Received: 8 March 2023 | Revised: 8 May 2023 | Accepted: 4 June 2023

DOI: 10.1002/oby.23848

Obesity A Research Journal | THE OBESITY SOCIETY | WILEY

REVIEW

Pediatric Obesity

Are 24-hour movement recommendations associated with obesity-related indicators in the young population? A meta-analysis

José Francisco López-Gil [1,2,3] | Miguel Angel Tapia-Serrano [4] | Javier Sevil-Serrano [4] | Pedro Antonio Sánchez-Miguel [4] | Antonio García-Hermoso [1]

[1]Navarrabiomed, Hospital Universitario de Navarra, Universidad Pública de Navarra, IdiSNA, Pamplona, Spain

[2]Department of Environmental Health, Harvard University T.H. Chan School of Public Health, Boston, Massachusetts, USA

[3]One Health Research Group, Universidad de Las Américas, Quito, Ecuador

[4]Department of Didactics of Musical, Plastic and Body Expression, Faculty of Teaching Training, University of Extremadura, Avenida de la Universidad, Cáceres, Spain

Correspondence
Antonio García-Hermoso, Navarrabiomed, Hospital Universitario de Navarra, Universidad Pública de Navarra, IdiSNA, Pamplona, Spain.
Email: antonio.garciah@unavarra.es

Abstract

Objective: This study aimed to determine the relationship between meeting all three 24-hour movement recommendations (i.e., physical activity, sleep duration, and screen time) and obesity-related indicators among young people.

Methods: Four databases were systematically searched (PubMed, Scopus, Web of Science, and Cochrane Library).

Results: Meeting the 24-hour movement recommendations was cross-sectionally associated with lower overall obesity-related indicators ($r = -0.09$, 95% CI: -0.11 to -0.06), but no longitudinal association was found. Regarding each obesity-related indicator separately, meeting all three recommendations was related to lower odds of overweight/obesity (odds ratio = 0.65, 95% CI: 0.56 to 0.76) and obesity alone (odds ratio = 0.28, 95% CI: 0.16 to 0.50). An inverse relationship between meeting 24-hour movement recommendations and BMI, BMI *z* score, waist circumference, and body fat was also found. Regarding subgroup analysis, the association between 24-hour movement recommendations and overall obesity-related indicators was similar regardless of sex, comparison used (meeting all three vs. not meeting [i.e., those who met zero to two of the movement behaviors] or meeting all three vs. none), and type of measure to assess 24-hour movement recommendations (i.e., self-reported or accelerometer-based measures).

Conclusions: Meeting all 24-hour movement recommendations may be a crucial factor in maintaining a healthy weight status in the young population.

INTRODUCTION

In past decades, the rate of overweight and obesity among preschoolers, children, and adolescents worldwide has continued to rise. Childhood obesity has been identified as one of the severe public health problems of the 21st century due to its chronic adverse consequences [1]. In 2016, more than 340 million children and adolescents aged 5 to 19 years worldwide had excess weight (i.e., overweight or obesity) [2]. Having excess weight during childhood significantly increases total annual medical costs ($307.72 due to obesity and $190.51 due to overweight) in comparison with healthy weight peers [3]. The likelihood of early puberty in children [4], irregular menstruation in teenage girls [5], obstructive sleep apnea [5], and cardiovascular risk factors, including prediabetes, type 2 diabetes, high cholesterol levels, hypertension, nonalcoholic fatty liver disease, and metabolic syndrome [5], increases with obesity. Children and adolescents with obesity may also experience psychological problems such as depression, anxiety, low self-esteem, body image issues, difficulties with peer relationships, and eating disorders [6]. Children and adolescents with obesity are approximately five times more likely to have obesity in adulthood than those who do not [7]. Having excess weight in childhood or adolescence increases the risk of morbidity and mortality in adulthood [8], which also increases the risk of suffering noncommunicable diseases (e.g., type 2 diabetes, cardiovascular diseases) [9].

There is compelling evidence indicating that physical activity, sleep duration, and sedentary behaviors, including screen time (i.e., 24-hour movement behaviors), are related to a wide range of health indicators in the young population [10]. The 24-hour movement recommendations for youth shift the focus from single behaviors to an integration of all movement-related behaviors in the 24-hour time-use continuum [11]. Thus, these guidelines recommend that children and adolescents aged 5 to 17 years should engage in at least 60 min/d of moderate-to-vigorous physical activity, restrict their recreational screen time (≤120 min/d for children/adolescents), and have adequate sleep duration (e.g., 9–11 h/d for children, 8–10 h/d for adolescents) in a period of 24 hours [11, 12]. Moreover, according to these recommendations, preschoolers (3–4 years) should engage in at least 180 minutes of physical activity (a minimum of 60 minutes should be moderate-to-vigorous physical activity), less than 1 h/d of sedentary screen time, and 10 to 13 hours of good-quality sleep [13]. To improve health outcomes, such recommendations indicate that the clustering and interactions among all domains of 24-hour movement behaviors should be targeted simultaneously [14]. A recent meta-analysis of 387,437 participants (51% girls) aged 3 to 18 years from 23 countries [15] revealed a global adherence rate of only 7.12% to the 24-hour movement recommendations, highlighting the low compliance with these guidelines.

Although the etiology of obesity is complex [16], environmental factors may significantly contribute to the dysregulation of body weight [17]. In this sense, high physical activity levels, low screen time, and adequate sleep duration have been independently associated with reduced obesity-related indicators in previous systematic reviews and meta-analyses [18–22]. The systematic review conducted by Saunders et al. [23] also found that children and adolescents with a combination of high physical activity/low sedentary behaviors/high sleep had more desirable obesity-related indicators compared with those with the opposite combination. Similarly, a recent systematic review published by Rollo et al. [10] showed that, in most of the studies examined, meeting 24-hour movement recommendations was related to lower obesity-related indicators (i.e., body mass index [BMI], BMI *z* score [zBMI], excess weight, and body fat). However, adherence to 24-hour movement recommendations seems not to be associated with obesity-related indicators in children under 5 years of age [24]. To our knowledge, no previous studies have meta-analyzed the association between 24-hour movement recommendations and obesity-related indicators among preschoolers, children, and adolescents. Thus, the aim of this study was to determine the association between meeting all three 24-hour movement recommendations and obesity-related indicators among young people aged 3 to 18 years.

Study Importance

What is already known?

- High physical activity levels, low screen time, and adequate sleep duration have been independently associated with reduced obesity-related outcomes; however, no previous studies have performed a meta-analysis quantifying the association between the combination of these behaviors (i.e., 24-hour movement guidelines) and obesity-related indicators among preschoolers, children, and adolescents.

What does this review add?

- Meeting the 24-hour movement guidelines was cross-sectionally associated with lower overall obesity-related indicators, specifically BMI, BMI *z* score, waist circumference, and body fat percentage.
- Meeting all three guidelines was associated with lower odds of excess weight (i.e., overweight and/or obesity) and obesity alone.

How might these results change the direction of research or the focus of clinical practice?

- Our findings highlight that all components of the 24-hour movement continuum should be addressed jointly to prevent overweight and obesity from early childhood to adolescence, which is one of the greatest challenges to public health in the 21st century.

METHODS

The protocol was published in PROSPERO under registration number CRD42022349490 and conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines published in 2021 [25].

Information sources and search strategy

Four electronic databases (PubMed, Scopus, Web of Science, and Cochrane Database of Systematic Reviews), from June 16, 2016, to October 26, 2022, were searched by two independent researchers

(Miguel Angel Tapia-Serrano and Javier Sevil-Serrano) to identify potentially relevant manuscripts. The year 2016 was set as the start date because 24-hour movement recommendations were published in this year [11].

The research strategy was based on PECOS (Population, Exposure, Comparator, Outcome, and Study design), using the following BMI, "body mass index", overweight, obes*, "weight status" OR "body composition", "body fat", fatness, adiposity, "weight circumference", "trunk fat mas", "waist to height ratio"; "movement behavio*", "24-hour*"; preschool*, early*, child*, young*, adolesc*, student*, youth, teena*; recommendations, guidelines; screen, "physical activity", sleep*. The specific search terms for each of the previously mentioned databases, in combination with specific filters, are shown in Supporting Information Table S1. Finally, a hand-searching of the reference list of studies included in this meta-analysis and relevant review studies was also done to ensure that no eligible studies were missed. Only peer-reviewed, English- and Spanish-language journal-published studies were examined.

Selection criteria

To be eligible for inclusion in this meta-analysis, each study needed to meet the following PECOS criteria: (a) population, apparently healthy young people aged 3 to 18 years; (b) exposure, meeting all three 24-hour movement recommendations (i.e., physical activity, screen time, and sleep duration); (c) comparator, youth who met all 24-hour movement recommendations compared with those who did not meet the three recommendations and/or none; (d) outcome, any of the following obesity-related indicators: excess weight, obesity, BMI, zBMI, waist circumference, and body fat; and (e) study design, no restriction, except for gray literature (e.g., editorials, abstracts, congress communications), systematic reviews and/or meta-analyses, and qualitative studies. Studies were excluded if they (a) were carried out only among young people with overweight or obesity or who have disabilities; (b) were carried out prior to 2016 or where data were gathered during the COVID-19 lockdown; (c) were conducted with babies, toddlers, infants, adults, and older people; and (d) did not assess global adherence to 24-hour movement recommendations and obesity-related indicators.

After identifying eligible studies in each database, Zotero (Version 5.0.85) was used to eliminate duplicate studies. Two researchers (Miguel Angel Tapia-Serrano and Javier Sevil-Serrano) screened each title and abstract to identify potentially relevant articles. The full texts of the final studies identified by the two authors were independently reviewed for eligibility. Any disagreement was resolved by consensus or by a third researcher (Antonio García-Hermoso).

Data collection process and data items

The data extraction process was conducted by one researcher (Miguel Angel Tapia-Serrano) and checked for accuracy by a second researcher (Javier Sevil-Serrano). Discrepancies were resolved by agreement between the two investigators or a third researcher (Antonio García-Hermoso). The studies that fulfilled the selection criteria provided the following data: author(s), publication year, country or countries, number of participants, age range, study design, and method used to measure physical activity, screen time, and sleep duration. In cases in which a study used both self-reported and device-based measures, the latter was given preference. Information extracted from each study is shown in Supporting Information Table S2.

Quality assessment in individual studies

The methodological quality of the studies (i.e., low quality, medium quality, and high quality) was separately evaluated by two researchers (Pedro Antonio Sánchez-Miguel and Miguel Angel Tapia-Serrano). A third researcher resolved disagreements and conflicts (Javier Sevil-Serrano). Using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies, the studies' methodological quality was evaluated. Eleven of the fourteen items in this checklist for longitudinal studies are applicable to observational and cross-sectional research (except Items 7, 10, and 13). This 14-item instrument assesses the following 14 factors: (a) research problem; (b and c) study population; (d) groups participating in the same population and meeting eligibility requirements; (e) sample size; (f) exposure measured before results assessment; (g) sufficient time to have an effect; (h) multiple levels of the exposure of concern; (i) exposure assessment and measurement; (j) repeated exposure measurement; (k) outcome assessment; and (l) blinding of result. The bottom of Supporting Information Table S3 includes the whole list of quality evaluation inquiries. Each item was given a value of 1 point if the text adequately described it and was then classed as "yes" (1 point), "no" (0 points), "not applicable," or "not reported." Additionally, if an item's description was insufficient or unclear, it was graded as "not reported," whereas "not applicable" was assigned to items for which the measurement criteria might not be applicable. The maximum possible score for longitudinal research was 14 points (all of which were awarded), compared with 11 for observational studies. Score ranges were taken into account for the next three categories: low quality (4 points), medium quality (5–9 points), and high quality (>10 points) for longitudinal studies and low quality (3 points), medium quality (4–7 points), and high quality (>8 points) for cross-sectional studies, following the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.

Meta-analysis

STATA version 17.0 was used for all analyses (Stata Corp LLC, College Station, Texas). For the current meta-analysis, the correlation coefficient (*r*) served as the primary effect size. We used various formulas [26–28] to convert other statistics, such as odds ratios (OR), standardized regression coefficients, unstandardized regression coefficients, and Cohen *d*, to correlation coefficients. The DerSimonian–Laird random effects model [29] was used to pool the correlation coefficients' effect sizes.

According to previous literature [30, 31], an overall impact of adhering to all three 24-hour movement recommendations on outcomes associated with obesity was identified. Using the following hierarchy, we chose just one correlation coefficient from each study to prevent duplication: (a) dual-energy x-ray absorption or magnetic resonance imaging; (b) skinfold thickness; (c) bioelectrical impedance analysis; (d) waist circumference; (e) zBMI; and (f) BMI and excess weight. On the basis of the information provided, separate pooled analyses were also carried out on the following obesity-related indicators: excess weight (overweight and obesity), obesity, BMI, zBMI, waist circumference, and body fat (percentage or kilogram).

To account for the anticipated between-study heterogeneity, the total variance (*Q*) and the inconsistency index (I^2) [32] were used. I^2 readings were divided into three categories: low inconsistency (25%), moderate inconsistency (25%–75%), and extreme inconsistency (>75%) [33].

Doi plots and computation of the Luis Furuya–Kanamori (LFK) index were conducted to assess small-study effects (i.e., publication bias). The asymmetry of the LFK index was classified as follows: a value >1 or <−1 indicates minor asymmetry, and a value >2 or <−2 indicates major asymmetry [34].

Whenever possible, subgroup analysis was conducted using the overall obesity-related indicator results according to design of the studies (i.e., cross-sectional and longitudinal) and by sex, age group (i.e., preschoolers, children, and adolescents), assessment of the movement behaviors (i.e., self-reported measures vs. accelerometer-based measures), and comparison used (i.e., meeting all three versus not meeting or meeting all three versus none).

Finally, to determine the effects of each result from each study on the pooled correlation coefficients or OR, the results were analyzed with each study removed from the analysis once.

RESULTS

Study selection

The aforementioned databases yielded a total of 9043 studies (Figure 1). There were 1856 studies left after screening for duplicates, gray literature, and other factors. After titles and abstracts were scrutinized, 1644 papers were eliminated, and 222 full-text articles were checked for eligibility. Finally, 29 papers were included in the current meta-analysis because they satisfied the inclusion and exclusion criteria (Table 1). The reasons for exclusion are listed in Supporting Information Table S2. Figure 1 displays the PRISMA flow diagram that

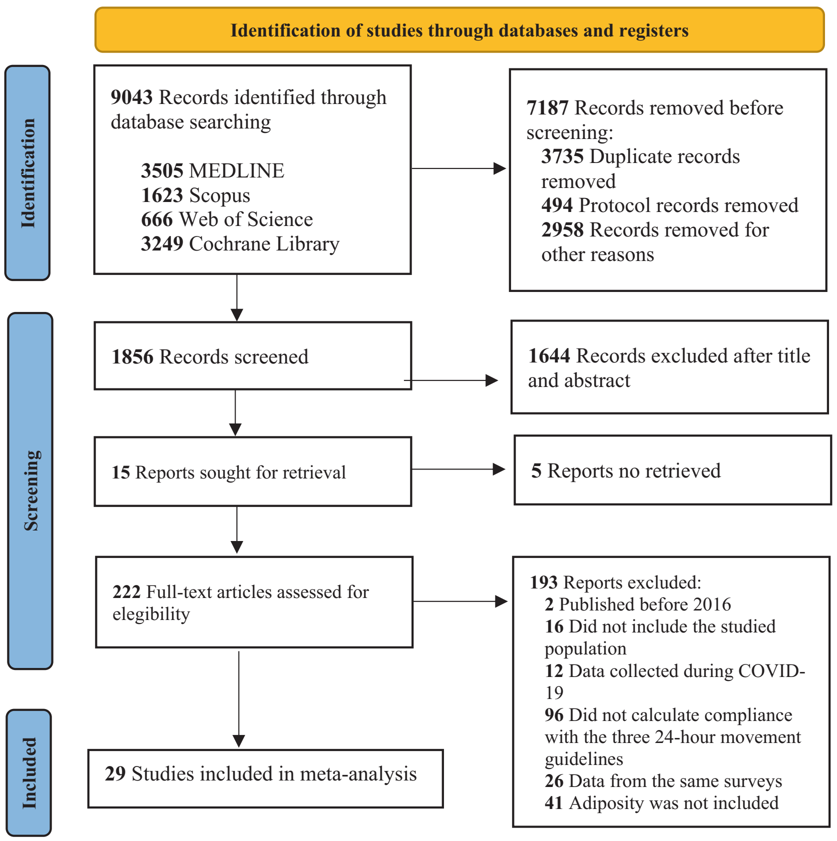

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Characteristics of included studies ($n = 29$)

Author(s) and year	Population and age	Design	24-Hour movement recommendations compliance/ non-compliance	Obesity-related indicator	Physical activity measure	Screen time measure	Sleep duration measure
Berglind et al. (2018) [35]	830 (371 girls) 4–5 years	Longitudinal study (1-year follow-up)	18.4%/0.5%	BMI; BMI *z* score; overweight/obesity	Accelerometers	Parents' self-report	Parents' self-report
Carson et al. (2017) [36]	4157 (2012 girls) 6–17 years	Cross-sectional study	17.1%/11.0%	BMI; WC	Participants' self-report	Participants' self-report	Participants' self-report
Chaput et al. (2017) [37]	803 (403 girls) 3–5 years	Cross-sectional study	12.7%/3.3%	BMI *z* score; overweight/obesity	Accelerometers	Parents' self-report	Accelerometers
Chemtob et al. (2021) [38]	630 (286 girls) 8–13 years 564 (251 girls) 14–15 years 377 (176 girls) 15–17 years	Longitudinal study (2- and 7-year follow-up)	14.2%/0.8% 6.1%/5.4% 0%/12.5%	BMI *z* score; WC; body fat (dual-energy x-ray absorptiometry)	Accelerometers	Participants' self-report	Accelerometers
Chen et al. (2021) [39]	11,4072 (57,971 girls) 11–17 years	Cross-sectional study	5.12%/NR	BMI	Participants' self-report	Participants' self-report	Participants' self-report
Decraene et al. (2021) [40]	2468 (1164 girls) 4–5 years	Cross-sectional	10.1%/15.0%	BMI *z* score	Accelerometers	Parents' self-report	Parents' self-report
Feng et al. (2021) [41]	251 (110 girls) 3–6 years	Cross-sectional study	2.9%/15.1%	BMI; overweight/obesity	Accelerometers	Parents' self-report	Accelerometers
Fung et al. (2023) [42]	10,574 (5070 girls) 9–14 years	Longitudinal study (2-years follow-up)	4%/31%	BMI *z* score	Parents' self-report	Parents' self-report	Parents' self-report
Guan et al. (2020) [43]	254 (119 girls) 4–6 years	Cross-sectional study	15.0%/2.7%	Overweight/obesity	Accelerometers	Parents' self-report	Accelerometers
Guimarâes et al. (2021) [44]	276 (276 girls) 12–17 years	Cross-sectional study	2.2%/25.4%	BMI *z* score	Participants' self-report	Participants' self-report	Participants' self-report
Hinkley et al. (2020) [45]	450 (98 girls) 6–11 years	Longitudinal study (2, 3 and 7 years of follow-up)	20.0%/NR	BMI *z* score; WC	Accelerometers	Parents' self-report	Parents' self-report
Jakubec et al. (2020) [46]	679 (387 girls) 8–18 years	Cross-sectional study	6.5%/33.0%	BMI *z* score; overweight/obesity	Accelerometers	Participants' self-report	Accelerometers
Janssen et al. (2017) [47]	17,951 (9478 girls) 10–17 years	Cross-sectional study	2.6%/21.4%	BMI *z* score	Participants' self-report	Participants' self-report	Participants' self-report

(Continues)

TABLE 1 (Continued)

Author(s) and year	Population and age	Design	24-Hour movement recommendations compliance/ non-compliance	Obesity-related indicator	Physical activity measure	Screen time measure	Sleep duration measure
Katzmarzyk and Staiano (2017) [48]	357 (NR) 5–18 years	Cross-sectional study	8.4%/26.9%	BMI; WC; obesity	Participants' self-report	Participants' self-report	Participants' self-report
Kim et al. (2020) [49]	421 (199 girls) 3–5 years	Cross-sectional study	21.5%/3.6%	BMI z score	Accelerometers	Parents' self-report	Parents' self-report
Kim et al. (2021) [50]	247 (111 girls) 6–12 years	Longitudinal study (2-year follow-up)[a]	10.9%/14.9%	Overweight/obesity	Participants' self-report	Participants' self-report	Participants' self-report
Kim et al. (2022) [51]	103 (45 girls) 3–5 years	Cross-sectional study	17.5%/5.8%	Overweight/obesity	Accelerometers	Parents' self-report	Parents' self-report
Lee et al. (2021) [52]	230 (194 girls) 4–6 years	Cross-sectional study	6.5%/17.0%	Overweight/obesity	Accelerometers	Parents' self-report	Parents' self-report
Leppänen et al. (2019) [53]	721 (379 girls) 3–6 years	Cross-sectional study	23.6%/NR	BMI; WC	Accelerometers	Parents' self-report	Parents' self-report
Leppänen et al. (2022) [54]	512 (236 girls) 6–8 years	Longitudinal study (2-year follow-up)	52.5%/0.7%	WC	Accelerometers	Participants' self-report	Accelerometers
Meredith-Jones et al. (2019) [55]	389 (girls: 194) 5 years	Longitudinal study (3-year follow-up)[b]	36.9%/NR	BMI *z* score; body fat (dual-energy x-ray absorptiometry)	Accelerometers	Parents' self-report	Accelerometers
Roman-Viñas et al. (2016) [56]	6128 (3365 girls) 9–11 years	Cross-sectional study	7.2%/19.0%	BMI *z* score; overweight/obesity	Accelerometers	Participants' self-report	Accelerometers
Sai-Chuen Hui et al. (2021) [57]	12,590 (6027 girls) 12–15 years	Cross-sectional study	0.8%/51.1%	Body fat (bioelectrical impedance analysis)	Participants' self-report	Participants' self-report	Participants' self-report
Shi et al. (2020) [58]	1039 (370 girls) 11–18 years	Cross-sectional study	1.0%/38.7%	BMI	Accelerometers	Participants' self-report	Accelerometers
Tanaka et al. (2020) [59]	243 (120 girls) 6–12 years	Cross-sectional study	10.5%/13.2%	Overweight/obesity	Accelerometers	Parents' self-report	Parents' self-report
Vanderloo et al. (2021) [60]	767 (378 girls) 3–4 years	Cross-sectional study	10.6%/26.4%	WC	Parents' self-report	Parents' self-report	Parents' self-report
Yang et al. (2022) [61]	1849 (930 girls) 14–17 years	Cross-sectional study	2.1%/NR	Overweight/obesity	Participants' self-report	Participants' self-report	Participants' self-report
Zhou et al. (2022) [62]	978 (458 girls) 8–10 years	Cross-sectional study	26.1%/5.9%	Body fat (bioelectrical impedance analysis); overweight/obesity	Participants' self-report	Participants' self-report	Participants' self-report
Zhu et al. (2020) [63]	30,478 (15,524 girls) 10–17 years	Cross-sectional study	9.4%/9.1%	Overweight/obesity; obesity	Parents' self-report	Parents' self-report	Parents' self-report

Abbreviations: NR, not reported; WC, waist circumference.
[a]We used only cross-sectional results.
[b]We used only cross-sectional results at 5 years old.

shows how many studies were removed at each stage of the meta-analysis.

Study characteristics

The main characteristics of the 29 studies included in this meta-analysis can be found in Table 1. A total of 211,388 young people aged 3 to 18 years were involved. Regarding age group, 7948 were preschoolers (3–5 years; 3.74%), 122,906 were children (6–12 years; 58.17%), 45,048 were adolescents (13–18 years; 21.31%), and 35,486 were children and adolescents (6–18 years; 16.78%). Sample sizes across studies ranged from 103 [35] to 114,072 participants [39]. Regarding sex, 28 studies included both boys and girls, except 1 study that included only girls [44]. Regarding the study design, 22 studies were cross-sectional and 7 longitudinal (from 1 to 7 years of follow-up) [35, 38, 42, 45, 51, 54, 55]. However, we included only 5 studies [35, 38, 42, 45, 54] in our analysis of longitudinal results due to the following reasons: (i) Meredith-Jones et al. [55] provided longitudinal data from age 1 year and we used cross-sectional data from the 5-year-old time point and (ii) Kim et al. [50] used longitudinal data during the COVID-19 pandemic and therefore we used only cross-sectional results at baseline.

Measurements

Regarding obesity-related indicators, the most common obesity-related indicators were zBMI [35, 37, 38, 40, 42, 44–47, 49, 55, 56], waist circumference [36, 38, 45, 48, 53, 54, 60], BMI [35, 36, 39, 41, 48, 53, 58], body fat by bioelectrical impedance analysis [57, 62] or dual-

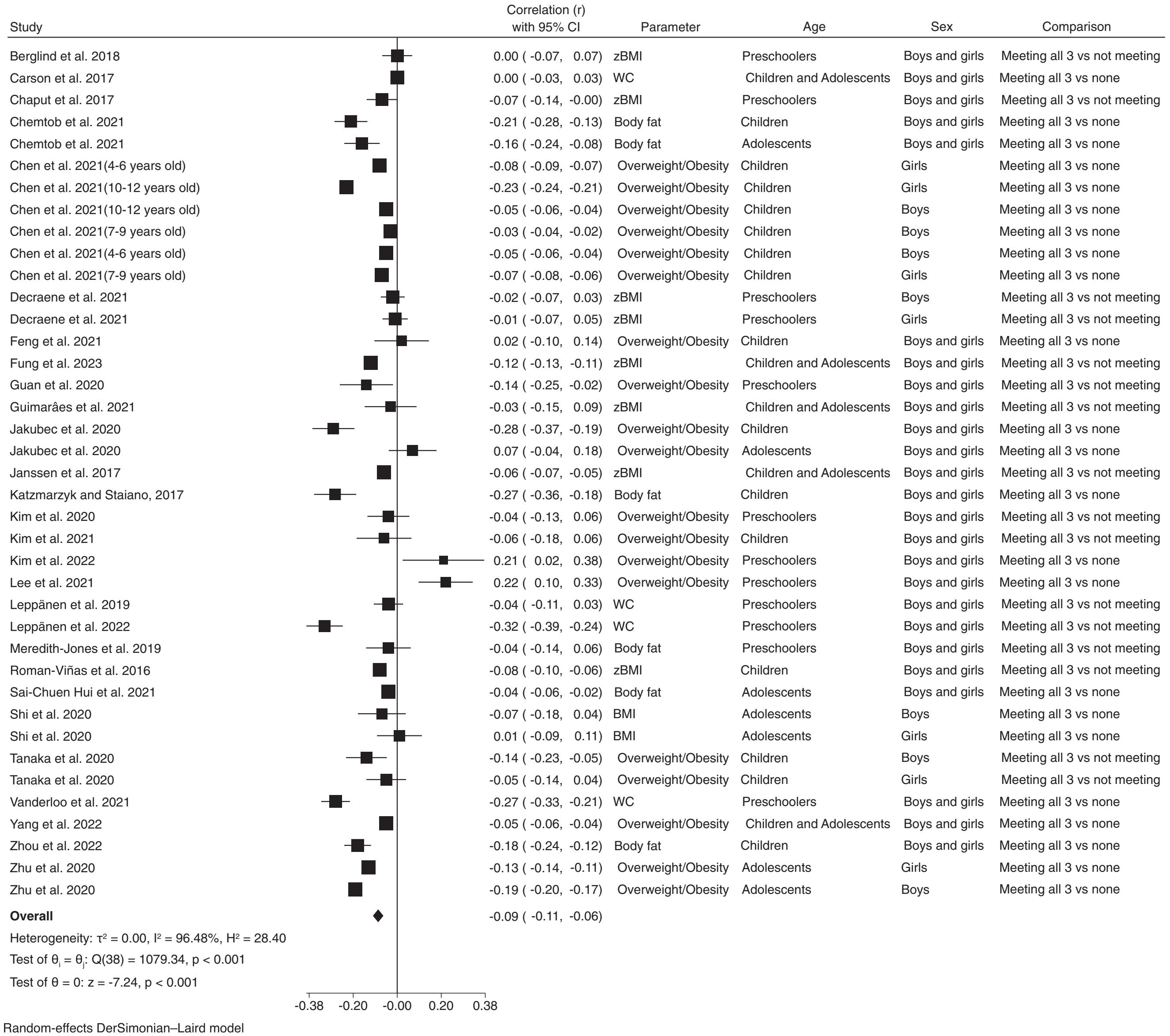

FIGURE 2 Forest plot showing the correlation of 24-hour movement recommendations and obesity-related indicators in cross-sectional studies. WC, waist circumference; zBMI, BMI *z* score

energy x-ray absorptiometry [38, 55], only obesity [48, 63], and overweight/obesity [35, 37, 41, 43, 46, 50–52, 56, 59, 61–63]. Regarding the measurement of the 24-hour movement recommendations, physical activity was assessed by accelerometer-based measures in 17 studies [35, 37, 38, 40, 41, 43, 45, 46, 49, 51–56, 58, 59] and self-reported measures by young people and parents in 12 studies [36, 39, 42, 44, 47, 48, 50, 57, 60–63]. Screen time was self-reported by young people in 14 studies [36, 38, 39, 44, 46–48, 50, 54, 56–58, 61, 62] and by parents in 15 studies [35, 37, 40–43, 45, 49, 51–53, 55, 59, 60, 63]. Sleep duration was determined by accelerometer-based measures in 9 studies and self-reported measures by young people and parents in 20 studies [35, 36, 40, 42–45, 47–53, 57, 59–63]. Finally, 15 studies compared meeting all three recommendations with meeting any of the recommendations (i.e., not meeting all three) [35, 37, 40, 42–45, 47, 49, 50, 53–56, 59], whereas 14 studies compared meeting all three recommendations with meeting none of the recommendations [36, 38, 39, 41, 46, 48, 51, 52, 57, 58, 60–63].

Quality assessment in individual studies

In Supporting Information Table S3, the findings of the methodological quality evaluation are presented. In this sense, 82.75% of the studies were classified as high quality, and 17.75% appeared as medium quality. Most studies complied with the reporting requirements for samples (Items 1–4), with the exception of the sample size, which was described by just 14% of studies (Item 5). The exposure(s) of interest were measured before the outcome was measured in all cohort and longitudinal studies (21%). Moreover, only 21% (Item 7) of the studies included more than one measurement over time (four longitudinal studies and two cohort studies). All the studies had distinct amounts of exposure to the independent and dependent variables, and they all precisely defined and described the variables (Items 8, 9, and 11). However, only 21% tracked these factors throughout time (Item 10). No studies made it clear whether outcome evaluators were blinded

TABLE 2 Subgroup analyses of 24-hour movement recommendations on obesity-related indicators among preschoolers, children, and adolescents

Design/obesity-related indicators	*n*	Correlation (*r*) or OR	95% CI	*p*	I^2	LFK index
Cross-sectional designs						
Overall studies	28	−0.09	−0.11 to −0.06	<0.001	96.5	0.17
Boys	5	−0.08	−0.13 to −0.02	0.010	97.8	−1.30
Girls	5	−0.09	−0.15 to −0.03	<0.001	98.3	2.46
Boys and girls	23	−0.09	−0.12 to −0.06	<0.001	91.8	0.03
Preschoolers	11	−0.05	−0.13 to 0.02	0.200	90.8	0.39
Children	9	−0.12	−0.16 to −0.08	<0.001	97.5	3.02
Adolescents	5	−0.08	−0.14 to −0.02	<0.001	96.7	3.89
Meeting all three vs. not meeting	14	−0.07	−0.10 to −0.05	<0.001	84.3	1.24
Meeting all three vs. none	13	−0.09	−0.12 to −0.06	<0.001	97.8	0.58
Self-reported measures	11	−0.11	−0.14 to −0.08	<0.001	98.2	−3.85
Accelerometer-based measures[a]	17	−0.06	−0.10 to −0.02	<0.001	86.2	0.39
Obesity-related indicators						
Excess weight	14	*0.65*	*0.56 to 0.76*	<0.001	69.6	−2.49
Obesity	4	*0.28*	*0.16 to 0.50*	<0.001	74.9	−0.56
BMI	6	−0.08	−0.13 to −0.02	0.010	82.8	3.05
BMI *z* score	9	−0.09	−0.13 to −0.05	<0.001	89.4	−0.56
Waist circumference	6	−0.18	−0.29 to −0.07	<0.001	95.3	−4.21
Body fat	5	−0.15	−0.23 to −0.06	<0.001	91.9	−6.72
Longitudinal designs						
Overall studies	5	−0.04	−0.13 to 0.06	0.102	92.1	4.94
Obesity-related indicators						
BMI *z* score	4	−0.04	−0.14 to 0.05	0.371	90.2	5.86

Note: Italics indicate OR values.
Abbreviations: LFK, Luis Furuya–Kanamori; OR, odds ratio; zBMI, BMI z score.
[a]Refers to studies that assessed physical activity and/or sleep duration accelerometers.

during the investigation (Item 12), and they all reported individual losses during follow-up (Item 13). All the studies (100%) also included variables related to following the 24-hour movement recommendations (e.g., socioeconomic status, age, sex).

Synthesis of results of the meta-analysis

Regarding cross-sectional designs, the association between 24-hour movement recommendations and obesity-related indicators was statistically significant ($r = -0.09$, 95% confidence interval [CI]: −0.11 to −0.06, $p < 0.001$; $I^2 = 96.5\%$; Figure 2). The LFK index for the Doi plots showed no asymmetry, verifying the absence of publication bias (LFK index = 0.17; Supporting Information Figure S1). Additionally, the sensitivity analyses indicated no modifications in the results after removing one study at a time (Supporting Information Figure S2).

For each obesity-related indicator separately, meeting all 24-hour movement recommendations was associated with a lower likelihood of both overweight/obesity (OR = 0.65, 95% CI: 0.56 to 0.76, $p < 0.001$; $I^2 = 69.6\%$; Supporting Information Figure S3) and obesity alone (OR = 0.28, 95% CI: 0.16 to 0.50, $p < 0.001$; $I^2 = 74.9\%$; Supporting Information Figure S4). Additionally, there was a negative relationship between 24-hour movement recommendations and BMI ($r = -0.08$, 95% CI: −0.13 to −0.02, $p = 0.010$; $I^2 = 82.8\%$; Supporting Information Figure S5), zBMI ($r = -0.09$, 95% CI: −0.13 to −0.05, $p < 0.001$; $I^2 = 89.4\%$; Supporting Information Figure S6), waist circumference ($r = -0.18$, 95% CI: −0.29 to −0.07, $p = 0.001$; $I^2 = 95.3\%$; Supporting Information Figure S7), and body fat percentage ($r = -0.15$, 95% CI: −0.23 to −0.06, $p < 0.001$; $I^2 = 91.9\%$; Supporting Information Figure S8 and Table 2).

Regarding subgroup analyses, the association between 24-hour movement recommendations and overall obesity-related indicators was similar regardless of sex (boys: $r = -0.08$, 95% CI: −0.13 to −0.02; girls: $r = -0.09$, 95% CI: −0.15 to −0.03; p difference between groups = 0.922) and comparison (meeting all three vs. not meeting: $r = -0.07$, 95% CI: −0.10 to −0.05; meeting all three vs. none: $r = -0.09$, 95% CI: −0.12 to −0.06; p difference between groups = 0.422). In contrast, that association was higher in children ($r = -0.12$, 95% CI: −0.16 to −0.08) and adolescents ($r = -0.08$, 95% CI: −0.14 to −0.02) in comparison with preschoolers ($r = -0.05$, 95% CI: −0.13 to 0.02; p difference between groups < 0.001; Table 2) and using self-reported measures ($r = -0.11$, 95% CI: −0.14 to −0.08) in comparison with accelerometer-based measures ($r = -0.06$, 95% CI: −0.12 to −0.03) to assess 24-hour movement recommendations (p difference between groups 0.045).

Regarding longitudinal design, meeting all three 24-hour movement recommendations was not negatively associated with obesity-related indicators ($r = -0.04$, 95% CI: −0.13 to 0.06, $p = 0.443$; $I^2 = 92.1\%$; Supporting Information Figure S9). Additionally, the sensitivity analyses indicated no modifications in the results after removing one study at a time (Supporting Information Figure S10). The LFK index for the Doi plots showed asymmetry, verifying the presence of publication bias (LFK index = 4.94; Supporting Information Figure S11). There was no significant association between 24-hour movement recommendations and zBMI (Supporting Information Figure S12; Table 2).

DISCUSSION

Available evidence from 29 studies, including a total of 211,388 preschoolers, children, and adolescents, showed that meeting all three 24-hour movement recommendations was associated with reduced obesity-related indicators in cross-sectional studies. Likewise, this result remained significant when segmented by sex (i.e., boys and girls), comparison (i.e., meeting all three vs. not meeting or meeting all three vs. none), and 24-hour movement behavior assessment (i.e., self-reported and accelerometer-based measures). Moreover, meeting all the 24-hour movement recommendations was associated with lower obesity-related indicators for all of the parameters analyzed (i.e., excess weight, obesity, BMI, zBMI, waist circumference, and body fat). Notwithstanding, the effect sizes found for all these associations were small.

Overall, our findings are in line with the previous systematic review by Rollo et al. [10] who suggested a favorable association between meeting all three recommendations and obesity-related indicators in all studies, including children and adolescents. Moreover, the systematic review conducted by Saunders et al. [23] also found that young people with high sleep duration, low sedentary behaviors, and high physical activity had more desirable obesity-related indicators than those who had the opposite combination. On the other hand, we also found that meeting all three 24-hour movement recommendations was related to lower obesity-related indicators for all of the parameters analyzed in cross-sectional studies (i.e., excess weight, obesity, BMI, zBMI, waist circumference, and body fat). Our results highlight the importance of 24-hour movement recommendations for a healthier body composition during childhood and adolescence [64]. In contrast, although the information is limited to only five studies, we did not observe a significant association with longitudinal outcomes. This finding is contrary to that of García-Hermoso et al. [65] who found that adolescents who met all 24-hour movement recommendations had lower risk of abdominal obesity later in life. It should also be noted that subgroup analyses revealed a stronger association between meeting the 24-hour movement recommendations and obesity-related indicators in children and adolescents compared with preschoolers. These findings are consistent with a recent meta-analysis that found no association between meeting the 24-hour movement guidelines and adiposity in children under 5 years old [24]. One possible explanation could be that preschoolers may require repeated exposure to movement behaviors over time for associations with outcomes such as obesity-related indicators to manifest themselves [45].

There are a few reasons that might be used to support these findings. Because one movement behavior might replace an equal length of time for one (or more) of the others, codependence between movement behaviors is the most likely explanation for our findings [66] (e.g., sedentary behavior may displace sleep duration, physical activity, or both). For instance, when a physically active lifestyle is changed to a more sedentary lifestyle in later life, the amount of energy consumed is reduced [67], which could lead to an increase in obesity-related indicators. Furthermore, high physical activity [68] and low sedentary behavior (particularly screen time) [69] individually, as well as meeting 24-hour movement recommendations in combination [70], have been associated with higher and lower sleep quality, respectively. Thus, a meta-analysis by Fatima et al. [71] found that poor sleep quality was related to excess weight among the young population. Inadequate sleep time also was associated with lower basal metabolic rate, lower physical activity, and higher sedentary behaviors in children [72]. Similarly, short sleep duration was shown to considerably raise the risk of obesity in a dose–response manner [21] because of metabolic and endocrine changes and increased appetite, which could lead to higher caloric consumption, greater systemic inflammation, and reduced physical activity associated with daytime sleepiness [73]. Another possible explanation is that healthy behaviors (e.g., healthy eating patterns and 24-hour movement behaviors) tend to be clustered among children and adolescents [74]. Thus, 24-hour movement recommendations seem to interact with food intake [75–77] and with diet quality [78, 79]. Additionally, high screen time and inadequate sleep duration have both been shown to increase food intake [75, 76], whereas regular physical activity may help to control appetite [77]. It is possible that meeting 24-hour movement recommendations favors a higher diet quality, which was suggested as a relevant health-related behavior to end childhood obesity by the World Health Organization [80].

Importantly, subgroup analyses showed that the relationship between meeting all three 24-hour movement recommendations and lower obesity-related indicators was maintained according to sex (i.e., boys and girls), comparison (i.e., meeting all three vs. not meeting or meeting all three vs. none), and 24-hour movement behavior assessment (i.e., self-reported and accelerometer-based measures). Despite the differences between sexes [15] and the decreasing trend from preschool to adolescence [15] in meeting overall 24-hour movement recommendations, our results suggest that children and adolescents with an adequate combination of all three 24-hour movement recommendations (i.e., high physical activity, low sedentary behavior, and sufficient sleep) could have lower levels of obesity-related indicators, regardless of their sex. Given that the need to integrate sex- and age-specific strategies to help young people develop and maintain health over time has been emphasized [10, 15], these results call for the promotion of 24-hour movement recommendations for obesity prevention in young people [64].

It is important to recognize the limitations of the current investigation. First, a causal association cannot be established because the majority of the included studies are cross-sectional in nature. Additional longitudinal and intervention research is necessary to confirm the causation of these connections. Second, approximately half of the studies assessed physical activity levels and/or sleep duration using self-reported measures; as a result, both recollection bias and social desirability may have affected the results. Third, only 4% of the sample was made up of preschoolers. More research on this association in this age group therefore seems to be needed. Future research should look at the duration of sleep and device-based physical activity to obtain a better understanding of this association. Fourth, although various studies include self-reported assessments of movement behaviors (i.e., physical activity and sleep), sensitivity analysis shows similar associations using objective measures. Finally, the small effect sizes in addition to their high heterogeneity make it necessary to interpret the obtained results with caution. The key strength of our study is that no prior meta-analysis has determined the pooled estimation of fulfilling all of these (non)movement behaviors on obesity-related indicators.

CONCLUSION

Meeting all 24-hour movement recommendations may be a crucial factor in maintaining a healthy weight status in the young population. Our findings highlight that all components of the 24-hour movement continuum should be addressed jointly to prevent overweight and obesity from early childhood to adolescence [65], which is one of the greatest challenges to public health in the 21st century [1].O

ACKNOWLEDGEMENT

Open access funding provided by Universidad Pública de Navarra.

DISCLOSURE

The authors declared no conflict of interest.

ORCID

José Francisco López-Gil https://orcid.org/0000-0002-7412-7624
Miguel Angel Tapia-Serrano https://orcid.org/0000-0003-2954-2375
Javier Sevil-Serrano https://orcid.org/0000-0002-2077-1983
Pedro Antonio Sánchez-Miguel https://orcid.org/0000-0002-1660-535X
Antonio García-Hermoso https://orcid.org/0000-0002-1397-7182

REFERENCES

1. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. *Lancet*. 2017;390(10113):2627-2642. doi:10.1016/S0140-6736(17)32129-3
2. World Health Organization. Obesity and overweight. Updated June 9. 2021 https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
3. Ling J, Chen S, Zahry NR, Kao TA. Economic burden of childhood overweight and obesity: a systematic review and meta-analysis. *Obes Rev*. 2022;27:e13535. doi:10.1111/obr.13535
4. De Leonibus C, Marcovecchio ML, Chiarelli F. Update on statural growth and pubertal development in obese children. *Pediatr Rep*. 2012;4(4):e35. doi:10.4081/pr.2012.e35
5. Gurnani M, Birken C, Hamilton J. Childhood obesity. *Pediatr Clin North Am*. 2015;62(4):821-840. doi:10.1016/j.pcl.2015.04.001
6. Rankin J, Matthews L, Cobley S, et al. Psychological consequences of childhood obesity: psychiatric comorbidity and prevention. *Adolesc Health Med Ther*. 2016;7:125-146. doi:10.2147/AHMT.S101631

7. Simmonds M, Llewellyn A, Owen CG, Woolacott N. Predicting adult obesity from childhood obesity: a systematic review and meta-analysis: adult obesity from childhood obesity. *Obes Rev*. 2016;17(2):95-107. doi:10.1111/obr.12334
8. Kumar S, Kelly AS. Review of childhood obesity: from epidemiology, etiology, and comorbidities to clinical assessment and treatment. *Mayo Clin Proc*. 2017;92(2):251-265. doi:10.1016/j.mayocp.2016.09.017
9. Park MH, Falconer C, Viner RM, Kinra S. The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review: childhood obesity and long-term morbidity. *Obes Rev*. 2012;13(11):985-1000. doi:10.1111/j.1467-789X.2012.01015.x
10. Rollo S, Antsygina O, Tremblay MS. The whole day matters: understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. *J Sport Health Sci*. 2020;9:493-510. doi:10.1016/j.jshs.2020.07.004
11. Tremblay MS, Carson V, Chaput JPP, et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab*. 2016;41(6 suppl 3):S311-S327. doi:10.1139/apnm-2016-0203
12. World Health Organization. Guidelines on physical activity, sedentary behaviour, and sleep for children under 5 years of age. WHO; 2019.
13. Tremblay MS, Chaput JP, Adamo KB, et al. Canadian 24-hour movement guidelines for the early years (0–4 years): an integration of physical activity, sedentary behaviour, and sleep. *BMC Public Health*. 2017;17(suppl 5):874. doi:10.1186/s12889-017-4859-6
14. Chaput JP, Carson V, Gray C, Tremblay M. Importance of all movement behaviors in a 24 hour period for overall health. *Int J Environ Res Public Health*. 2014;11(12):12575-12581. doi:10.3390/ijerph111212575
15. Tapia-Serrano MA, Sevil-Serrano J, Sánchez-Miguel PA, López-Gil JF, Tremblay MS, García-Hermoso A. Prevalence of meeting 24-hour movement guidelines from pre-school to adolescence: a systematic review and meta-analysis including 387,437 participants and 23 countries. *J Sport Health Sci*. 2022;11:427-437. doi:10.1016/j.jshs.2022.01.005
16. Torres-Carot V, Suárez-González A, Lobato-Foulques C. The energy balance hypothesis of obesity: do the laws of thermodynamics explain excessive adiposity? *Eur J Clin Nutr*. 2022;4:1374-1379. doi:10.1038/s41430-021-01064-4
17. Nicolaidis S. Environment and obesity. *Metabolism*. 2019;100:153942. doi:10.1016/j.metabol.2019.07.006
18. Poitras VJ, Gray CE, Borghese MM, et al. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab*. 2016;41(6 suppl 3):S197-S239. doi:10.1139/apnm-2015-0663
19. Chaput JP, Gray CE, Poitras VJ, et al. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab*. 2016;41(6 suppl 3):S266-S282. doi:10.1139/apnm-2015-0627
20. Felső R, Lohner S, Hollódy K, Erhardt É, Molnár D. Relationship between sleep duration and childhood obesity: systematic review including the potential underlying mechanisms. *Nutr Metab Cardiovasc Dis*. 2017;27(9):751-761. doi:10.1016/j.numecd.2017.07.008
21. Deng X, He M, He D, Zhu Y, Zhang Z, Niu W. Sleep duration and obesity in children and adolescents: evidence from an updated and dose–response meta-analysis. *Sleep Med*. 2021;78:169-181. doi:10.1016/j.sleep.2020.12.027
22. Carson V, Hunter S, Kuzik N, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. *Appl Physiol Nutr Metab*. 2016;41(6 suppl 3):S240-S265. doi:10.1139/apnm-2015-0630
23. Saunders TJ, Gray CE, Poitras VJ, et al. Combinations of physical activity, sedentary behaviour and sleep: relationships with health indicators in school-aged children and youth. *Appl Physiol Nutr Metab*. 2016;41(6 suppl 3):S283-S293. doi:10.1139/apnm-2015-0626
24. Feng J, Zheng C, Sit CH, Reilly JJ, Huang WY. Associations between meeting 24-hour movement guidelines and health in the early years: a systematic review and meta-analysis. *J Sports Sci*. 2021;39(22):2545-2557.
25. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;n71. doi:10.1136/bmj.n71
26. Nieminen P, Lehtiniemi H, Vähäkangas K, Huusko A, Rautio A. Standardised regression coefficient as an effect size index in summarising findings in epidemiological studies. *Epidemiol Biostat Public Health*. 2013;10(4). doi:10.2427/8854
27. Peterson RA, Brown SP. On the use of beta coefficients in meta-analysis. *J Appl Psychol*. 2005;90(1):175-181. doi:10.1037/0021-9010.90.1.175
28. Bring J. How to standardize regression coefficients. *Am Stat*. 1994;48(3):209-213. doi:10.1080/00031305.1994.10476059
29. Hardy RJ, Thompson SG. A likelihood approach to meta-analysis with random effects. *Stat Med*. 1996;15(6):619-629. doi:10.1002/(SICI)1097-0258(19960330)15:6<619::AID-SIM188>3.0.CO;2-A
30. Cliff DP, Hesketh KD, Vella SA, et al. Objectively measured sedentary behaviour and health and development in children and adolescents: systematic review and meta-analysis. *Obes Rev*. 2016;17(4):330-344. doi:10.1111/obr.12371
31. García-Hermoso A, Ezzatvar Y, Ramírez-Vélez R, Olloquequi J, Izquierdo M. Is device-measured vigorous physical activity associated with health-related outcomes in children and adolescents? A systematic review and meta-analysis. *J Sport Health Sci*. 2021;10(3):296-307. doi:10.1016/j.jshs.2020.12.001
32. Higgins JPT. Measuring inconsistency in meta-analyses. *BMJ*. 2003;327(7414):557-560. doi:10.1136/bmj.327.7414.557
33. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002;21(11):1539-1558. doi:10.1002/sim.1186
34. Furuya-Kanamori L, Barendregt JJ, Doi SAR. A new improved graphical and quantitative method for detecting bias in meta-analysis. *Int J Evid Based Healthc*. 2018;16(4):195-203. doi:10.1097/XEB.0000000000000141
35. Berglind D, Ljung R, Tynelius P, Brooke HL. Cross-sectional and prospective associations of meeting 24-h movement guidelines with overweight and obesity in preschool children: 24-h movement guidelines in children. *Pediatr Obes*. 2018;13(7):442-449. doi:10.1111/ijpo.12265
36. Carson V, Chaput JP, Janssen I, Tremblay MS. Health associations with meeting new 24-hour movement guidelines for Canadian children and youth. *Prev Med*. 2017;95:7-13. doi:10.1016/j.ypmed.2016.12.005
37. Chaput JP, Colley RC, Aubert S, et al. Proportion of preschool-aged children meeting the Canadian 24-hour movement guidelines and associations with adiposity: results from the Canadian Health Measures Survey. *BMC Public Health*. 2017;17(suppl 5):829. doi:10.1186/s12889-017-4854-y
38. Chemtob K, Reid RER, Guimarães R de F, et al. Adherence to the 24-hour movement guidelines and adiposity in a cohort of at risk youth: a longitudinal analysis. *Pediatr Obes*. 2021;16(4):e12730. doi:10.1111/ijpo.12730
39. Chen ST, Liu Y, Tremblay MS, et al. Meeting 24-hour movement guidelines: prevalence, correlates and the relationships with overweight and obesity among Chinese children and adolescents. *J Sport Health Sci*. 2021;10(3):349-359. doi:10.1016/j.jshs.2020.07.002

40. Decraene M, Verbestel V, Cardon G, et al. Compliance with the 24-hour movement behavior guidelines and associations with adiposity in European preschoolers: results from the ToyBox-study. *Int J Environ Res Public Health*. 2021;18(14):7499. doi:10.3390/ijerph18147499
41. Feng J, Huang WY, Reilly JJ, Wong SHS. Compliance with the WHO 24-h movement guidelines and associations with body weight status among preschool children in Hong Kong. *Appl Physiol Nutr Metab*. 2021;46(10):1273-1278. doi:10.1139/apnm-2020-1035
42. Fung H, Yeo BTT, Chen C, Lo JC, Chee MWL, Ong JL. Adherence to 24-hour movement recommendations and health indicators in early adolescence: cross-sectional and longitudinal associations in the Adolescent Brain Cognitive Development study. *J Adolesc Health*. 2023;72(3):460-470. doi:10.1016/j.jadohealth.2022.10.019
43. Guan H, Zhang Z, Wang B, et al. Proportion of kindergarten children meeting the WHO guidelines on physical activity, sedentary behaviour and sleep and associations with adiposity in urban Beijing. *BMC Pediatr*. 2020;20(1):70. doi:10.1186/s12887-020-1969-6
44. Guimarães R de F, Gilbert JA, Lemoyne J, Mathieu ME. Better health indicators of FitSpirit participants meeting 24-h movement guidelines for Canadian children and youth. *Health Promot Int*. 2021;36(3):836-845. doi:10.1093/heapro/daaa102
45. Hinkley T, Timperio A, Watson A, et al. Prospective associations with physiological, psychosocial and educational outcomes of meeting Australian 24-hour movement guidelines for the early years. *Int J Behav Nutr Phys Act*. 2020;17(1):36. doi:10.1186/s12966-020-00935-6
46. Jakubec L, Gába A, Dygrýn J, Rubín L, Šimůnek A, Sigmund E. Is adherence to the 24-hour movement guidelines associated with a reduced risk of adiposity among children and adolescents? *BMC Public Health*. 2020;20(1):1119. doi:10.1186/s12889-020-09213-3
47. Janssen I, Roberts KC, Thompson W. Is adherence to the Canadian 24-hour movement behaviour guidelines for children and youth associated with improved indicators of physical, mental, and social health? *Appl Physiol Nutr Metab*. 2017;42(7):725-731. doi:10.1139/apnm-2016-0681
48. Katzmarzyk PT, Staiano AE. Relationship between meeting 24-hour movement guidelines and cardiometabolic risk factors in children. *J Phys Act Health*. 2017;14(10):779-784. doi:10.1123/jpah.2017-0090
49. Kim H, Ma J, Harada K, Lee S, Gu Y. Associations between adherence to combinations of 24-h movement guidelines and overweight and obesity in Japanese preschool children. *Int J Environ Res Public Health*. 2020;17(24):9320. doi:10.3390/ijerph17249320
50. Kim H, Ma J, Kim J, Xu D, Lee S. Changes in adherence to the 24-hour movement guidelines and overweight and obesity among children in northeastern Japan: a longitudinal study before and during the COVID-19 pandemic. *Obesities*. 2021;1(3):167-177. doi:10.3390/obesities1030015
51. Kim TV, Pham TND, Nguyen CLD, Nguyen TTD, Okely AD, Tang HK. Prevalence of physical activity, screen time, and sleep, and associations with adiposity and motor development among preschool-age children in Vietnam: the SUNRISE Vietnam pilot study. *Indian J Pediatr*. 2022;89(2):148-153. doi:10.1007/s12098-021-03895-2
52. Lee ST, Wong JE, Chan GKL, Poh BK. Association between compliance with movement behavior guidelines and obesity among Malaysian preschoolers. *Int J Environ Res Public Health*. 2021;18(9):4611. doi:10.3390/ijerph18094611
53. Leppänen MH, Ray C, Wennman H, et al. Compliance with the 24-h movement guidelines and the relationship with anthropometry in Finnish preschoolers: the DAGIS study. *BMC Public Health*. 2019;19(1):1618. doi:10.1186/s12889-019-7967-7
54. Leppänen MH, Haapala EA, Väistö J, et al. Longitudinal and cross-sectional associations of adherence to 24-hour movement guidelines with cardiometabolic risk. *Scand J Med Sci Sports*. 2022;32(1):255-266. doi:10.1111/sms.14081
55. Meredith-Jones K, Galland B, Haszard J, et al. Do young children consistently meet 24-h sleep and activity guidelines? A longitudinal analysis using actigraphy. *Int J Obes (Lond)*. 2019;43(12):2555-2564. doi:10.1038/s41366-019-0432-y
56. Roman-Viñas B, Chaput JP, Katzmarzyk PT, et al. Proportion of children meeting recommendations for 24-hour movement guidelines and associations with adiposity in a 12-country study. *Int J Behav Nutr Phys Act*. 2016;13(1):123. doi:10.1186/s12966-016-0449-8
57. Sai-Chuen Hui S, Zhang R, Suzuki K, et al. The associations between meeting 24-hour movement guidelines and adiposity in Asian adolescents: the Asia-fit study. *Scand J Med Sci Sports*. 2021;31(3):763-771. doi:10.1111/sms.13893
58. Shi Y, Huang WY, Sit CHP, Wong SHS. Compliance with 24-hour movement guidelines in Hong Kong adolescents: associations with weight status. *J Phys Act Health*. 2020;17(3):287-292. doi:10.1123/jpah.2019-0230
59. Tanaka C, Tremblay MS, Okuda M, Inoue S, Tanaka S. Proportion of Japanese primary school children meeting recommendations for 24-h movement guidelines and associations with weight status. *Obes Res Clin Pract*. 2020;14(3):234-240. doi:10.1016/j.orcp.2020.05.003
60. Vanderloo LM, Maguire JL, Keown-Stoneman CDG, et al. Associations between meeting the 24-hour movement guidelines and cardiometabolic risk in young children. *Pediatr Exerc Sci*. 2021;33(3):112-119. doi:10.1123/pes.2020-0249
61. Yang Y, Yuan S, Liu Q, et al. Meeting 24-hour movement and dietary guidelines: prevalence, correlates and association with weight status among children and adolescents: a national cross-sectional study in China. *Nutrients*. 2022;14(14):2822. doi:10.3390/nu14142822
62. Zhou L, Liang W, He Y, et al. Relationship of 24-hour movement behaviors with weight status and body composition in Chinese primary school children: a cross-sectional study. *Int J Environ Res Public Health*. 2022;19(14):8586. doi:10.3390/ijerph19148586
63. Zhu X, Healy S, Haegele JA, Patterson F. Twenty-four-hour movement guidelines and body weight in youth. *J Pediatr*. 2020;218:204-209. doi:10.1016/j.jpeds.2019.11.031
64. Chaput JP, Saunders TJ, Carson V. Interactions between sleep, movement and other non-movement behaviours in the pathogenesis of childhood obesity: sleep, movement behaviours and obesity in children. *Obes Rev*. 2017;18:7-14. doi:10.1111/obr.12508
65. García-Hermoso A, Ezzatvar Y, Alonso-Martinez AM, Ramírez-Vélez R, Izquierdo M, López-Gil JF. Twenty-four-hour movement guidelines during adolescence and its association with obesity at adulthood: results from a nationally representative study. *Eur J Pediatr*. 2022;21:1009-1017. doi:10.1007/s00431-022-04760-w
66. Dumuid D, Stanford TE, Martin-Fernández JA, et al. Compositional data analysis for physical activity, sedentary time and sleep research. *Stat Methods Med Res*. 2018;27(12):3726-3738. doi:10.1177/0962280217710835
67. Westerterp KR. Changes in physical activity over the lifespan: impact on body composition and sarcopenic obesity: physical activity and body composition. *Obes Rev*. 2018;19:8-13. doi:10.1111/obr.12781
68. Kredlow MA, Capozzoli MC, Hearon BA, Calkins AW, Otto MW. The effects of physical activity on sleep: a meta-analytic review. *J Behav Med*. 2015;38(3):427-449. doi:10.1007/s10865-015-9617-6
69. Fadzil A. Factors affecting the quality of sleep in children. *Children (Basel)*. 2021;8(2):122. doi:10.3390/children8020122
70. St. Laurent CW, Burkart S, Rodheim K, Marcotte R, Spencer RMC. Cross-sectional associations of 24-hour sedentary time, physical activity, and sleep duration compositions with sleep quality and habits in preschoolers. *Int J Environ Res Public Health*. 2020;17(19):7148. doi:10.3390/ijerph17197148

71. Fatima Y, Doi SAR, Mamun AA. Sleep quality and obesity in young subjects: a meta-analysis: sleep quality and obesity. *Obes Rev*. 2016; 17(11):1154-1166. doi:10.1111/obr.12444
72. Jindal I, Puyau M, Adolph A, Butte N, Musaad S, Bacha F. The relationship of sleep duration and quality to energy expenditure and physical activity in children. *Pediatr Obes*. 2021;16(6). doi:10.1111/ijpo.12751
73. Leproult R, Van Cauter E. Role of sleep and sleep loss in hormonal release and metabolism. *Endocr Dev*. 2010;17:11-21.
74. Liberali R, Del Castanhel F, Kupek E, Assis de MAA. Latent class analysis of lifestyle risk factors and association with overweight and/or obesity in children and adolescents: systematic review. *Child Obes*. 2021;17(1):2-15. doi:10.1089/chi.2020.0115
75. Chaput JP. Sleep patterns, diet quality and energy balance. *Physiol Behav*. 2014;134:86-91. doi:10.1016/j.physbeh.2013.09.006
76. Thivel D, Tremblay MS, Chaput JP. Modern sedentary behaviors favor energy consumption in children and adolescents. *Curr Obes Rep*. 2013;2(1):50-57. doi:10.1007/s13679-012-0032-9
77. Thivel D, Chaput JP. Are post-exercise appetite sensations and energy intake coupled in children and adolescents? *Sports Med*. 2014;44(6):735-741. doi:10.1007/s40279-014-0160-3
78. Tapia-Serrano MA, Sánchez-Miguel PA, Sevil-Serrano J, García-Hermoso A, López-Gil JF. Is adherence to the 24-hour movement guidelines associated with Mediterranean dietary patterns in adolescents? *Appetite*. 2022;179:106292. doi:10.1016/j.appet.2022.106292
79. Thivel D, Tremblay MS, Katzmarzyk PT, et al. Associations between meeting combinations of 24-hour movement recommendations and dietary patterns of children: a 12-country study. *Prev Med*. 2019; 118:159-165. doi:10.1016/j.ypmed.2018.10.025
80. World Health Organization. Report of the commission on ending childhood obesity. WHO; 2016.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: López-Gil JF, Tapia-Serrano MA, Sevil-Serrano J, Sánchez-Miguel PA, García-Hermoso A. Are 24-hour movement recommendations associated with obesity-related indicators in the young population? A meta-analysis. *Obesity (Silver Spring)*. 2023;1-13. doi:10.1002/oby.23848