Time Reallocations From Sedentary Behavior to Physical Activity and Cardiovascular Risk Factors in Children and Adolescents: A Systematic Review

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Background: Recent statistical approaches have allowed consideration of the integrated relationships between sedentary behavior (SB) and physical activity (PA) with different health outcomes. The present paper aimed to systematically review the literature and synthesize evidence about associations between hypothetical reallocations from SB to different PA intensities and cardiovascular risk factors in youth. Methods: A systematic search of 8 databases was performed. Observational studies with a population of children and/or adolescents and based on statistical analysis that investigated the associations between time reallocations from SB to PA and cardiovascular risk factors were included. Results: Twenty-eight studies met the inclusion criteria. Level of evidence (derived from cross-sectional studies) indicated that the reallocation from SB to moderate to vigorous PA was beneficially associated with adiposity, cardiorespiratory fitness, and cardiometabolic biomarkers in youth. Reallocation from SB to light PA was not associated with the analyzed outcomes. Associations derived from longitudinal studies were mostly inconclusive. Conclusion: Cardiovascular risk factors could be improved by increasing moderate to vigorous PA at the expense of time spent in SB in pediatric populations. Prospective studies or studies investigating the effects of reallocating sedentary bouts to PA are needed.

Keywords: epidemiology, public health, adiposity, obesity, physical fitness, youth

Movement behaviors, constituted by sleep, sedentary behavior (SB), and the different physical activity (PA) intensities collectively constitute the total 24-hour day period 1–3 and are distinctly associated with cardiovascular risk factors in the pediatric population. Adequate sleep is favorably associated with cardiovascular health in children and adolescents, 4 and meeting the recommendations of 60 minutes per day of moderate to vigorous physical activity (MVPA) contributes to better cardiometabolic health indicators. 5 On the other hand, high levels of SB can lead to negative health outcomes, which may be moderated by time spent in MVPA. 6

As the duration of a day is fixed and finite, and sleep, SB, and PA are multicollinear and mutually exclusive behaviors of the total 24-hour period, a time change in one movement behavior inevitably leads to a time change in at least one of the remaining behaviors. 1 However, most epidemiologic studies have analyzed associations between components of movement behaviors and health outcomes individually, 2 disregarding the intrinsic interactions and the codependency among movement behavior components. 7,8 More recently, the epidemiologic research area has focused on studies using statistical analyses that simultaneously consider sleep, SB, and PA to analyze the integrated associations of these components and health outcomes. 3,7–10

The isontemporal substitution model 9 and compositional data analysis 7,10 provide a mathematical approach capable of evaluating the hypothetical effects on health outcomes related to the reallocation of time spent in one behavior to another while allowing the adjustment of the remaining behaviors and confounding variables. Thus, the use of these analyses in epidemiologic studies can provide relevant information for the development of intervention strategies to promote PA and provide evidence for the creation of specific recommendations on the replacement of time in SB.

Previous reviews 11,12 concluded that the reallocation of SB to MVPA was associated with a reduction in adiposity indicators and an improvement in cardiorespiratory fitness (CRF) in the pediatric population. There has been a growing number of scientific studies published each year on this theme 13–31; therefore, an update is necessary, especially to advance the understanding of the impact of reallocation of SB to PA on cardiometabolic biomarkers 12 and incorporate new information about recently investigated behaviors, such as the substitution of SB patterns with PA. 6

The purpose of this study was to carry out a systematic literature review and synthesize evidence about associations between hypothetical time reallocations from SB to different PA intensities and cardiovascular risk factors in children and adolescents.

Methods

Protocol

This was a systematic review of observational studies that analyzed associations between time reallocations from SB to different PA intensities and cardiovascular risk factors in children and adolescents. The study was carried out in accordance with the Preferred
Reporting Items for Systematic Review and Meta-Analyses statement, and the protocol was registered with the International Prospective Register of Systematic Reviews under registration number CRD42020219289.

Search Strategy

The systematic literature search was performed in April 2022 in the following databases: PubMed/MEDLINE, Scopus, SPORTDiscus, Web of Science, CINAHL, PsycINFO, Cochrane, and EMBASE. The PICO principle (population, intervention, comparison, and outcome) was adapted and used to develop a search strategy based on the aim of the review. The terms used for the search were combined with Boolean operators, and no limitations regarding publication date were applied. The complete search strategy is shown in Supplementary Table S1 (available online).

Inclusion and Exclusion Criteria

Studies were included in the review if they met the following inclusion criteria: (1) original studies involving children and/or adolescents (6–18 y); (2) studies that reported at least one cardiovascular risk factor (eg, adiposity, CRF, and cardiometabolic biomarkers); (3) studies that used isetemporal substitution analysis or compositional data analysis to explore the effects of replacing time spent in SB (SB patterns, sitting time) with PA (light physical activity [LPA], moderate physical activity [MPA], vigorous physical activity [VPA], MVPA, PA patterns, and standing time); and (4) studies written in English. Experimental studies were excluded.

Study Selection

Search results were downloaded and analyzed, and duplicate articles were excluded using the Rayyan QCRI software (Qatar Computing Research Institute). The selection process and evaluation of articles were carried out by 2 independent reviewers (Volpato and Daniel Zanardini Fernandes [DZF]), with a third reviewer (M. Romanzini) sought in case of disagreements. First, articles were screened and selected for eligibility based on title, with subsequent analysis of the abstract. Then, the full text was read by 2 independent reviewers (Volpato and DZF), and after confirming the inclusion criteria, data were extracted. Inconsistencies between reviewers were resolved with discussion and consensus or in consultation with a third investigator (M. Romanzini). Reference lists of included articles were also reviewed to detect studies potentially eligible for inclusion.

Methodological Quality Assessment

The methodological quality of cross-sectional studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies or the JBI Critical Appraisal Checklist for Cohort Studies. Two independent reviewers (Volpato and Costa) assessed whether each study met each of the 8 items (cross-sectional studies) or 11 items (cohort studies) on the checklist, indicating “yes,” “no,” “unclear,” or “not applicable.” Differences between reviewers were resolved by mutual consensus, and if disagreement persisted, assessment was performed by a third reviewer (M. Romanzini). In each checklist, 1 item was considered “not applicable” for the characteristics of evaluated studies. Thus, the score could vary between 0 and 7 for cross-sectional studies and between 0 and 10 for cohort studies. These checklists did not have cutoff point for classifying studies as to high or low risk of bias. Thus, a score was allocated based on the number of criteria that were met (“yes”). The higher the score, the higher the quality of the study.

Data Extraction

The information extracted from included studies was as follows: author and year of publication; study location; study design; population of interest; age group of participants; sample size; methods used to measure SB, PA, and sleep; methodological information related to the measuring instrument (eg, equipment type and model); statistical approach used to investigate reallocations of time; amount of reallocated time; SB patterns bout range; cardiovascular risk factor of interest; covariates that were included in the statistical analyses; and results of the reallocations of time in SB to different PA intensities. In studies that analyzed more than one PA intensity (eg, LPA, MPA, and VPA), results were considered separately for each PA intensity. Among studies that reported multivariate statistical analyses, results of adjusted analyses were considered. When the same study presented cross-sectional and prospective associations, only results based on prospective analyses were extracted.

To summarize results, the following criteria were considered: (1) effect of reallocation of time in SB to PA on cardiovascular risk factors was individually counted considering each PA intensity (LPA, MPA, VPA, or MVPA); (2) when PA patterns were analyzed, the bout was considered as an indicator of the respective intensity, that is, bouts in MPA were considered as time in MPA and bouts in VPA as time in VPA; (3) results were separated according to the study design (cross-sectional or prospective); (4) in analyses reallocating time from sitting time to standing time, standing time was considered as an LPA indicator; and (5) for studies that analyzed reallocations from sedentary bouts to PA, if the reallocation of at least one bout was associated with a cardiovascular risk factor, results were classified as significant.

Levels of Evidence

Aiming at simplifying and standardizing the presentation of results, associations of time reallocation from SB to each PA intensity were coded using an approach previously described by Sallis et al and later used by Cliff et al. Results were classified as: (1) “no association” (0) if 0% to 33% of studies reported a significant association, (2) inconsistent/uncertain (?) if 34% to 59% of studies reported significant associations or if fewer than 5 studies reported results for a given outcome, and (3) significantly beneficial (+) or significantly detrimental (−) if ≥60% established significant associations.

Meta-analysis procedures were considered to analyze the relationship between reallocations from SB to PA and cardiovascular risk factors. However, studies included in this review showed considerable heterogeneity regarding the indicators used in each of the outcomes analyzed in the study (adiposity, CRF, and cardiometabolic biomarkers) and statistical approaches used (isetemporal substitution or compositional data analysis). Therefore, due to the lack of comparability among methodological approaches, it was decided not to perform meta-analysis. In this way, narrative syntheses for the levels of evidence of associations between reallocations from sedentary time to PA and cardiovascular risk factors were presented using the code system according to criteria previously described.

Results

The search strategy identified 2062 studies in the different databases (Figure 1). After duplicates were removed, a total of
1419 studies remained for analysis. After titles and abstracts were screened, 48 full-text articles were selected for reading. Of those, 27 studies met the inclusion criteria and were included in the present review. By screening the references lists of included articles (1313 articles), 1 additional study relevant for the present review was identified. Therefore, the total number of studies included in this review was 28.

The total number of studies included in this review showed a total of 52,232 children and adolescents, with sample size ranging from 84 to 18,200 participants and with most studies (67.85%) published from the year 2018 on. Of the included studies, 21 had a cross-sectional design and 7 were prospective cohort studies. Among prospective cohort studies, the follow-up period ranged from 9 months to 6 years, with a follow-up period, on average, of 31.5 months. Fourteen studies involved samples composed of children, and 11 were composed of both age groups. Most studies were performed in Europe (39.2%), followed by Oceanian countries (21.4%), Asia (14.2%), North America (14.2%), and South America (7.1%). One study used data from “The International Children’s Accelerometry Database” that encompassed regions in Europe, Australia, and the United States.

The total amount of time in SB reallocated to PA ranged from 2 to 120 minutes. Specifically for SB patterns, analyses were conducted considering short bouts (1–9 min) to long bouts (≥30 min). Replacing school and out-of-school SB with PA was considered in one study, and another evaluated substitution of sitting time for standing time. Sleep period was included in 13 studies. To estimate time spent in SB and different PA intensities, accelerometers were used in 26 studies, whereas questionnaires and motion and heart rate sensors were used in one study. The isotemporal substitution model was used in 17 studies, whereas compositional data analysis was used in 11 studies.

Cardiovascular risk factors were categorized into 3 groups: adiposity (n = 22 studies), CRF (n = 8 studies), and cardiometabolic biomarkers (n = 8 studies). The total sum of associations exceeded the number of 28 articles as some studies assessed more than one cardiovascular risk factor. For adiposity, 16 studies had a cross-sectional design, and 6 had a cohort prospective design, whereas compositional data analysis was used in 11 studies.

Obesity indicators included body mass index (BMI) (BMI z score and percentile); waist circumference; body fat (percentage, android, gynoid, and trunk fat mass); fat mass (fat mass index, percentage, and trunk fat mass index); truncal fat percentage; nontruncal fat percentage; fat-free mass (percentage and index); triceps and subscapularis skinfold; waist-to-height ratio; visceral adipose tissue; and weight status change.

(Ahead of Print)
Associations between reallocations of SB to PA and CRF were analyzed in 7 cross-sectional studies17–19,27,39,41,45 and in only 1 prospective study.26 CRF was evaluated through physical tests (20-m shuttle run test, Canadian aerobic fitness, and running 1000 and 800 m), vital capacity, and cycle ergometer test. Among the 8 included studies analyzing the substitution of SB and cardiometabolic biomarkers, all had a cross-sectional design.20–22,28–31,45 The outcomes analyzed included blood pressure indicators (systolic and diastolic), triglycerides, cholesterol (total high density lipoprotein (HDL), low density lipoprotein (LDL) and non-HDL), glucose, C-reactive protein, insulin (HOMA-IR and HOMA2-S), beta cell function (HOMA2-β), apolipoprotein B/A1, concentrations and mean particle diameter of lipoprotein particles, cholesterol, triglycerides, syndrome severity score, and cardiometabolic risk score. Methodological characteristics and results of studies are described in Supplementary Table S2 (available online).

The level of evidence regarding the associations between time reallocations from SB to different PA intensities (LPA, MPA, VPA, and MVPA) and each cardiovascular risk factor based on cross-sectional studies is presented in Table 1. For all analyzed outcomes (adiposity, CRF, and cardiometabolic biomarkers), the level of evidence classification was “no association” for reallocation from SB to LPA, “inconsistent/uncertain” for reallocation from SB to MPA or VPA, and “positive (+)” for reallocation from SB to MVPA.

The level of evidence of results based on prospective studies is shown in Table 2. For adiposity, the level of evidence classification was “no association” for reallocation from SB to LPA. For all other reallocations tested, classification was “inconsistent/uncertain.” No prospective studies testing the association between reallocation from SB to PA and cardiometabolic biomarkers were identified. A small number of studies have analyzed the effects of reallocating SB bouts on cardiovascular risk factors (Table 3). Therefore, the level of evidence (based on the combined analysis of cross-sectional and longitudinal studies) was classified as “inconsistent/uncertain” for all analyzed outcomes.

The mean score (numbers of “yes”) on the JBI Critical Appraisal Checklist for Analytical Cross-Sectional Studies and JBI Critical Appraisal Checklist for Cohort Studies was 6.76 and 8.0, respectively. Scores ranged from 5 to 7 “yes” in cross-sectional studies and from 7 to 9 in prospective studies. The methodological quality scores for each study are presented in Supplementary Tables S3A and S3B (available online).

Table 1 \(\text{Level of Evidence From Cross-Sectional Studies Examining Associations Between Reallocations of Time in SB to Different PA Intensities and Cardiovascular Risk Factors in Children and Adolescents}\)

<table>
<thead>
<tr>
<th>Reallocation of SB</th>
<th>Associated (citations)</th>
<th>Not associated (citations)</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SB to LPA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>13, 16, 21, 39, 46</td>
<td>14, 15, 18–20, 22, 41, 43–45</td>
<td>4/16 (25%) 0</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>17, 18</td>
<td>19, 27, 39, 41, 45</td>
<td>2/7 (28.5) 0</td>
</tr>
<tr>
<td>Cardiometabolic biomarkers</td>
<td>20, 21, 29</td>
<td>22, 31, 40, 45</td>
<td>3/7 (42.8%) 0</td>
</tr>
<tr>
<td><strong>SB to MPA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>39</td>
<td>16</td>
<td>1/2 (50%) ?</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>39</td>
<td>—</td>
<td>1/1 (100%) ?</td>
</tr>
<tr>
<td>Cardiometabolic biomarkers</td>
<td>31</td>
<td>30</td>
<td>1/2 (50%) ?</td>
</tr>
<tr>
<td><strong>SB to MVP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>13–15, 18, 20–22, 41, 43–46</td>
<td>17, 19</td>
<td>12/14 (85.7%) +</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>17–19, 27, 41</td>
<td>45</td>
<td>5/6 (83.3%) +</td>
</tr>
<tr>
<td>Cardiometabolic biomarkers</td>
<td>20, 22, 28</td>
<td>21, 45</td>
<td>3/5 (60%) +</td>
</tr>
<tr>
<td><strong>SB to VPA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>39</td>
<td>16</td>
<td>1/2 (50%) ?</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>39</td>
<td>—</td>
<td>1/1 (100%) ?</td>
</tr>
<tr>
<td>Cardiometabolic biomarkers</td>
<td>30, 31</td>
<td>—</td>
<td>2/2 (100%) ?</td>
</tr>
</tbody>
</table>

**Abbreviations:** LPA, light PA; MPA, moderate PA; MVPA, moderate to vigorous PA; PA, physical activity; SB, sedentary behavior; VPA, vigorous PA; +, significantly beneficial; −, significantly detrimental; 0, no association; ?, inconsistent/uncertain.

*Studies that identified detrimental associations.

**Discussion**

This study adds new information about associations between reallocations from different SB exposures to PA and cardiovascular risk factors in children and adolescents. In this systematic literature review, it was observed that the substitution of SB with MVPA is beneficially associated with adiposity, CRF, and cardiometabolic biomarkers in the pediatric population. In addition, no association was observed between reallocation from SB to LPA and cardiovascular risk factors. Results regarding the effects of switching from SB to MPA or VPA on outcomes are still uncertain. Finally, this review found that most current evidence is supported by cross-sectional studies, and studies investigating the effect of substituting SB patterns on cardiovascular risk factors in children and adolescents are still scarce.

The impact of reallocation time of SB to different PA intensities on the health outcomes of children and adolescents has shown growing interest in recent investigations. The present study found that about 70% of studies on this topic were published after previous reviews.11,12 Despite this growing interest, summarizing...
the level of evidence is still poorly explored. Based on the results of cross-sectional studies, a meta-analysis showed that the isotemporal substitution of SB with MVPA (not with LPA) was associated with body fat percentage (but not with BMI and waist circumference).\(^{11}\) This evidence was reinforced by the findings of this study, which identified, through associations derived from cross-sectional studies, that the reallocation of SB to MVPA is associated with adiposity in young subjects, even in indicators such as BMI and waist circumference. The confirmation of this level of evidence, as well as the determination of a possible cause and effect relationship between these variables, still needs to be shown in prospective studies.

Another finding of this review is that reallocation from SB to MVPA was beneficially associated with higher CRF values. This is relevant as CRF is considered a predictor of a number of health indicators in youth,\(^{47}\) and high CRF levels during adolescence are associated with lower risks of developing cardiometabolic diseases in adulthood.\(^{48}\) Although VPA is considered a strong determinant of CRF in youth,\(^{47}\) from an integrated behavior replacement perspective, we observed that reallocation from SB to MVPA seems to be sufficient to improve CRF in children and adolescents.

Recent guidelines on PA for children and adolescents were built on the basis that PA is associated with a more favorable cardiometabolic profile.\(^{5,49}\) Similarly, the level of evidence observed in this review indicates that reallocation of SB to MVPA is beneficially associated with cardiometabolic biomarkers. To summarize this evidence, it has been observed that some biomarkers (systolic blood pressure, diastolic blood pressure; LDL cholesterol; triglycerides; insulin; glucose; apolipoprotein B/A1; C-reactive protein; syndrome severity score; concentrations of lipoprotein particle, cholesterol, and triglycerides; and mean particle diameter) were associated with reallocations of SB to MVPA in at

### Table 2 Level of Evidence From Prospective Cohort Studies Examining Associations Between Reallocations of Time in SB to Different PA Intensities and Cardiovascular Risk Factors in Children and Adolescents

<table>
<thead>
<tr>
<th>Reallocation of SB</th>
<th>Associated (citations)</th>
<th>Not associated (citations)</th>
<th>n/N for outcome (%)</th>
<th>Association (+, −, 0, ?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB to LPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>—</td>
<td>24, 25, 38, 40, 42</td>
<td>0/5 (0%)</td>
<td>0</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>—</td>
<td>26</td>
<td>1/1 (100%)</td>
<td>?</td>
</tr>
<tr>
<td>SB to MPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>—</td>
<td>23, 25, 38</td>
<td>0/3 (0%)</td>
<td>?</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>—</td>
<td>26</td>
<td>1/1 (100%)</td>
<td>?</td>
</tr>
<tr>
<td>SB to MVPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>40, 42</td>
<td>24</td>
<td>2/3 (66.6%)</td>
<td>?</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>23, 25</td>
<td>38</td>
<td>2/3 (66.6%)</td>
<td>?</td>
</tr>
</tbody>
</table>

### Table 3 Level of Evidence From Studies Examining Associations Between Reallocations of Time in SB Bouts to Different PA Intensities and Cardiovascular Risk Factors in Children and Adolescents

<table>
<thead>
<tr>
<th>Reallocation of SB bouts</th>
<th>Associated (citations)</th>
<th>Not associated (citations)</th>
<th>n/N for outcome (%)</th>
<th>Association (+, −, 0, ?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB bouts to LPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>—</td>
<td>15, 18, 25</td>
<td>0/3 (0%)</td>
<td>?</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>—</td>
<td>18</td>
<td>0/1 (0%)</td>
<td>?</td>
</tr>
<tr>
<td>SB bouts to MPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>—</td>
<td>25</td>
<td>0/1 (0%)</td>
<td>?</td>
</tr>
<tr>
<td>SB bouts to MVPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>15, 18</td>
<td>—</td>
<td>2/2 (100%)</td>
<td>?</td>
</tr>
<tr>
<td>Cardiorespiratory fitness</td>
<td>18</td>
<td>—</td>
<td>1/1 (100%)</td>
<td>?</td>
</tr>
<tr>
<td>SB bouts to VPA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiposity</td>
<td>25</td>
<td>—</td>
<td>1/1 (100%)</td>
<td>?</td>
</tr>
</tbody>
</table>

Abbreviations: LPA, light PA; MPA, moderate PA; MVPA, moderate to vigorous PA; PA, physical activity; SB, sedentary behavior; VPA, vigorous PA; +, significantly beneficial; −, significantly detrimental; 0, no association; ?, inconsistent/uncertain.
least one study, whereas other biomarkers were not associated (total cholesterol, HDL cholesterol, non-HDL, insulin resistance and sensitivity, beta cell function, and cardiometabolic risk score). Thus, the evidence established in this study reflects the effects of reallocations from SB to MVPA on the overall cardiometabolic profile. Evidence regarding the impact of these reallocations on individual cardiometabolic biomarkers (eg, blood pressure, LDL cholesterol, insulin, glucose) could not be established due to an insufficient number of studies.

The lack of association between reallocation of time in SB to LPA on adiposity, CRF, and cardiometabolic biomarkers was further evidence observed in this study. Although LPA has the potential to reduce time in SB and increase PA levels, and is more easily achievable than MVPA, the potential health benefits related to LPA practice in children and adolescents are still poorly understood, with divergent results in the literature. This is partly due to the lower accuracy of the LPA estimation using accelerometer thresholds. In this sense, estimation errors can attenuate the magnitude of the association toward the null value, corroborating the level of evidence identified in the present study.

Previous studies have suggested that a more favorable SB pattern may be associated with lower adiposity indicators in young subjects. However, it was identified that the level of evidence is still uncertain regarding the effects of the hypothetical reallocation of SB bouts on cardiovascular risk factors in children and adolescents. The few studies available so far are promising regarding the beneficial effects of reallocating SB bouts to MVPA/VPA on adiposity and CRF and tend not to confirm the effects of reallocating SB bouts to LPA.

Although previous reviews analyzing the reallocation of time in SB to PA are available, to our knowledge, this was the first systematic review to (1) systematize evidence regarding the effect of reallocation of SB to PA on different cardiovascular risk factors (specially CRF and cardiometabolic biomarkers) in children and adolescents and (2) include studies that investigated the effect of reallocation of SB pattern parameters (SB bouts) by different intensities on cardiovascular risk factors. In addition, the evidence derived from this review is supported by studies rated with high methodological quality. Some limitations of this review should be highlighted. Only results from studies replacing periods of waking time (SB to PA) were included. Thus, reallocations of sleep time were not considered. Furthermore, limitations inherent to studies included in this review should also be considered. Methodological decisions regarding accelerometer data acquisition procedures (epoch, cutoff points, and device worn time) varied among studies, which may have affected the estimates of time spent in movement behaviors (SB and PA) and associations with cardiovascular risk factors. Adjustment for confounders varied significantly across studies, which may have impacted the magnitude of associations. Finally, most studies included in the present review had a cross-sectional design, preventing determination of causality in associations.

Regarding the statistical approaches, some considerations are needed. To summarize the effects of reallocation from SB to different PA intensities in children and adolescents, studies that used the isotemporal substitution model or compositional data analysis were included. Although based on time reallocation analyses, these approaches differ from each other. Briefly, the isotemporal substitution technique estimates the effects of substituting a specific part of the use time for another; that is, it considers that the change in the duration of time in a certain behavior will inevitably lead to change in the duration of another behavior. In this sense, it would be possible to test, for example, the effects of substituting (hypothetical) a certain amount of time in SB for the same amount of time in MVPA on health outcomes. The analysis of compositional data, in turn, treats the use time as a composition, that is, as a relative distribution of different parts that add up to a constant whole (100% of the time). In this technique, time use data are expressed as a set of log ratios, which are analyzed in traditional statistical models. Thus, it is possible to analyze how changes in the use time proportions are associated with different health outcomes.

In short, although the isotemporal substitution model deals with the substitution of a specific part of the use time with another (absolute values), compositional data analysis treats the use time as a relative composition. Both techniques have advantages and limitations, and the preference for using one technique over another has been the subject of recent debates in the literature.

Conclusion

The present systematic review observed beneficial associations of reallocations of different time intervals of SB to MVPA on adiposity, CRF, and cardiometabolic biomarkers in the pediatric population. The association between reallocations from SB to LPA was classified as no association for adiposity and CRF and was inconsistent with cardiometabolic biomarkers. In addition, most of the evidence presented in this review was based on the results of cross-sectional studies, and studies investigating the relationship between reallocation of SB patterns to PA and adiposity, CRF, and cardiometabolic biomarkers in children and adolescents are scarce. Future studies with a prospective cohort design, considering the effect of reallocations of time in SB patterns to PA on adiposity, CRF, and cardiometabolic biomarkers and investigating the reallocation of SB to specific intensities, such as MPA and VPA, are needed to better understand the effect of reallocations of SB to different PA intensities on cardiovascular risk factors throughout childhood and adolescence. Studies considering devices capable of distinguishing posture transitions, investigating all movement behaviors, and analyzing different health outcomes, such as bone health, cognition, mental health, and social, economic, and environmental aspects, can provide important information about the effect of reallocations of SB and SB patterns to PA on the health of the pediatric population.

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