weak	1	1	Strong	1	1	Strong	0	0	Moderate

PA: physical activity; SB: sedentary behavior; ?: impossible to determine; * IDEA study = 1 and ECHO study = ?;

Q1: Are the individuals selected to participate in the study likely to be representative of the target population?; Q2: Is there a description of the representativeness of the sample?; Q3: Was the sampling method described?; Q4: Was the method appropriate?; Q5: Is there a prior validation report of the tool?; Q6: Is there information that makes it possible to replicate the tool?; Q7: Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?; Q8: Indicate the percentage of participants completing the study

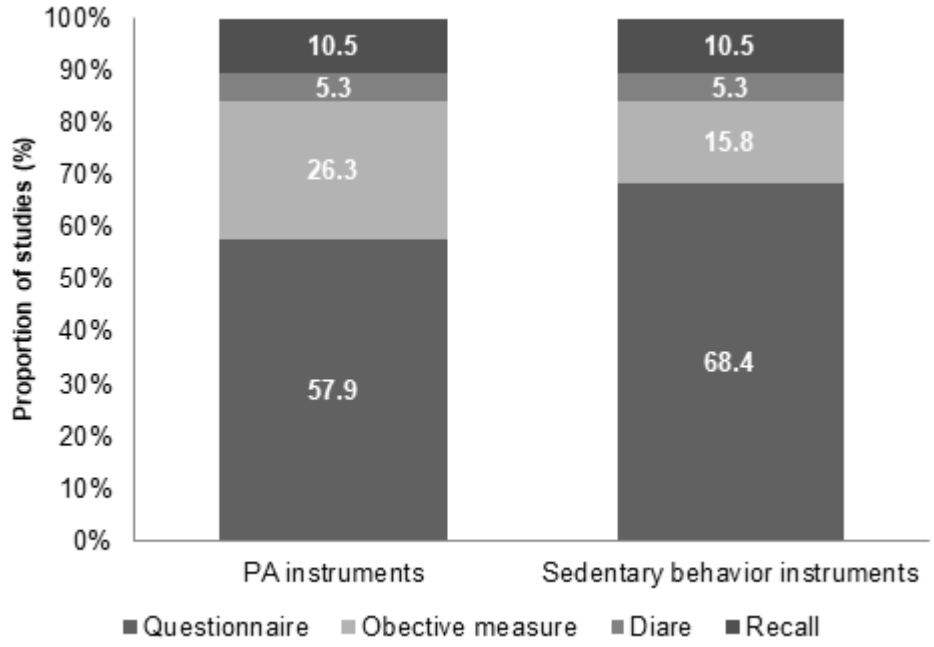
Table S7. Clusters variables details before authors classifications.

First author (publication year)	Clusters outcomes (indicator; instrument; variable treatment / unit of measurement)	
	PA	**SB**
De Bourdeaudhuij (2013)	Accelerometer *Indicator:* minutes of MVPA	Accelerometer *Indicator:* minutes of sedentary time
Gorely (2007)	Self-report diary of ‘‘free-time’’ *Indicator:* sports or exercises during leisure-time (weekly)	Self-report diary of "free-time" *Indicators:* television/video viewing, computer use, socialising behaviours, homework, and working (weekly)
Huang (2015)	Questionnaire (CLASS-C) *Indicator:* min/day spent on MVPA in leisure-time (weekly)	Questionnaire (CLASS-C) *Indicators:* time spent on doing homework, watching TV, playing electronic games, using the Internet, reading, listening to music and engaging in socializing behavior (weekly)
Kim (2016)	Self-report Indicators: frequency of MVPA, sports team participation, and muscle-strengthening exercise (days/week)	Self-report Indicators: hours/day watching TV, and using a computer
Lazarou (2009)	Semi-quantitative questionnaire *Indicators:* frequency and duration of everyday physical activities (physical activity and sports after school + home chores and outside home chores, aerobics, gymnastics, sports + sports for all, afterschool activities [except sports])	Semi-quantitative questionnaire *Indicators:* frequency and duration of everyday sedentary activities (video, electronic games, and computers + watching TV, video, and DVD + homework and private lessons + theater cinema, use of mobile phone + afternoon sleep, fewer private lessons)
Marshall (2002)	SAPAC: Modified version. *Indicator:* metabolic equivalent values, classified as: no, low, moderate, and high activity (weekly)	SAPAC Modified version. *Indicators:* time spent on the computer/internet, playing video games, doing homework, reading (not for school), sitting and talking/listening to music, and talking on the telephone (weekly)
Melkevik (2010)	Self-report *Indicators:* leisure time: VPA and MVPA	Self-report *Indicators:* time spent watching television (including videos), playing PC-games or TV-games, and using a computer (weekly)
Nelson (2005)	7-day recall questionnaire *Indicators:* Week Bouts (Hobbies, housework, skating, sports, exercise). Number for year (school academic clubs, school team sports, school individual sports); Weekdays (school physical education). Llikelihood of playing sport with a parent. Likelihood of using a recreation center.	7-day recall questionnaire *Indicators:* Week bouts (Hang out). Week hours (television viewing, video viewing, video game playing. Likelihood of making own television decisions
Nelson (2006)	7-day recall questionnaire *Indicators:* Week bouts (Hobbies, housework, skating, sports, exercise). Number for year (school academic clubs, school team sports, school individual sports). Weekdays (school physical education). Llikelihood of playing sport with a parent. Likelihood of using a recreation center.	7-day recall questionnaire *Indicators:* Week bouts (Hang out). Week hours (television viewing, video viewing, video game playing. Likelihood of making own television decisions
O'Neill (2016)	Self and parental report *Indicators:* active favourite hobby, and travel to school (active commuting)	Self-report *Indicators:* total daily time in SB (watching TV, using the computer, time spent playing video games, and reading time)
Patnode (2011)	Accelerometer, and 3-Day Physical Activity Recall *Indicators:* MVPA on weekdays and weekend days, traditional sports, fitness activities, other sports and physical activities, and chores/work	Self-administered Project EAT Items adapted *Indicators*: time spent watching television, watching DVDs or videos, reading/homework, Nintendo/Play Station/computer games, internet/computers, and talking on the phone or cell phone/text messaging for both typical weekdays and weekend days
Ramos (2012)	HBSC questionnaire *Indicators:* MVPA recommendation, and VPA (weekly)	HBSC questionnaire *Indicators*: daily screen time (watching television, playing with the computer or the console, and using the computer)
Spengler (2015)	Questionnaire MoMo-PAQ *Indicators:* weekly duration of elective PA at school, PA at sports clubs, and leisure time PA outside of sports clubs	KiGGS telephone interview. *Indicators:* daily time spent watching television or video, using a computer, and playing console games

Table S7. Continued.

First author (publication year)	Clusters outcomes (indicator; instrument; variable treatment / unit of measurement)	
	PA	**SB**
Taverno Ross (2016)	Accelerometer, and PAC instrument *Indicators:* MVPA, individual physical activities, team sports, lifestyle activities, wheel activities (weekly)	PAC instrument *Indicators:* educational sedentary, and electronic media (weekly)
te Velde (2007)	Pro Children Project website questionnaire. *Indicator:* hours spent on leisure-time PA (weekly)	Pro Children Project website questionnaire. *Indicators:* hours/day spent on usual TV viewing, PC use, and TV viewing during dinner
Wang (2006)	Modified SAPAC *Indicators:* minutes/week and metabolic equivalent (MET) values of 32 physical activities (physical activity levels categorized as inactive, low, moderate, and high)	Modified SAPAC *Indicators:* time spent on computer/internet, video game, time studying, reading, sitting/talking, using telephone, and watching TV (weekly)
Wang (2012)	SAPAC, and a 7-day PA recall questionnaire *Indicators:* minutes/week of 28 physical activities	SAPAC, and a 7-day PA recall questionnaire *Indicators:* time spent on computer/internet, video game, time studying, reading, sitting/talking, using telephone, and watching TV (weekly)

(A) Instrument Types



(B) Questionnaires Classification

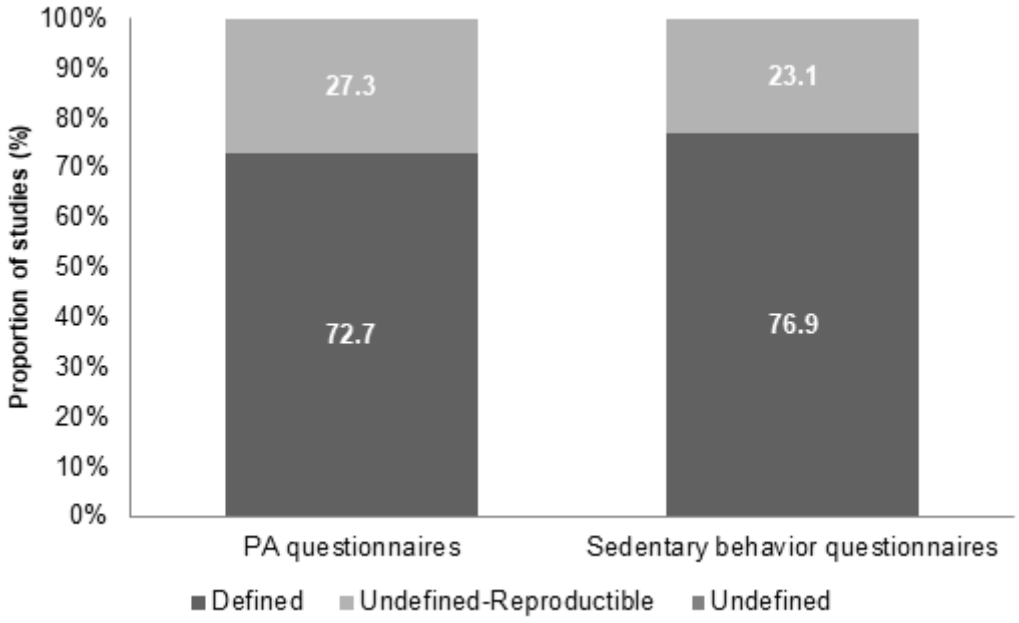


Figure S1. Instrument used and questionnaires classification according to each behavior.

Table S8. Clusters detail

Author (publication year)	Clusters types identified in paper (N / %)	Cluster types defined by review authors
De Bourdeaudhuij (2013)	Boys (n= 361) Cluster 1 (n= 100, 27.70%) Cluster 2 (n= 72, 19.95%) Cluster 3 (n= 107, 29.64%) Cluster 4 (n= 82, 22.71%) Girls (n= 405) Cluster 1 (n= 97, 23.95%) Cluster 2 (n= 85, 20,99%) Cluster 3 (n= 119, 29.38%) Cluster 4 (n= 104, 25.68%)	Girls Cluster 1 - Low PA High SB Cluster 2 High Pa Low SB Cluster 3 - Low PA Low SB Cluster 4 - High SB Boys Cluster 1 - Low PA High SB Cluster 2 - High Pa Low SB Cluster 3 - Low PA Low SB Cluster 4 - High PA High SB
Gorely (2007)	Boys (n= 484) Cluster 1 – sedentary homeworkers (n= 93, 19.2%) Cluster 2 – semi-active socializers (n= 97, 20.0%) Cluster 3 – sedentary television watchers (n= 144, 30%) Cluster 4 – actives (n= 75, 15.4%) Cluster 5 – sedentary computer users (n= 75, 15.4%) Girls (n= 785) Cluster 1 – sedentary homeworkers (n= 198, 25.2%) Cluster 2 – sedentary socializers (n= 206, 26.2%) Cluster 3 – sedentary television watchers (n= 181, 23.1%) Cluster 4 – actives (n= 114, 14.5%) Cluster 5 – sedentary workers (n= 86, 11.0%)	Girls Cluster 1 – Low PA High/Low SB Cluster 2 – Low PA High/Low SB Cluster 3 – Low PA High/Low SB Cluster 4 – High PA Low SB Cluster 5 – Low PA High/Low SB Boys Cluster 1 – Low PA High/Low SB Cluster 2 – Low PA High/Low SB Cluster 3 – Low PA High/Low SB Cluster 4 – High PA Low SB Cluster 5 – Low PA High/Low SB
Huang (2015)	Boys (n= 471) Cluster 1 – actives (n= 43, 9.1%) Cluster 2 – inactive (n= 280, 59.4%) Cluster 3 – sedentary homeworkers (n= 22, 4.7%) Cluster 4 – sedentary TV viewers (n= 78, 16.6%) Cluster 5 – Sedentary games players (n= 48, 10.2%) Girls (n= 480) Cluster 1 – actives (n= 57, 11.9%) Cluster 2 – uninvolved inactive (n= 190, 39.5%) Cluster 3 – sedentary homeworkers (n= 54, 11.3%) Cluster 4 – sedentary TV viewers (n= 41, 8.5%) Cluster 5 – sedentary socializers (n= 138, 28.8%)	Girls Cluster 1 – s High PA Low SB Cluster 2 – Low PA Low SB Cluster 3 – High PA High SB Cluster 4 – High SB Cluster 5 – Low PA High SB Boys Cluster 1 – High PA Low SB Cluster 2 – Low PA Low SB Cluster 3 – High/Low SB Cluster 4 – High PA High SB Cluster 5 – High SB

Table S8. Continued.

Author (publication year)	Clusters types identified in paper (N / %)	Cluster types defined by review authors
Kim (2016)	Boys (n= 6,109) Class 1 – high PA and high SB (n= 1240, 20.3%) Class 2 – high PA and low SB (n= 2351, 38.5%) Class 3 – low PA and high SB (n= 471, 7.7%) Class 4 – low PA and low SB (n= 2047, 33.5%) Girls (n= 5,972) Class 1 – high PA and high SB (n= 1051, 17.6%) Class 2 – high PA and low SB (n= 1380, 23.1%) Class 3 – low PA and high SB (n= 1577, 26.4%) Class 4 – low PA and low SB (n= 1964, 32.9%)	Equal to boys and girls Class 1 - High PA/ High SB Class 2 - High PA / Low SB Class 3 - Low PA / High SB Class 4 - Low PA / Low SB
Lazarou (2009)	3 PA factors / 5 SB factors Factor 1 – physical activity, and sports after school (significantly higher for boys compared to girls) Factor 2 – video, electronic games, and computers (significantly higher for boys compared to girls) Factor 3 – watching TV, video, and DVD Factor 4 – homework, and private lessons (significantly higher for girls compared to boys) Factor 5 – home chores, and outside home chores, aerobics, gymnastics, sports Factor 6 – theater cinema, use of mobile phone (significantly higher for girls compared to boys) Factor 7 – afternoon sleep, less private lessons Factor 8 – sports for all, after-school activities (except sports)	3 PA factors - High PA 5 SB factors - High SB
Marshall (2002)	Boys (n= 819) Cluster 1 – techno-actives (n= 333, 40.7%) Cluster 2 – non-socializing actives (n= 383, 46.7%) Cluster 3 – uninvolved inactives (n= 103, 12.6%) Girls (n= 1,570) Cluster 1 – sociable actives (n= 243, 15.5%) Cluster 2 – non-socializing actives (n= 562, 35.8%) Cluster 3 – uninvolved inactives (n= 765, 48.7%)	Boys Cluster 1 - High PA High SB Cluster 2 - High PA Low SB Cluster 3 - Low PA Low SB Girls Cluster 1 - High PA High SB Cluster 2 - High PA Low SB Cluster 3 - Low PA Low SB
Melkevik (2010)	Boys (n= 2,520) Cluster 1 – moderate SBSB and very high PA (n= 605, 24%) Cluster 2 – moderate SBSB and high PA (n= 630, 25%) Cluster 3 – moderate SBSB and moderate PA (n= 580, 23%) Cluster 4 – low SBSB and low PA (n= 302, 12%) Cluster 5 – high SBSB and low PA (n= 353, 14%) Cluster 6 – very high SBSB and low PA (n= 50, 2%) Girls (n= 2,328) Cluster 1 – moderate SBSB and very high PA (n= 303, 13%) Cluster 2 – moderate SBSB and high PA (n= 466, 20%) Cluster 3 – moderate SBSB and moderate PA (n= 628, 27%) Cluster 4 – moderate SBSB and low PA (n= 256, 11%) Cluster 5 – moderate SBSB (no gaming) and low PA (n= 419, 18%) Cluster 6 – high SBSB and moderate PA (n= 256,11%)	Boys Cluster 1 - High PA - High PA Cluster 2 - High PA Cluster 3 - none Cluster 4 - Low PA Low SB Cluster 5 - Low PA High SB Cluster 6- Low PA High SB Girls Cluster 1 - High PA Cluster 2 - High PA Cluster 3 - none Cluster 4 - Low PA Cluster 5 - Low PA Cluster 6 - High SB

Table S8. Continued.

Author (publication year)	Clusters types identified in paper (N / %)	Cluster types defined by review authors
Nelson (2005)	Cluster 1 – TV/video and gaming (n= 2494, 20.9%) Cluster 2 – skaters and gamers (n= 1119, 9.4%) Cluster 3 – sports with parents (n= 1681, 14.1%) Cluster 4 – uses recreation center (n= 1309, 10.9%) Cluster 5 – limited TV decisions (n= 1522, 12.7%) Cluster 6 – reports few activities (n= 2897, 24.2%) Cluster 7 – active in school (n= 935, 7.8%)	Cluster 1 - High SB Cluster 2 - High PA High SB Cluster 3 - High PA Cluster 4- High PA Cluster 5 - Low SB Cluster 6- Low PA Low SB Cluster 7- High PA
Nelson (2006)	Cluster 1 – TV/video and gaming (n= 2494, 20.9%) Cluster 2 – skaters and gamers (n= 1119, 9.4%) Cluster 3 – sports with parents (n= 1681, 14.1%) Cluster 4 – uses recreation center (n= 1309, 10.9%) Cluster 5 – limited TV decisions (n= 1522, 12.7%) Cluster 6 – reports few activities (n= 2897, 24.2%) Cluster 7 – active in school (n= 935, 7.8%)	Cluster 1 - High SB Cluster 2 - High PA High SB Cluster 3 - High PA Cluster 4- High PA Cluster 5 - Low SB Cluster 6- Low PA Low SB Cluster 7- High PA
O'Neill (2016)	Boys (n= 4,298)* Cluster 1 – high PA and 4.03 mean hours of SB (n= 1924, 43.9%) Cluster 2 – high PA and 4.24 mean hours of SB (n= 807, 18.4%) Cluster 3 – low PA and 4.57 mean hours of SB (n= 578, 13.2%) Cluster 4 – low PA and 4.39 mean hours of SB (n= 989, 22.6%) * 83 cases were excluded due to missing data on one or more of the above variables Girls (did not found coherent profiles)	Boys Cluster 1 - High PA High SB Cluster 2 - High PA High SB Cluster 3 - Low PA High SB Cluster 4 - Low PA High SB
Patnode (2011)	Boys (n= 352) Cluster 1 – active (n= 148, 42.1%) Cluster 2 – sedentary (n= 88, 24.9%) Cluster 3 – low media/moderate activity (n= 116, 33.0%) Girls (n= 368) Cluster 1 – active (n= 69, 18.7%) Cluster 2 – sedentary (n= 175, 47.6%) Cluster 3 – low media/functional activity (n= 124, 33.7%)	Boys Cluster 1 - High PA Low SB Cluster 2 - Low PA High/Low SB - Cluster 3 - Low PA Low SB Girls Cluster 1 - High PA and High/Low SB Cluster 2 - Low PA high SB Cluster 3 - Low PA High/Low SB
Ramos (2012)	Cluster 1 – high MVPA/VPA and low SB (n= 5042, 25.4%) Cluster 2 – high SB and low MVPA/VPA (n= 4404, 22.1%) Cluster 3 – low MVPA/VPA and low SB (n= 10889, 52.5%)	Cluster 1 - High PA Low Cluster 2 - Low PA High SB Cluster 3 - Low PA Low SB

Table S8. Continued.

Author (publication year)	Clusters types identified in paper (N / %)	Cluster types defined by review authors
Spengler (2015)	Boys (n= 1,031) Cluster 1 (n= 343, 33.3%) Cluster 2 (n= 126, 12.2%) Cluster 3 (n= 147, 14.3%) Cluster 4 (n= 50, 4.8%) Cluster 5 (n= 53, 5.2%) Cluster 6 (n= 65, 6.3%) Cluster 7 (n= 50, 4.8%) Cluster 8 (n= 197, 19.1%) Girls (n= 1,052) Cluster 1 (n= 443,42.1%) Cluster 2 (n= 97, 9.2%) Cluster 3 (n= 164, 15.6%) Cluster 4 (n= 65, 6.2%) Cluster 5 (n= 54, 5.1%) Cluster 6 (n= 105, 10.0%) Cluster 7 (n= 124, 11.8%)	Boys (1) Low PA Low SB (2) Low PA High/Low SB (3) Low PA High/Low SB (4) Low PA High SB (5) High/Low PA (6) High/Low PA (7) High/Low PA (8) High/Low PA Low SB Girls (1) Low PA Low SB (2) Low PA High/Low SB (3) Low PA High/Low SB (4) Low PA High SB (5) High/Low PA Low SB (6) High/Low PA Low SB (7) Low PA Low SB
Taverno (2016)	Boys (n= 221) Cluster 1 – low PA and low SB (n= 156, 70.6%) Cluster 2 – moderate PA and high SB (n= 34, 15.4%) Cluster 3 – high PA and high SB (n= 31, 14.0%) Girls (n= 274) Cluster 1 – low PA and low SB (n= 149, 54.4%) Cluster 2 – moderate PA and high SB (n= 90, 32,8%) Cluster 3 – high PA (n= 35, 12.8%)	Boys Class 1 - Low PA Low SB Class 2 - High SB Class 3 - High PA High SB Girls Class 1 - Low PA Low SB Class 2 - High SB Class 3 - High PA
Te velde (2007)	Boys (n= 6,255) Cluster 1 – healthy behavior pattern (n= 2624, 42.0%) Cluster 2 – high TV viewers (n= 1100, 17.6%) Cluster 3 – mixed pattern (n= 1494, 23.9%) Cluster 4 – high PC users (n= 601, 9.6%) Cluster 5 – unhealthy behavior pattern (n= 436, 6.9%) Girls (n= 6,283) Cluster 1 – healthy behavior pattern (n= 1337, 21.3%) Cluster 2 – high TV viewers (n= 1339, 21.3%) Cluster 3 – low SB and low physical exercise behavior (n= 2794, 44.5%) Cluster 4 – high PC users (n= 584, 9.3%) Cluster 5 – high SB and high physical exercise (n= 229, 3.6%)	Boys Cluster 1 - Low SB Cluster 2 - High PA High SB Cluster 3- Low PA High/Low SB Cluster 4 - Low PA High/Low SB Cluster 5 - Low PA High SB Girls Cluster 1 - High PA Low SB Cluster 2 - Low PA High SB Cluster 3 - Low PA Low SB Cluster 4 - Low PA High/Low Cluster 5 - High PA High SB

Table S8. Clusters detail

Author (publication year)	Clusters types identified in paper (N / %)	Cluster types defined by review authors
Wang (2006)	Boys (n= 285)	Boys
	Cluster 1 – non-academically-inclined (n= 75, 26.3%)	Cluster 1 - High PA High/Low SB
	Cluster 2 – academically-inclined (n= 108, 37.9%)	Cluster 2- High PA High/Low SB
	Cluster 3 – techno actives (n= 102, 35.8%)	Cluster 3 - High PA High SB
	Girls (n= 482)	Girls
	Cluster 1 – academically-inclined (n= 134, 27.8%)	Cluster 1 - Low PA High/Low SB
	Cluster 2 – active socialisers (n= 276, 57.3%)	Cluster 2 - High PA High SB
	Cluster 3 – inactive and non-academically-inclined (n= 72, 14.9%)	Cluster 3 - Low PA Low SB
Wang (2011)	Cluster 1 (n= 134, 15.8%)	Cluster 1 - High/Low SB
	Cluster 2 (n= 107, 12.6%)	Cluster 2 - Low PA Low SB
	Cluster 3 (n= 122, 14.5%)	Cluster 3 - High PA High SB
	Cluster 4 (n= 386, 45.6%)	Cluster 4 - Low PA High/Low SB
	Cluster 5 (n= 98, 11.5%)	Cluster 5 - High PA High SB

Note. PA: Physical activity. SB: Sedentary behavior.

APPENDIX D – SUPLEMENTARRY MATERIAL TOPIC 2.3

Table S1. Prisma Checklist

PRISMA 2020 Checklist

Section and Topic	Item#	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Pages 3, 4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Pages 5
Information sources	6	Specify all databases, registers, websites, organizations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 5 and Table S1
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Table S1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 5 and 6
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Pages 7, 8
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in eachstudy were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Pages 7, 8
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Pages 7, 8
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Pages 6, 7
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Pages 7, 8
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Pages 7, 8
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or dataconversions.	Not applicable
	13c	Describe any methods used to tabulate or visually display results of	Page 8

		individual studies and syntheses.	
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe themodel(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Not applicable
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Not applicable
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Not applicable
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Pages 6, 7
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Not applicable

PRISMA 2020 Checklist

Section and Topic	Item#	Checklist item	Location where item is reported
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included inthe review, ideally using a flow diagram.	Page 8, 9 and Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Figure 1
Study characteristics	17	Cite each included study and present its characteristics.	Page 9 and Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Table S2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimates and its precision(e.g. confidence/credible interval), ideally using structured tables or plots.	Pages 10-13, Table 1, 2, Figure 3, Tables S3-S5
Results of syntheses	20a	For each synthesis, briefly summarize the characteristics and risk of bias among contributing studies.	Page 9-10 and Figure 2
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g.confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Not applicable
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Not applicable
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not applicable
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Not applicable
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not applicable
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Pages 13
	23b	Discuss any limitations of the evidence included in the review.	Page 16
	23c	Discuss any limitations of the review processes used.	Page 16
	23d	Discuss implications of the results for practice, policy, and future research.	Page 16-17
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 4-5
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 4-5
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not applicable
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 18
Competing interests	26	Declare any competing interests of review authors.	Page 18
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from includedstudies; data used for all analyses; analytic code; any other materials used in the review.	Electronic Supplementary Material

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Table S2. SWiM checklist

The citation for the Synthesis Without Meta-analysis explanation and elaboration article is: Campbell M, McKenzie JE, Sowden A, Katikireddi SV, Brennan SE, Ellis S, Hartmann-Boyce J, Ryan R, Shepperd S, Thomas J, Welch V, Thomson H. Synthesis without meta-analysis (SWiM) in systematic reviews: reporting guideline BMJ 2020;368:l6890 http://dx.doi.org/10.1136/bmj.l6890

SWiM is intended to complement and be used as an extension to PRISMA			
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
Methods			
1 Grouping studies for synthesis	1a) Provide a description of, and rationale for, the groups used in the synthesis (e.g., groupings of populations, interventions, outcomes, study design)	Not applicable	
	1b) Detail and provide rationale for any changes made subsequent to the protocol in the groups used in the synthesis	Not applicable	
2 Describe the standardised metric and transformation methods used	Describe the standardised metric for each outcome. Explain why the metric(s) was chosen, and describe any methods used to transform the intervention effects, as reported in the study, to the standardised metric, citing any methodological guidance consulted	Not applicable	
3 Describe the synthesis methods	Describe and justify the methods used to synthesise the effects for each outcome when it was not possible to undertake a meta-analysis of effect estimates	Not applicable	
4 Criteria used to prioritise results for summary and synthesis	Where applicable, provide the criteria used, with supporting justification, to select the particular studies, or a particular study, for the main synthesis or to draw conclusions from the synthesis (e.g., based on study design, risk of bias assessments, directness in relation to the review question)	Not applicable	
SWiM reporting item	**Item description**	**Page in manuscript where item is reported**	**Other***
5 Investigation of heterogeneity in reported effects	State the method(s) used to examine heterogeneity in reported effects when it was not possible to undertake a meta-analysis of effect estimates and its extensions to investigate heterogeneity	Not applicable	
6 Certainty of evidence	Describe the methods used to assess certainty of the synthesis findings	Pages 7, 8	
7 Data presentation methods	Describe the graphical and tabular methods used to present the effects (e.g., tables, forest plots, harvest plots). Specify key study characteristics (e.g., study design, risk of bias) used to order the studies, in the text and any tables or graphs, clearly referencing the studies included	Not applicable	

Results			
8 Reporting results	For each comparison and outcome, provide a description of the synthesised findings, and the certainty of the findings. Describe the result in language that is consistent with the question the synthesis addresses, and indicate which studies contribute to the synthesis	Pages 8-13	
Discussion			
9 Limitations of the synthesis	Report the limitations of the synthesis methods used and/or the groupings used in the synthesis, and how these affect the conclusions that can be drawn in relation to the original review question	Page 16	

Table S3. Search of all strategy

PUBMED

Search Group	Search Terms
Physical Activity	sport* OR sports[mesh] OR sports OR "motor activity"[mesh] OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise[mesh] OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness"[mesh] OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR "physical inactivity")
Sedentary Behavior	sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle"[mesh] OR "sedentary lifestyle" OR television[mesh] OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers[mesh] OR computers OR "computer time" OR "computer use" OR "video game*"
Diet Behavior	diet[mesh] OR diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet"[mesh] OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior"[mesh] OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences"[mesh] OR "food preferences" OR "unhealthy food" OR "nutritional quality"
Analysis	"cluster analysis"[mesh] OR "cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity
Population	youth OR adolesce* OR adolescent[mesh] OR adolescent OR adolescent* OR adolescence OR student* OR students[mesh] OR students OR teen* OR teenage* OR schoolchildren OR child* OR child[mesh] OR child OR children[mesh] OR children

Web of Science

Search Group	Search Terms
Physical Activity	TS=(sport* OR sports OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	TS=(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle" OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game*")
Diet Behavior	TS=(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Analysis	TS=("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	TS=(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

SCOPUS

Search Group	Search Terms
Physical Activity	TITLE-ABS-KEY(sport* OR sports OR "motor activity" OR "physical activity" OR "physical activit*" OR exercise OR "exercise*" OR "physical exercise*" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activit*" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	TITLE-ABS-KEY(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyle*" OR "sedentary lifestyle" OR television OR "television time" OR "television watch*" OR "TV watch*" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game*")
Diet Behavior	TITLE-ABS-KEY(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Analysis	TITLE-ABS-KEY("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	TITLE-ABS-KEY(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

LILACS, MEDLINE AND PSYCINFO

Search Group	Search Terms
Physical Activity	(sport OR sports OR "motor activity" OR "physical activity" OR "physical activities" OR exercise OR exercises OR "physical exercise" OR "exercise program*" OR "physical education" OR "physical fitness" OR "leisure time" OR "leisure activity" OR "leisure activities" OR "aerobic activity" OR recreation OR "physical inactivity")
Sedentary Behavior	(sedentarism OR sedentary OR "sedentary behavior" OR "sedentary behaviors" OR "sedentary behaviour" OR "sedentary behaviours" OR "sedentary lifestyles" OR "sedentary lifestyle" OR television OR "television time" OR "television watch" OR "television watches" OR "TV watch" OR "TV watching" OR "TC watches" OR "screen time" OR "screen viewing" OR "screen media" OR "media screen time" OR "time sitting" OR sitting OR "sitting time" OR computers OR "computer time" OR "computer use" OR "video game" OR "video games")
Diet Behavior	(diet OR "diet behavior" OR "diet behaviour" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavior" OR "feeding behavior" OR "feeding behaviors" OR "feeding behaviour" OR "feeding behaviours" OR "eating behavior" OR "eating behaviors" OR "eating behaviour" OR "eating behaviours" OR "food consumption" OR "food choice" OR "food intake" OR "food habit" OR "food habits" OR "food preferences" OR "unhealthy food" OR "nutritional quality")
Clustering	("cluster analysis" OR cluster OR cluster* OR clustering OR co-occur OR co-occurrence OR "behavior pattern" OR "behavior patterns" OR "behaviour pattern" OR "behaviour patterns" OR "lifestyle pattern" OR "lifestyle patterns" OR "latent class" OR "factor analysis" OR "factorial analysis" OR simultaneity)
Population	(youth OR adolesce* OR adolescent OR adolescent* OR adolescence OR student* OR students OR teen* OR teenage* OR schoolchildren OR child* OR child OR children)

Table S4. Assessment of the bias risk of studies.

Article (publication year)	Selection bias		Study design				Assessment tool														
							PA			Diet			SB			Sleep			Withdrawals and drop-outs		
	Q1	Bias	Q2	Q3	Q4	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q5	Q6	Bias	Q7	Q8	Bias
Androutsos (2014) [a]	0	Moderate	1	1	1	Strong	0	0	Weak	1	1	Strong	0	1	Weak	0	1	Weak	1	1	Strong
Collese (2018) [b]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	0/?	Weak
Descarpentrie (2021)	1	Strong	1	1	1	Strong	0	1	Weak	1	1	Strong	0	1	Weak	0	1	Weak	1	-1	Weak
Descarpentrie (2022)	1	Strong	1	1	1	Strong	0	1	Weak	0	1	Weak	1	1	Strong	0	1	Weak	1	1	Strong
Descarpentrie (2023)	1	Strong	1	1	1	Strong	0	1	Weak	1	1	Strong	0	1	Weak	0	1	Weak	1	-1	Weak
D' Souza (2021)	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
D' Souza (2022)	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	-1	Weak
Dumuid (2017)	0	Moderate	0	1	*	Weak	1	1	Strong	1	1	Strong	0	1	Weak	1	1	Strong	1	1	Strong
Dumuid (2017) [c]	-1	Weak	0	1	1	Moderate	1	1	Strong	1	1	Strong	0	1	Weak	1	1	Strong	1	-1	Weak
Dumuid (2016) [c]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Fernández-Alvira (2013) [a]	0	Moderate	1	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Weak	1	1	Strong	0	1	Strong
Ferrar and Golley (2015) [a]	c	Strong	0	-1	1	Weak	1	1	Strong	0	1	Weak	1	1	Strong	0	1	Weak	0	1	Strong
Knebel (2022)	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Magee (2013) [a]	?	Weak	0	-1	1	Weak	0	1	Weak	0	1	Weak	0	1	Weak	0	1	Weak	0	?	Weak
Miguel-Berges (2017)[39] [a]	0	Moderate	0	1	1	Moderate	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Moraes (2016) [c]	-1	Weak	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	0	Moderate
Moschonis (2013) [a]	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Weak	1	0	Moderate
Moschonis (2014) [a]	0	Moderate	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Weak	1	0	Moderate
Nuutinen (2017) [a]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Strong
Pereira (2015) [a]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	?	Weak
Pérez-Rodrigo (2015) [a]	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Weak	1	-1	Weak
Saldanha-Gomes (2020)	1	Strong	1	1	1	Strong	0	1	Weak	1	1	Strong	0	1	Weak	0	1	Weak	0	-1	Weak
Wiersma (2022)	1	Strong	1	1	1	Strong	1	1	Strong	1	1	Strong	0	1	Weak	0	1	Weak	0	1	Strong

PA: physical activity; SB: sedentary behavior; Q1: Are the individuals selected to participate in the study likely to be representative of the target population?; Q2: Is there a description of the representativeness of the sample?; Q3: Was the sampling method described?; Q4: Was the method appropriate?; Q5: Is there a prior validation report of the tool?; Q6: Is there information that makes it possible to replicate the tool?; Q7: Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?; Q8: Indicate the percentage of participants completing the study; ?: impossible to determine; *The selection method differed among study countries. [a] High-Income Countries; [b] Upper-Middle Income Countries; [c] Involves samples from more than one country and with different income classification (Intercontinental Studies with Different Income Countries).

Table S5. Instruments used and questionnaires classification according to each behavior.

Author(s) (publication year)	Instruments classification			
	PA	**SB**	**Sleep**	**Diet**
Androutsos (2014)	Undefined	Undefined	Undefined-reproductible	Interview (24-h recall 2-week days plus one weekend day)
Collese (2018)	Defined	Defined	Defined	Defined
Descarpentrie (2021) [#]	Undefined-reproductible	Undefined-reproductible	Undefined-reproductible	Defined
Descarpentrie (2022)	Undefined-reproductible	Undefined-reproductible	Undefined-reproductible	Undefined-reproductible
Descarpentrie (2023) [#]	Undefined-reproductible	Undefined-reproductible	Undefined-reproductible	Defined
D' Souza (2021)	Accelerometer and questionnaire (Defined)	Accelerometer and questionnaire (Defined)	Defined	Defined
D' Souza (2022)	Accelerometer and questionnaire (Defined)	Accelerometer and questionnaire (Defined)	Defined	Defined
Dumuid (2017)	Accelerometer (Defined)	Accelerometer (Defined)	Accelerometer (Defined)	Defined
Dumuid (2017)[38]	Accelerometer (Defined)	Undefined	Accelerometer (Defined)	Defined
Dumuid (2016)	Accelerometer (Defined)	Undefined	Accelerometer (Defined)	Defined
Fernández-Alvira (2013)	Defined	Defined	Defined	Defined
Ferrar and Golley (2015)[88]	Defined	Defined	Defined	Defined
Knebel (2022)	Defined	Defined	Defined	Defined
Magee (2013)	Dieries	Dieries	Diarie	Undefined-reproductible
Miguel-Berges (2017)	Pedometer (Defined)*	Defined	Defined	Defined
Moraes (2016)	Defined	Defined	Defined	Defined
Moschonis (2013)	Defined	24-h recall	Undefined-reproductible	Interview (24-h recall 2-week days plus one weekend day)
Moschonis (2014)	Defined	24-h recall	Undefined-reproductible	Interview (24-h recall 2-week days plus one weekend day)
Nuutinen (2017)	Defined	Defined	Defined	Defined
Pereira (2015)	Accelerometer (Defined)	Defined	Accelerometer (Defined)	Defined
Pérez-Rodrigo (2015)	Defined	Defined	Undefined-reproductible	Interview 24-h recall (one day) plus three-day record
Saldanha-Gomes (2020)	Undefined-reproductible	Undefined-reproductible	Undefined-reproductible	Defined
Wiersma (2022)	Accelerometer (Defined) and questionnaire (Undefined-reproductible)	Accelerometer (Defined) and questionnaire (Undefined-reproductible)	Undefined-reproductible	Defined

PA: physical activity. SB: sedentary behavior. * Used two instruments (pedometer and questionnaire). [#]Interview. (1) Defined (reported the validation process); (2) Undefined (reported question and/or response option and instrument reference); (3) Undefined-Reproducible (reported question and response options but no instrument reference)

Table S6. Behavioral outcomes used to define PA, sedentary behavior, sleep and diet included in data driven cluster procedures.

	Physical activity outcomes																							
Author (publication year)	LTPA	Total PA (min/day)	Overall, PA (3 domains) (min/day)	Overall, PA (3 domains) (min/week)	Overall, PA (2 domains) (min/week)	LPA (min/day)	MPA (min/day)	VPA (min/day)	MVPA (min/day)	Play (min/day)	Team sports (min/day)	Non-team sports (min/day)	Active transport (min/day)	Organized sport/PA or active play (h/day)	Organized sports (min/day)	Sports (hour/week)	Biking (min/day)	Walking (min/day)	Outdoor play (days/week)	Outdoor play (min/day)	Outdoor play (hour/day)	Walking (types of transport)	Walking (min/day)	Walking (hour/day)
Androutsos (2014)	■																							
Collese (2018)			■																					
Descarpentrie (2021) #																					■			■
Descarpentrie (2022)																			■					
Descarpentrie (2023) #																					■			■
D' Souza (2021)									■						■					■				
D' Souza (2022)									■						■					■				
Dumuid (2017)						■	■	■																
Dumuid (2017)						■	■	■																
Dumuid (2016)						■	■	■																
Fernández-Alvira (2013)					■																			
Ferrar and Golley (2015)										■	■	■	■											
Knebel (2022)		■																						
Magee (2013)														■										
Miguel-Berges (2017)																■								
Moraes (2016)				■																				
Moschonis (2013)									■															
Moschonis (2014)									■															
Nuutinen (2017)	■																							
Pereira (2015)									■															
Pérez-Rodrigo (2015)							■	■									■	■						
Wiersma (2022)									■											■				

Note: LTPA: leisure time physical activity. LPA: light physical activity. MVPA: moderate vigorous physical activity.

Sedentary behavior outcomes

Author (publication year)	Screen time: TV+PC+VG (hours/day)	Hours/day - screen time (TV+PC)	Min/day of screen time (TV+PC+VG)	Screen time: TV+PC (min/day)	Sedentary time - accelerometry (min/day)	TV (min/day)	PC (min/day)	VG (min/day)	TV (h/day)	PC (h/day)	VG (h/day)	Cellphone/Smartphone	Social interaction (min/day)	Eating (min/day)	Quiet time (min/day)	Study/homework/music (min/day)	Reading (min/day)	Passive transport (min/day)
Androutsos (2014)	■																	
Collese (2018)	■																	
Descarpentrie (2021) [#]	■																	
Descarpentrie (2022)	■																	
Descarpentrie (2023) [#]	■																	
D' Souza (2021)				■	■			■							■			
D' Souza (2022)				■	■			■							■			
Dumuid (2017)					■													
Dumuid (2017)	■				■													
Dumuid (2016)	■				■													
Fernández-Alvira (2013)				■														
Ferrar and Golley (2015)						■	■	■					■	■	■	■	■	■
Knebel (2022)									■	■	■	■						
Magee (2013)		■																
Miguel-Berges (2017)		■																
Moraes (2016)	■																	
Moschonis (2013)	■																	
Moschonis (2014)	■																	
Nuutinen (2017)									■	■	■							
Pereira (2015)	■																	
Pérez-Rodrigo (2015)			■															
Wiersma (2022)				■	■													

Note: Acc: accelerometer. TV: television. PC: computer. VG: video game.

	Sleep outcomes					
Author (publication year)	Hours/day	Min/day	Accelerometer (min/day)	Accelerometer (hour/day)	Sleep Discrepancy	Sleep quality
Androutsos (2014)	■					
Collese (2018)	■					
Descarpentrie (2021) [#]	■					
Descarpentrie (2022)	■					
Descarpentrie (2023) [#]	■					
D' Souza (2021)		■				
D' Souza (2022)		■				
Dumuid (2017)			■			
Dumuid (2017)			■			
Dumuid (2016)			■			
Fernández-Alvira (2013)	■					
Ferrar and Golley (2015)		■				
Knebel (2022)	■					
Magee (2013)	■					
Miguel-Berges (2017)	■					
Moraes (2016)	■					
Moschonis (2013)	■					
Moschonis (2014)	■					
Nuutinen (2017)	■				■	■
Pereira (2015)				■		
Pérez-Rodrigo (2015)	■					
Wiersma (2022)		■				

Diet outcomes

Author (publication year)	F&V (portion/day)	F&V (CDC daily recommendation)	F&V (times/day)	F&V (serves/week)	F&V (times/week)	Water (portion/day)	Sugary drinks (portion/day)	Sugary drinks (grams/day)	Sugary drinks (times/day)	Sweet beverages (portion/day)	Sweet beverages (ml/day)	Sweet beverages (serves/week)	Sweet beverages (times/week)	Sweet snacks and desserts (time/week)	Rice/pasta (times/week)	Bread (times/week)	Crisps (times/week)	French fries (times/week)	Savory discretionary food intake (times/day)	Sweet discretionary food intake (times/day)	Fast food (times/day)	Junk food (times/week)	Score - positive food group	Score - negative food group	PCA - F&V	PCA - Healthy eating pattern#	PCA - Unhealthy eating pattern*	PCA - ultra processed foods	EFA - Mediterranean	EFA- Sandwich	EFA - Pasta	EFA - Milk-sugary foods
Androutsos (2014)								■																								
Collese (2018)				■								■																				
Descarpentrie (2021) [#]													■	■			■	■														
Descarpentrie (2022)													■		■	■		■														
Descarpentrie (2023) [#]													■	■			■	■														
D' Souza (2021) [£]																			■	■												
D' Souza (2022) [£]																			■	■												
Dumuid (2017)																										■	■					
Dumuid (2017)																										■	■					
Dumuid (2016)																										■	■					
Fernández-Alvira (2013)											■																					
Ferrar and Golley (2015)																																
Knebel (2022)																									■			■				
Magee (2013)			■						■												■											
Miguel-Berges (2017)	■					■	■			■																						
Moraes (2016)					■								■																			
Moschonis (2013)								■																								
Moschonis (2014)								■																								
Nuutinen (2017)					■																	■										
Pereira (2015)					■								■																			
Pérez-Rodrigo (2015)																												■	■	■	■	
Wiersma (2022)																							■	■								

Diet outcomes - continued

Author (publication year)	Breakfast and meal frequency	Fruit (serves/day)	Fruit (grams/day)	Fruit (times/day)	Fruit (times/week)	Fruit (not specified)	Vegetable (serves/day)	Vegetable (grams/day)	Vegetables (times/day)	Vegetable (times/week)	Vegetable (not specified)	Whole-grain products (serves/day)	Whole-grain products (grams/day)	Processed meat (times/week)	Red meat (serves/day)	Red meat (grams/day)	Red meat (not specified)	Fish (grams/day)	Fish (times/week)	Fish (not specified)	Yogurts (times/week)	Dairy (serves/day)	Dairy (grams/day)	Dairy (times/week)	Healthy fat (serves/day)	Extra foods (serves/day)
Androutsos (2014)	■		■					■					■			■		■								
Collese (2018)																										
Descarpentrie (2021) [#]					■					■				■					■					■		
Descarpentrie (2022)					■					■									■		■					
Descarpentrie (2023) [#]					■					■				■					■					■		
D' Souza (2021) [£]				■					■																	
D' Souza (2022) [£]				■					■																	
Dumuid (2017)																										
Dumuid (2017)																										
Dumuid (2016)																										
Fernández-Alvira (2013)																										
Ferrar and Golley (2015)		■					■					■			■							■			■	■
Knebel (2022)																										
Magee (2013)																										
Miguel-Berges (2017)																										
Moraes (2016)																										
Moschonis (2013)	■					■					■		■				■			■			■			
Moschonis (2014)	■					■					■		■				■			■			■			
Nuutinen (2017)																										
Pereira (2015)																										
Pérez-Rodrigo (2015)																										
Wiersma (2022)																										

Table S7. Clusters Detail

Authors (publication year)	Clusters types identified in paper (N / %)	Cluster types defined by review authors
Androutsos (2014)	Component 1 Component 2 Component 3 Component 4 Component 5	Component 1 – High FV Component 2 – High FV Component 3 – High SB UPF Low sleep Component 4 – High PA Component 5 – Specific diet
Collese (2018)	**HELENA Boys (n=592)** Cluster 1 – Sedentary (n=141, 23.9%) Cluster 2 – Healthy (n=253, 42.7%) Cluster 3 – Unhealthy Eating (n=197, 33.3%) **HELENA Girls (n=660)** Cluster 1 – Sedentary (n=137, 20.8%) Cluster 2 – Active (n=105, 15.9%) Cluster 3 – Unhealthy Eating (n=183, 27.7%) Cluster 4 – Healthy eating (n=237, 35.9%) **BRACAH Boys (n=312)** Cluster 1 – Sedentary (n=139, 44.7%) Cluster 2 – Active (n=67, 21.5%) Cluster 3 – Healthy Eating (n=105, 33.8%) **BRACAH Girls (n=370)** Cluster 1 – Sedentary (n=66, 17.8%) Cluster 2 – Active (n= 54, 14.5%) Cluster 3 – Unhealthy eating (n=134, 36.2%) Cluster 4 – Healthy Eating (n=116, 31.5%)	**HELENA Boys** Cluster 1 – High SB UPF Cluster 2 – High PA FV Sleep Low SB UPF Cluster 3 – Low PA FV Sleep **HELENA Girls** Cluster 1 – High SB UPF Cluster 2 – High PA Cluster 3 – Low FV Sleep Cluster 4 – Low SB UPF High FV Sleep **BRACAH Boys** Cluster 1 – Low PA FV High SB UPF Cluster 2 – High PA FV Cluster 3 – Low PA SB UPF High FV **BRACAH Girls** Cluster 1 – High SB Sleep Cluster 2 – High PA Cluster 3 – High UPF Low FV Cluster 4 – High FV Low UPF
Descarpentrie (2021)[167]	**Boys (n=519)** Component 1 – Unhealthy Component 2 – Healthy Component 3 – Mixed **Girls (n=459)** Component 1 – Unhealthy Component 2 – Healthy Component 3 – Mixed	**Boys (n=519)** Component 1 – High SB UPF Low sleep Component 2 – Low SB High FV Specific diet Component 3 – High PA SB sleep Specific diet **Girls (n=459)** Component 1 – High SB UPF Low FV Component 2 – Low SB High FV Specific diet Component 3 – High PA SB UPF Low sleep

Descarpentrie (2022)	**Boys (n=121)** Component 1 – LP1 Component 2 – LP2 **Girls (n=114)** Component 1 – LP1	**Boys (n=121)** Component 1 – High PA FV UPF Sleep Specific diet Component 2 – High PA UPF Specific diet **Girls (n=114)** Component 1 – High FV UPF sleep Specific diet
Descarpentrie (2023)	**Boys (n=519)** Component 1 – Unhealthy Component 2 – Healthy Component 3 – Mixed **Girls (n=459)** Component 1 – Unhealthy Component 2 – Healthy Component 3 – Mixed	**Boys (n=519)** Component 1 – High SB UPF Low sleep Component 2 – Low SB High FV Specific diet Component 3 – High PA SB sleep Specific diet **Girls (n=459)** Component 1 – High SB UPF Low FV Component 2 – Low SB High FV Specific diet Component 3 – High PA SB UPF Low sleep
D' Souza (2021)	**K-means** 1 – Unhealthy (n=133) 2 – Active healthy eaters (n=102) 3 – Active sleepers, non-sedentary unhealthy eaters (n=197) **LPA** 1 – Unhealthy (n=206) 2 – Active healthy eaters (n=84) 3 – Active non-sedentary unhealth eaters (n=142) **PCA** 1 – Component 1 – Active sleepers, non-sedentary unhealth eaters 2 – Component 2 – Activate healthy eaters 3 – Component 3 – Poor sleepers and sedentary snackers 4 – Component 3 – Inactive sedentary sleepers	**K-means** 1 – Low PA FV sleep High SB UPF 2 – High PA FV Low SB UPF 3 – High PA sleep Low SB FV **LPA** 1 – Low PA FV High SB 2 – High PA FV 3 – High PA UPF Low SB FV **PCA** 1 – High PA UPF Low SB Satisfactory Sleep 2 – High PA FV 3 – High SB UPF Low Sleep 4 – Low PA High SB sleep
D' Souza (2022)	**K-means** 1 – Unhealthy (n=133) 2 – Active healthy eaters (n=102) 3 – Active sleepers, non-sedentary unhealthy eaters (n=197) **LPA** 1 – Unhealthy (n=206) 2 – Active healthy eaters (n=84) 3 – Active non-sedentary unhealth eaters (n=142) **PCA** 1 – Component 1 – Active sleepers, non-sedentary unhealth eaters 2 – Component 2 – Activate healthy eaters 3 – Component 3 – Poor sleepers and sedentary snackers 4 – Component 3 – Inactive sedentary sleepers	**K-means** 1 – Low PA FV sleep High SB UPF 2 – High PA FV Low SB UPF 3 – High PA sleep and Low SB FV **LPA** 1 – Low PA FV High SB 2 – High PA FV 3 – High PA UPF Low SB FV **PCA** 1 – High PA UPF Low SB Satisfactory Sleep 2 –High PA FV 3 – High SB UPF Low Sleep 4 – Low PA High SB sleep

Dumuid (2017)	**Australia:** Sitters (n=105, 24%); Actives (n=98,23%);Junk food screeners (n=99, 23%); All-rounders (n=127, 30%). **Brazil:** Retro-actives (n=134, 31%); Sitters (n=127, 29%); Junk food techno-actives (n=56, 13%), Techno-active (n=118, 27%). **Canada:** Junk food screeners (n=152, 31%); Junk food techno-actives (n=22, 4%); Sitters (n=136, 27%); All-rounders (n=185, 37%). **China:** Junk food screeners (n=47, 10%); All-rounders (n=104, 23%); Actives (n=167, 36%); Sitters (n=140, 31%). **Colombia:** Low sleep (n=244, 30%); Sitters (n=161, 20%); Junk food techno-actives (n=180, 22%), All-rounders (n=235, 29%). **England:** Junk food screeners (n=94, 25%); Actives (n=87, 23%); Sitters (n=84, 23%); All-rounders (n=108, 29%). **Finland:** Actives (n=150, 35%); All-rounders (n=122, 28%); Sitters (n=139, 32%); Junk food screeners (n=21, 5%). **India:** All-rounders (n=119, 23%); Sitters (n=18, 35%), Junk food screeners (n=59, 13%); Actives (n=165, 31%). **Kenya:** Retro-active (n=123, 27%), Lightly active (n=130, 29%); Junk food techno-actives (n=98, 22%); Sitters (n=99, 22%). **Portugal:** All-rounders (n=164,29%); Actives (n=166, 30%); Sitters (n=158, 28%); Junk food screeners (n=74 , 13%). **South Africa:** Low food intake (n=99, 27%); Sitters (n=92, 25%); Retro-actives (n=81, 23%); Junk food screeners (n=89, 25%). **US:** Sitters (n=88, 21%); Actives (n=113, 27%); All-rounders (n=150, 36%); Junk food screeners (n=67; 16%).	Sitters – Low PA Sleep High SB Actives – High PA Low Sleep Junk food screeners – High SB UPF Low Sleep Junk food techno actives – High PA SB UPF Low Sleep Techno-actives – High PA SB Low Sleep Retro-actives – High PA Low SB Sleep All-rounders – Low SB High FV Low food intake – Low PA FV Sleep High SB Lightly active – Moderate PA Low sleep – High PA SB Low sleep
Dumuid (2017)	Junk Food Screeners (n=19, 6.7%) All-Rounders (n=30, 10.7%) Actives (n=24, 8.5%) Sitters (n=27, 9.5%)	Junk Food Screeners – High SB UPF Low FV Satisfactory Sleep All-Rounders – Low SB UPF High FV Satisfactory Sleep Actives – High PA Low SB Satisfactory Sleep Sitters – Low PA High SB Satisfactory Sleep
Dumuind (2016)	**Boys** (n = 2576) Cluster 1 – Junk Food Screeners (n=274, 9%) Cluster 2 – Actives (n=887, 34%) Cluster 3 – Sitters (n=702, 27%) Cluster 4 – All-Rounders (n=713, 287%) **Girls** (n = 3134) Cluster 1 – Junk Food Screeners (n=325, 10%) Cluster 2 – Actives (n=958, 30%) Cluster 3 – Sitters (n=991, 32%) Cluster 4 – All-Rounders (n=860, 28%)	**Boys** Cluster 1 – High SB UPF Satisfactory Sleep Cluster 2 – High PA Low SB Satisfactory Sleep Cluster 3 – Low PA Low SB Satisfactory Sleep Cluster 4 – Low SB High FV Satisfactory Sleep **Girls** Cluster 1 – High SB UPF Satisfactory Sleep Cluster 2 – High PA Low SB Satisfactory Sleep Cluster 3 – Low PA Low SB Satisfactory Sleep Cluster 4 – Low SB High FV Satisfactory Sleep

Fernández-Alvira (2013)	**Girls (n= 2871)** Active pattern (n=641, 22.3%) Long sleepers inactive pattern (n=615, 21.4%) Sedentary sugared drinks consumers (n=436, 15.2%) Short sleepers inactive pattern (n=529, 18.4%) Low activity (n=650, 22.6%) **Boys (n=2413)** Active pattern (n=540, 22.4%) Long sleepers inactive pattern (n=479, 19.9%) Sedentary sugared drinks consumers (n=240, 9.9%) Short sleepers inactive pattern (n=753, 31.2%) Sedentary pattern (n=401, 16.6%)	**Girls** Active pattern – High PA Low SB UPF Long sleepers' inactive pattern – High Sleep Low PA SB UPF Satisfactory Sleep Sedentary sugared drinks consumers – High SB UPF Short sleepers' inactive pattern – Low Sleep PA SB UPF Low activity – Low PA SB UPF Satisfactory Sleep **Boys** Active pattern – High PA Low SB UPF Long sleepers' inactive pattern – Low PA SB UPF Satisfactory Sleep Sedentary sugared drinks consumers – High SB UPF Short sleepers inactive pattern – Low Sleep PA SB UPF Sedentary pattern – High SB
Ferrar (2015)	**Boys (n = 930)** Healthy Academic (n=189, 20.3%) Active sitter (n=318, 34.2%) Unhealthy (n=328, 35.3%) Social Helper (n=95, 10.2%) **Girls (n = 923)** Unhealthy Screener (n=309, 33.5%) Healthy Academic (n=257, 27.8%) Healthy and Unhealthy (n=213, 23.1%) Active Sitter (n=144, 15.6%).	**Boys** Healthy Academic – High PA SB FV Satisfactory Sleep Active sitter – High PA SB Satisfactory Sleep Unhealthy – High SB UPF Low FV Satisfactory Sleep Social Helper – High SB FV Satisfactory Sleep **Girls** Unhealthy Screener – High SB UPF Sleep Healthy Academic – High SB FV Satisfactory Sleep Healthy and Unhealthy – High PA SB FV UPF Satisfactory Sleep Active Sitter – High PA SB Sleep
Knebel (2022)	Phubbers (n=379, 50.53%) Healthier (n=200, 26.67%) Gamers (n=171, 22.80%)	Phubbers – Low PA SB Healthier – High PA FV Low SB Gamers – High SB UPF
Magee (2013)	Cluster 1 healthy (n=508, 27,7%) Cluster 2 sedentary (n=455, 24,8%) Cluster 3 unhealthy eaters (n=870, 47,5%)	Cluster 1 – High PA FV S**leep** Low SB UPF Cluster 2 – Low PA High SB Satisfactory Sleep Cluster 3 – High UPF Satisfactory Sleep
Miguel-Berges (2017)	Cluster 1: Healthy diet and low activity (NR) Cluster 2: Active (NR) Cluster 3: Healthy lifestyle (NR) Cluster 4: High water and screen time; low fruit and vegetables (NR) Cluster 5: Unhealthy lifestyle (NR) Cluster 6: High fruit and vegetables consumers (NR)	Cluster 1 – Low PA High FV Satisfactory Sleep Cluster 2 – High PA Low FV Satisfactory Sleep Cluster 3 – High PA FV Low SB UPF Satisfactory Sleep Cluster 4 – Low PA FV High SB Satisfactory Sleep Cluster 5 – Low PA FV High SB UPF Satisfactory Sleep Cluster 6 – Low PA High FV Satisfactory Sleep

Moraes (2016)	**HELENA Boys (n=592)** Cluster 1 – Sedentary (n=141, 23.9%) Cluster 2 – Healthy (n=253, 42.7%) Cluster 3 – Unhealthy Eating (n=197, 33.3%) **HELENA Girls (n=660)** Cluster 1 – Sedentary (n=137, 20.8%) Cluster 2 – Active (n=105, 15.9%) Cluster 3 – Unhealthy Eating (n=183, 27.7%) Cluster 4 – Healthy eating (n=237, 35.9%) **BRACAH Boys (n=312)** Cluster 1 – Sedentary (n=139, 44.7%) Cluster 2 – Active (n=67, 21.5%) Cluster 3 – Healthy Eating (n=105, 33.8%) **BRACAH Girls (n=370)** Cluster 1 – Sedentary (n=66, 17.8%) Cluster 2 – Active (n= 54, 14.5%) Cluster 3 – Unhealthy eating (n=134, 36.2%) Cluster 4 – Healthy Eating (n=116, 31.5%)	**HELENA Boys** Cluster 1 – High SB UPF Cluster 2 – High PA FV Sleep Low SB UPF Cluster 3 – Low PA FV Sleep **HELENA Girls** Cluster 1 – High SB UPF Cluster 2 – High PA Cluster 3 – Low FV Sleep Cluster 4 – Low SB UPF High FV Sleep **BRACAH Boys** Cluster 1 – Low PA FV High SB UPF Cluster 2 – High PA FV Cluster 3 – Low PA SB UPF High FV **BRACAH Girls** Cluster 1 – High SB Sleep Cluster 2 – High PA Cluster 3 – High UPF Low FV Cluster 4 – High FV Low UPF
Moschonis (2012)	Component 1 Component 2 Component 3 Component 4 Component 5	Component 1 – Specific diet Component 2 – High FV Component 3 – High SB UPF Low Sleep Component 4 – High PA Component 5 – Specific diet
Moschonis (2013)	Component 1 Component 2 Component 3 Component 4 Component 5	Component 1 – Specific diet Component 2 – High FV Component 3 – High SB UPF Low Sleep Component 4 – High PA Component 5 – Specific diet
Nuutinen (2017)	**Boys** Cluster 1 – Health lifestyle (n=996, 55%) Cluster 2 – High screen time, unhealthy lifestyle (n=308, 17%) Cluster 3 – Low/moderate screen time, unhealthy lifestyle (n=510, 28%) **Girls** Cluster 1 – Health lifestyle (n=1112, 54%) Cluster 2 – High screen time, unhealthy lifestyle (n=505, 25%) Cluster 3 – Poor sleep, unhealthy lifestyle (n=434, 21%)	**Boys** Cluster 1 – High PA FV Low SB UPF Satisfactory Sleep duration, (High quality and Low sleep discrepancy) Cluster 2 – Low PA FV Sleep High SB UPF (High discrepancy of sleep) Cluster 3 – Low PA FV Sleep High SB UPF (High discrepancy and quality of sleep) **Girls** Cluster 1 – High PA FV Low SB UPF Satisfactory Sleep duration, (High quality and Low sleep discrepancy) Cluster 2 – Low PA FV Sleep High SB UPF (Low discrepancy and quality)

		Cluster 3 – Low SB Satisfactory Sleep (Low discrepancy and quality of sleep)
Pereira (2015)	Class 1 – Sedentary, Poorer Diet Quality (n=242, 35.3%) Class 2 – Insufficiently Active, better diet quality (n=444, 64.7%)	Class 1 – Low PA FV Sleep High SB UPF Class 2 – Low PA UPF FV Sleep
Pérez-Rodrigo (2016)	1. Unhealthier Lifestyle Pattern (n=319, 76.9%) 2. Healthier Lifestyle Pattern (n=96, 23.1%)	1. Low PA FV High UPF 2. High PA FV Low SB UPF
Wiersma (2022)	Component 1 – High activity Component 2 – Low screen time, High sleep and Health diet Component 3 – High outdoor play	Component 1 – High PA Low SB Component 2 – Low SB High FV Sleep Component 3 – High PA Low FV

Note. PA: Physical activity. SB: Sedentary behavior. FV: Fruit and vegetables. UPF: ultra-processed foods. Specific Diet" involve consumption of foods that do not frame on FV and UPF (e.g., milk and meat consumption).

Table S8. Association between cluster types and health indicators (n = 16).

Authors (publication year)	Association Analysis	Indicators associated with clusters	Direction of association
Androutsos (2014)[44]	Linear regression	Insulin Resistance (continuous)	High FV **(0)** High FV **(0)** High SB UPF Low sleep **(+)** (β = 0.043/ p = 0.040) High PA **(-)** (β = -0.061/ p = 0.003) Specific diet **(0)**
Descarpentrie (2022)[46]	Linear regression	Specific phobia symptoms (continuous) Separation anxiety symptoms (continuous) Generalized anxiety symptoms (continuous) Depression/dysthymia symptoms (continuous) Opposition symptoms (continuous) Conduct problem symptoms (continuous) Hyperactivity–inattention symptoms (continuous) Strength and competencies (continuous) Emotional symptoms (continuous) Peer relationship problems (continuous) Conduct problem symptoms (continuous) Prosocial behaviors (continuous)	**Boys** High PA FV UPF Sleep Specific diet: Specific phobia symptoms (-) (β = -0.20 [95%CI = -0.39; -0.01]); Separation anxiety symptoms (-) (β = -0.22 [95%CI = -0.37; -0.06); Generalized anxiety symptoms (-) (β = -0.21 [95%CI = -0.39; -0.04]); Hyperactivity-inattention symptoms (-) (β = -0.20 [95%CI = -0.34; -0,06) High PA UPF Specific diet: Emotional symptoms (-) (β = -0.32 [95%CI = -0.50; -0.14]) **Girls** High FV UPF Sleep Specific diet: Peer relationship problems (-) (β = -0.24 [95%CI = -0.40; -0.09]); Prosocial behaviors (+) (β = 0.31 [95%CI = 0.17; 0.45])
Descarpentrie (2023)[162]	Linear regression	Prosocial behaviors (continuous) Total difficulties (continuous) Hyperactivity/inattention symptoms (continuous) Conduct problems (continuous) Emotional problems (continuous) Peer relationship problems (continuous) BMI z-score	**Boys** High SB UPF Low sleep **(0)** Low SB High FV Specific diet: Prosocial behaviors (+) (β = 0.14 [95%CI = 0.01; 0.26]); Hyperactivity/inattention symptoms (-) (β = -0.12 [95%CI = -0.12]) High PA SB sleep Specific diet **(0)** **Girls** High SB UPF Low FV **(0)** Low SB High FV Specific diet **(0)** High PA SB UPF Low sleep: Prosocial behaviors (+) (β = 0.12 [95%CI = 0.01; 0.24]

Table S8 – Continued

Authors (publication year)	Association Analysis	Indicators associated with clusters	Direction of association
D'Souza (2022)[165]	Linear regression	BMI z-score (continuous) Waist circumference (continuous) Health-related quality of life (HRQoL)	**CA** High PA sleep Low SB FV: emotional functioning HRQoL (+) (β = 6.02 / p-value = 0.021); social functioning HRQoL (+) (β = 7.50 / p-value = 0.017); psychosocial functioning HRQoL (+) (β = 5.70 / p-value = 0.035) **PCA** High PA UPF Low SB Satisfactory Sleep: Social functioning (+) (β = 1.80 / p-value = 0.035) High PA FV **(0)** High SB UPF Low Sleep: BMI z-score (+) (β = 0.09 / p-value = 0.015); Waist circumference (+) (β = 0.07 / p-value = 0.028) Low PA High SB Sleep: BMI z-score (-) (β = -0.10 / p-value = 0.021)
Dumuid (2017)[37]	ANCOVA	Health-related quality of life (HRQoL) (continuous)	Low PA Sleep High SB High PA Low Sleep High SB UPF Low Sleep High PA SB UPF Low Sleep High PA SB Low Sleep High PA Low SB Sleep Low SB High FV **(greatest HRQoL compared to others)** Low PA FV Sleep High SB High PA SB Low sleep
Dumuind (2016)[105]	ANCOVA	WC, body fat, BMI, overweight including obesity (continuous - z-score classified by WHO and Task force)	Significant differences in weight status and adiposity for both boys' and girls' clusters
Ferrar (2015)[88]	χ2	Weight status (binary – overweight/obese versus non-overweight/obese)	**Boys** High PA SB FV Satisfactory Sleep High PA SB Satisfactory Sleep **(Lower frequency of overweight/obesity)** Unhealthy – High SB UPF Low FV Satisfactory Sleep High SB FV Satisfactory Sleep **Girls** High SB UPF Sleep High SB FV Satisfactory Sleep **(Lower frequency of overweight/obesity)** High PA SB FV UPF Satisfactory Sleep High PA SB Sleep

Table S8 – Continued

Authors (publication year)	Association Analysis	Indicators associated with clusters	Direction of association
Magee (2013)[42]	Logistic regression	Obesity (classified by obesity task force - overweight/obesity)	High PA FV Sleep Low SB UPF **(ref.)** Low PA High SB Satisfactory Sleep **(+)** (OR = 1.61 [95%CI = 1.16; 2.22] baseline / OR = 1.59 [95%CI = 1.06; 2.38] follow-up) High UPF Satisfactory Sleep **(0/+)** (0 baseline / OR = 1.47 [95%CI = 1.03; 2.13] follow-up)
Miguel-Berges (2017)[39]	χ2	BMI (categorical - normal, overweight obesity classified by Cole)	0
Moraes (2016)[80]	Multilevel linear regression	Systolic blood pressure (SBP) (continuous) Diastolic blood pressure (DBP) (continuous)	**HELENA Boys** High SB UPF **(ref)** High PA FV Sleep Low SB UPF **(0)** Low PA FV Sleep **(+)** (SBP: β = 4.10 [95%CI = 0.80; 7.40]) **HELENA Girls** High SB UPF **(ref)** High PA **(0)** Low FV Sleep **(0)** Low SB UPF High FV Sleep **(-)** (DBP: β = −2.46 [95%CI = -4.62; -0.30]) **BRACAH Boys** Low PA FV High SB UPF **(ref)** High PA FV **(0)** Low PA SB UPF High FV **(-)** (SBP: β = −2.79 [95%CI = -3.10; -0.15]) **BRACAH Girls** High SB Sleep **(ref)** High PA **(0)** High UPF Low FV **(+)** (SBP: β = 4.54 [95%CI = 1.29; 7.79]) High FV Low UPF **(0)**
Moschonis (2012)[45]	Linear regression	Total cholesterol, HDL, LDL, Triglycerides (continuous)	Specific diet **(0)** High FV **(0)** High SB UPF Low Sleep **(-/+)**: HDL cholesterol (β = −0.077; p-value = <0.001); Total/HDL cholesterol ratio (β = 0.049; p-value = 0.025) High PA **(-):** total cholesterol (β = −0.064; p-value = 0.006); LDL (β = −0.065; p-value = 0.004); total/HDL (β = −0.043; p-value = 0.049) Specific diet **(0)**

Table S8 – Continued

Authors (publication year)	Association Analysis	Indicators associated with clusters	Direction of association
Moschonis (2013)[108]	Linear regression	BMI, WC, sum of skinfold thicknesses (SST), fat mass, trunk fat, visceral trunk fat (continuous)	Specific diet **(-)**: BMI (β = −0.06; p-value = 0.007); WC (β = −0.06; p-value = 0.007); SST (β = −0.08; p-value = <0.001); fat mass (β = −0.05; p-value = 0.029) High FV **(-)**: SST (β = −0.07; p-value = 0.002) High SB UPF Low Sleep **(0)** High PA **(-)**: BMI (β = −0.05; p-value = 0.024); WC (β = −0.06; p-value = 0.012); fat mass (β −0.08; p-value = <0.001); trunk fat (β = −0.09; p-value = 0.002) Specific diet **(-)**
Nuutinen (2017)[43]	Logistic regression	Overweight including obesity (binary - overweight/obesity and normal, classified by Cole)	**Boys** High PA FV Low SB UPF Satisfactory Sleep duration, (High quality and Low sleep discrepancy) **(ref.)** Low PA FV Sleep High SB UPF (High sleep discrepancy) **(0)** Low PA FV Sleep High UPF SB (High sleep discrepancy and quality) **(0)** **Girls** High PA FV Low SB UPF Satisfactory Sleep duration, (High quality and Low sleep discrepancy) **(ref.)** Low PA FV Sleep duration High SB UPF (High sleep discrepancy and quality) **(+) (β 1.42)** Low SB Satisfactory Sleep (Low sleep discrepancy and quality) **(0)**
Pereira (2015)[106]	Pearson x^2	Overweight including obesity (binary - overweight/obesity and normal, classified by WHO)	Low PA FV Sleep High SB UPF **(0)** Low PA UPF FV Sleep **(0)**
Pérez-Rodrigo (2016)[82]	Pearson x^2	Overweight including obesity (binary - overweight/obesity and normal, classified by Cole)	Low PA FV High UPF **(0)** High PA FV Low SB UPF **(0)**
Wiesman (2022)[163]	Logistic regression Linear regression	Overweight (yes/no) BMI z-score	High PA Low SB **(0)** Low SB High FV Sleep: Overweight (lower probability to be overweight at 10-11 years; OR = 0.776 [95%CI = 0.66; 0.92]); BMI z-score (-) (β = -0.071 [95%CI = -0.11; -0.03). High PA Low FV **(0)**

ANCOVA: Analysis of Covariance WC: weight circumference. BMI: body mass index. PA: physical activity. SB: sedentary behavior. UPF: ultra-processed foods. FV: fruit and vegetables. Specific Diet" involve consumption of foods that do not frame on FV and UPF (e.g., milk and meat consumption); (+) indicates positive association; (-) indicates negative association; (0) indicates no association.

ANNEX A – PROSPERO REGISTER

PROSPERO
International prospective register of systematic reviews

NHS National Institute for Health Research

UNIVERSITY of York
Centre for Reviews and Dissemination

Systematic review

A list of fields that can be edited in an update can be found here

1 [1.1 *changed] Review title.

Give the title of the review in English

The clustering of diet, physical activity and sedentary behavior in children and adolescents: a systematic review and meta-analysis

2 [2.1 Original language title.]

For reviews in languages other than English, give the title in the original language. This will be displayed with the English language title.

Agrupamento de hábitos alimentares, atividade física e comportamento sedentário em crianças e adolescentes: uma revisão sistemática e méta-análise

3 [3.1 *Anticipated or actual start date.]

Give the date the systematic review started or is expected to start.

25/05/2018

4 [4.1 *Anticipated completion date.]

Give the date by which the review is expected to be completed.

25/05/2019

5 [5.3 *Stage of review at time of this submission.]

This field uses answers to initial screening questions. It cannot be edited until after registration.

Tick the boxes to show which review tasks have been started and which have been completed.

Update this field each time any amendments are made to a published record.

The review has not yet started: No

Review stage	Started	Completed
Preliminary searches	No	Yes
Piloting of the study selection process	No	Yes
Formal screening of search results against eligibility criteria	No	Yes
Data extraction	No	Yes
Risk of bias (quality) assessment	No	Yes
Data analysis	No	Yes

Provide any other relevant information about the stage of the review here.

Published

1. Mello, G. T. D., Lopes, M. V. V., Minatto, G., Costa, R. M. D., Matias, T. S., Guerra, P. H., ... & Silva, K. S. (2021). Clustering of physical activity, diet and sedentary behavior among youth from low-, middle-, and high-income countries: a scoping review. International Journal of Environmental Research and Public Health, 18(20), 10924.

2. Mello, G. T. D., Bertuol, C., Minatto, G., Barbosa Filho, V. C., Oldenburg, B., Leech, R. M., & Silva, K. S. (2023). A systematic review of the clustering and correlates of physical activity and sedentary behavior among boys and girls. BMC Public Health, 23(1), 1-17.

Under review

1.Clusters of 24-hour movement behavior and diet and their relationship with health indicators among youth: a systematic review

Published

1. Mello, G. T. D., Lopes, M. V. V., Minatto, G., Costa, R. M. D., Matias, T. S., Guerra, P. H., ... & Silva, K. S. (2021). Clustering of physical activity, diet and sedentary behavior among youth from low-, middle-, and high-income countries: a scoping review. International Journal of Environmental Research and Public Health, 18(20), 10924.

2. Mello, G. T. D., Bertuol, C., Minatto, G., Barbosa Filho, V. C., Oldenburg, B., Leech, R. M., & Silva, K. S. (2023). A systematic review of the clustering and correlates of physical activity and sedentary behavior among boys and girls. BMC Public Health, 23(1), 1-17.

Under review

1.Clusters of 24-hour movement behavior and diet and their relationship with health indicators among youth: a systematic review

6. * Named contact.

The named contact is the guarantor for the accuracy of the information in the register record. This may be any member of the review team.

Gabrielli Mello

Email salutation (e.g. "Dr Smith" or "Joanne") for correspondence:

Ms Mello

7. * Named contact email.

Give the electronic email address of the named contact.

gabi.tmello@hotmail.com

8. Named contact address

Give the full institutional/organisational postal address for the named contact.

Federal University of Santa Catarina

School of Sports

Graduate Program in Physical Education

Campus Reitor JoÃ£o David Ferreira Lima, Trindade, FlorianÃ³polis, Santa Catarina, 88040-970, Brazil.

9. Named contact phone number.

Give the telephone number for the named contact, including international dialling code.

5554 991078363

10. * Organisational affiliation of the review.

Full title of the organisational affiliations for this review and website address if available. This field may be completed as 'None' if the review is not affiliated to any organisation.

Federal University of Santa Catarina

Organisation web address:

11. * Review team members and their organisational affiliations.

[11. changed]

Give the personal details and the organisational affiliations of each member of the review team. Affiliation refers to groups or organisations to which review team members belong. **NOTE: email and country now MUST be entered for each person, unless you are amending a published record.**

Ms Gabrielli Mello. Federal University of Santa Catarina
Mr Rafael Costa. Federal University of Santa Catarina
Mr Marcus Lopes. Federal University of Santa Catarina
Ms Giseli Minatto. Federal University of Santa Catarina
Mr Thiago Souza. Federal University of Santa Catarina
Mr Paulo Guerra. Federal University of Fronteira Sul
Ms Kelly Silva. Federal University of Santa Catarina

12. * Funding sources/sponsors.

Details of the individuals, organizations, groups, companies or other legal entities who have funded or sponsored the review.

None

Grant number(s)

State the funder, grant or award number and the date of award

13. * Conflicts of interest.

List actual or perceived conflicts of interest (financial or academic).

None

14. Collaborators.

Give the name and affiliation of any individuals or organisations who are working on the review but who are not listed as review team members. **NOTE: email and country must be completed for each person, unless you are amending a published record.**

15. * Review question.

[15. changed]

State the review question(s) clearly and precisely. It may be appropriate to break very broad questions down into a series of related more specific questions. Questions may be framed or refined using PI(E)COS or similar where relevant.

How patterns of three behaviors (diet, physical activity and sedentary behavior) cluster in children and adolescents?

How patterns of at least two behaviors (diet, physical activity and sedentary behavior) cluster in children and adolescents?

adolescents?

How theses patterns differ according to income countries levels?

[16.] Searches.

State the sources that will be searched (e.g. Medline). Give the search dates, and any restrictions (e.g. language or publication date). Do NOT enter the full search strategy (it may be provided as a link or attachment below.)

All the process will be made by peers. The systematic search will be made in electronic databases (MEDLINE, PubMed, Web of Science (Web of Knowledge), LILACS (Literatura Latino-Americana em Ciências da Saúde), Scopus, PsycINFO from May 2018 to Jun 2018 with no restrictions on publication period.

The search strategy included five groups of descriptors: (1) diet; (2) physical activity; (3) sedentary behavior; (4) population and (5) analysis. The Boolean operator "AND" will be use for combinations among descriptor groups.

The truncation symbols ($, * or "") specific to each database will be also use to increase the range of searches for the descriptor variations.

The searches will be conducted with the descriptors in English. The search of the electronic databases will be supplement by a screening of the reference list.

Search strategy: (sports OR "motor activity" OR "physical activity" OR "locomotor activity" OR "Physical activit*" OR "exercise*" OR "physical exercise*" OR "physical education" OR "acute exercise*" OR "aerobic exercise*" OR "aerobic activity" OR "leisure time physical activity" OR "leisure-time physical activity" OR "leisure time exercise" OR "leisure-time exercise" OR "school physical activity" OR "after-school physical activity") AND ("sedentary lifestyle" OR television OR TV OR inactivity OR "sedentary" OR "sedentary lifestyle*" OR "sedentary behavior" OR "sedentary behaviour" OR "screen time" OR "television time" OR "time sitting" OR "sitting position time" OR "seated position time" OR "cellular phone* time") AND ("diet" OR "diet behavior*" OR "diet consumption" OR "dietary intake" OR "unhealthy diet" OR "healthy diet" OR nutrition OR "food behavio*" OR "feeding behavio*") AND ("cluster analysis" OR clusters OR clustering OR "behavior patterns" OR "lifestyle patterns" OR "latent class" OR "simultaneity analysis" OR "factor analysis") AND ("youth*" OR "adolesce*" OR "adolescent*" OR "adolescence" OR "student*" OR "teen*" OR teenage* OR "adolescent* health" OR "female adolescent*" OR "male adolescent* OR schoolchildren")

17. URL to search strategy.

Upload a file with your search strategy, or an example of a search strategy for a specific database, (including the keywords) in pdf or word format. In doing so you are consenting to the file being made publicly accessible. Or provide a URL or link to the strategy. Do NOT provide links to your search **results**.

Alternatively, upload your search strategy to CRD in pdf format. Please note that by doing so you are consenting to the file being made publicly accessible.

Do not make this file publicly available until the review is complete

18. * Condition or domain being studied.

Give a short description of the disease, condition or healthcare domain being studied in your systematic review.

Clusters of at least two behaviors: diet, physical activity and sedentary behavior.

19. * Participants/population.

Specify the participants or populations being studied in the review. The preferred format includes details of both inclusion and exclusion criteria.

Children and adolescents (0 to 19 years old), will not be included clinical population (mental physical and intellectual deficient, metabolic disease, cardiovascular etc.).

20. * Intervention(s), exposure(s).

Give full and clear descriptions or definitions of the interventions or the exposures to be reviewed. The preferred format includes details of both inclusion and exclusion criteria.

Behaviors: diet, physical activity and sedentary behavior.

21. * Comparator(s)/control.

Where relevant, give details of the alternatives against which the intervention/exposure will be compared (e.g. another intervention or a non-exposed control group). The preferred format includes details of both inclusion and exclusion criteria.

Not applicable.

22. * Types of study to be included.

Give details of the study designs (e.g. RCT) that are eligible for inclusion in the review. The preferred format includes both inclusion and exclusion criteria. If there are no restrictions on the types of study, this should be stated.

Observational studies (cross-sectional and longitudinal).

23. Context.

Give summary details of the setting or other relevant characteristics, which help define the inclusion or exclusion criteria.

24. * Main outcome(s).

Give the pre-specified main (most important) outcomes of the review, including details of how the outcome is defined and measured and when these measurement are made, if these are part of the review inclusion criteria.

Behavior grouping (diet, physical activity and sedentary behavior).

Measures of effect

Please specify the effect measure(s) for you main outcome(s) e.g. relative risks, odds ratios, risk difference, and/or 'number needed to treat.

Not applicable.

25. * Additional outcome(s).

List the pre-specified additional outcomes of the review, with a similar level of detail to that required for main outcomes. Where there are no additional outcomes please state 'None' or 'Not applicable' as appropriate to the review

None.

Measures of effect

Please specify the effect measure(s) for you additional outcome(s) e.g. relative risks, odds ratios, risk difference, and/or 'number needed to treat.

Not applicable.

26. * Data extraction (selection and coding).

Describe how studies will be selected for inclusion. State what data will be extracted or obtained. State how this will be done and recorded.

All the process will be made by peers with conference process.

27. * Risk of bias (quality) assessment.

State which characteristics of the studies will be assessed and/or any formal risk of bias/quality assessment tools that will be used.

Two independent reviewers will assessment the risk of bias of the studies, and disagreements between reviewers will be resolved by consensus with a third reviewer, using an adapted version of the Risk of Bias Tool for Prevalence Studies developed by Hoy et al (2012). The Strengthening, the Reporting of Observational Studies in Epidemiology (STROBE) Checklist (reference) will used for assessment of quality

of the report.

28. * Strategy for data synthesis.

Describe the methods you plan to use to synthesise data. This **must not be generic text** but should be **specific to your review** and describe how the proposed approach will be applied to your data. If meta-analysis is planned, describe the models to be used, methods to explore statistical heterogeneity, and software package to be used.

This process will be conduct by peers and a third author will help when there will have disagreement. Data extracted will include: study name, local of the study, aim, study design, sample type, sample size, percentage of girls, age range, instrument description, behaviors investigated, clusters former. Meta-analyses will be conducted using the random-effects model in RevMan. The effect size will rate as very small (<0.20), small (0.20–0.49), intermediate (0.50–0.79) or large (?0.80) on the basis of Cohen's definition. The variability of the effects of cluster of behavior (diet, physical activity and sedentary behavior) will be tested for statistical heterogeneity, using I^2 and a $?^2$ test with a corresponding P value (Cochrane test). The heterogeneity will considered low (I^2 ? 50 %). Potential publication biases (i.e. bias sources related to the study, such as the impact of the sample size on the effect size) will be investigated by visual assessment of a funnel plot, using Review Manager (RevMan) software (http://tech.cochrane.org/revman/download). The funnel plot provides visual representation of the symmetrical distribution of data points, based on the average effect size.

29. * Analysis of subgroups or subsets.

State any planned investigation of 'subgroups'. Be clear and specific about which type of study or participant will be included in each group or covariate investigated. State the planned analytic approach.

Subgroups analyses may be undertaken it or not possible to specify the groups in advance.

30. * Type and method of review.

[1 change]

Select the type of review, review method and health area from the lists below.

Type of review

Cost effectiveness

No

Diagnostic

No

Epidemiologic

No

Individual patient data (IPD) meta-analysis

No

Intervention

No

Living systematic review
No

Meta-analysis
No

Methodology
No

Narrative synthesis
No

Network meta-analysis
No

Pre-clinical
No

Prevention
No

Prognostic
No

Prospective meta-analysis (PMA)
No

Review of reviews
No

Service delivery
No

Synthesis of qualitative studies
No

Systematic review
Yes

Other
No

Health area of the review

Alcohol/substance misuse/abuse
No

Blood and immune system
No

Cancer

No

Cardiovascular
No

Care of the elderly
No

Child health
No

Complementary therapies
No

COVID-19
No

Crime and justice
No

Dental
No

Digestive system
No

Ear, nose and throat
No

Education
No

Endocrine and metabolic disorders
No

Eye disorders
No

General interest
No

Genetics
No

Health inequalities/health equity
No

Infections and infestations
No

International development
No

Mental health and behavioural conditions

No

Musculoskeletal
No

Neurological
No

Nursing
No

Obstetrics and gynaecology
No

Oral health
No

Palliative care
No

Perioperative care
No

Physiotherapy
No

Pregnancy and childbirth
No

Public health (including social determinants of health)
Yes

Rehabilitation
No

Respiratory disorders
No

Service delivery
No

Skin disorders
No

Social care
No

Surgery
No

Tropical Medicine
No

Urological

No

Wounds, injuries and accidents

No

Violence and abuse

No

31. Language.

Select each language individually to add it to the list below, use the bin icon to remove any added in error.

Portuguese-Brazil

There is not an English language summary

32. * Country.

Select the country in which the review is being carried out. For multi-national collaborations select all the countries involved.

Brazil

33. Other registration details.

Name any other organisation where the systematic review title or protocol is registered (e.g. Campbell, or The Joanna Briggs Institute) together with any unique identification number assigned by them. If extracted data will be stored and made available through a repository such as the Systematic Review Data Repository (SRDR), details and a link should be included here. If none, leave blank.

34. Reference and/or URL for published protocol.

If the protocol for this review is published provide details (authors, title and journal details, preferably in Vancouver format)

Add web link to the published protocol.

Or, upload your published protocol here in pdf format. Note that the upload will be publicly accessible.

No I do not make this file publicly available until the review is complete

Please note that the information required in the PROSPERO registration form must be completed in full even if access to a protocol is given.

35. Dissemination plans.

Do you intend to publish the review on completion?

No

Give brief details of plans for communicating review findings.?

36. Keywords.

Give words or phrases that best describe the review. Separate keywords with a semicolon or new line. Keywords help PROSPERO users find your review (keywords do not appear in the public record but are included in searches). Be as specific and precise as possible. Avoid acronyms and abbreviations unless these are in wide use.

37. Details of any existing review of the same topic by the same authors.

If you are registering an update of an existing review give details of the earlier versions and include a full bibliographic reference, if available.

38. * Current review status.

Update review status when the review is completed and when it is published.New registrations must be ongoing so this field is not editable for initial submission.

Please provide anticipated publication date

Review_Ongoing

39. Any additional information.

Provide any other information relevant to the registration of this review.

40. Details of final report/publication(s) or preprints if available.

Leave empty until publication details are available OR you have a link to a preprint (NOTE: this field is not editable for initial submission). List authors, title and journal details preferably in Vancouver format.

Give the link to the published review or preprint.