Compensation or displacement of physical activity in children and adolescents—A systematic review of empirical studies

Franziska Beck (franzi.beck@fau.de)
Friedrich-Alexander-Universität Erlangen-Nürnberg: Friedrich-Alexander-Universitat Erlangen-Nurnberg
https://orcid.org/0000-0002-6360-8828

Florian A. Engel
Universität der Bundeswehr München: Universitat der Bundeswehr Munchen

Anne Kerstin Reimers
Friedrich Alexander University Erlangen Nuremberg: Friedrich-Alexander-Universitat Erlangen-Numberg

Research

Keywords: compensation, displacement, physical activity, children, adolescents

DOI: https://doi.org/10.21203/rs.3.rs-359374/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background: Regular physical activity during childhood and adolescence is associated with health benefits. Consequently, numerous health promotion programs for children and adolescents emphasize the enhancement of physical activity. However, the ActivityStat hypothesis states that increases in physical activity in one domain are compensated for by decreasing physical activity in another domain. Currently, little is known about how physical activity varies in children and adolescents within intervals of one and multiple days.

Objectives: This systematic review provides an overview of studies that analyze changes in (overall) physical activity, which are assessed with objective measurements, or compensatory mechanisms caused by increases or decreases in physical activity in a specific domain in children and adolescents.

Methods: A systematic search of electronic databases (PubMed, Scopus, Web of Science, SportDiscus) was performed with a priori defined inclusion criteria. Two independent researchers screened the literature and identified and rated the methodological quality of the studies.

Results: A total of 77 peer-reviewed articles were included that analyze compensatory mechanisms with multiple methodological approaches. Of 40,829 participants, 16,265 indicated compensation associated with physical activity. Subgroup analyses separated by study design, participants, measurement instrument, physical activity context, and intervention duration also showed mixed results toward indication of compensation. Quality assessment of the included studies revealed high quality (mean = 0.866).

Conclusion: This review provides inconclusive results about compensation in relation to physical activity. A trend toward increased compensation in interventional studies and in interventions of longer duration can be observed.

1 Background

1.1 Health benefits of physical activity

Regular physical activity (PA) during childhood and adolescence is associated with numerous health benefits [1]. As a result of regular PA, physical fitness in children increases and is associated with improvements in cardiovascular [2] and cardiometabolic [1,2] health. Additionally, PA is associated with better mental health in children [3] and adolescents [4] and with a reduction of obesity risk [5-7]. Furthermore, establishing a physically active lifestyle at an early age seems to be important because PA levels at early ages (3 to 6 years) predict PA levels during adolescence and young adulthood [8]. In line with these finding, the World Health Organization (WHO) [9, 10] developed PA recommendations for children and adolescents. Briefly, it is recommended for children 3 to 4 years of age to be physically active for at least 180 minutes daily and for children 5 to 17 years of age to accumulate at least 60 minutes of moderate-to-vigorous PA (MVPA) daily [10]. However, recent analyses have demonstrated that PA levels of children and adolescents in many regions worldwide are not meeting the WHO recommendations [11-13].

1.2 Promotion of physical activity

There have been and continue to be numerous efforts to promote PA in children and adolescents, aiming at helping them develop a more active lifestyle [14-17]. Various contexts serve as a setting for PA promotion. In fact, there are several reviews that underpin the benefits of PA programs among healthy children [15, 18, 19]. Schools, for example, have been identified as an ideal setting for the promotion of PA among children and adolescents because no other institution has as much influence on children during their first two decades of life [15, 18]. Furthermore, walking is identified as an ideal option for health promotion because it is both cheap and easy to implement and no training is required [20]. However, there is little evidence regarding the magnitude of the contribution that active commuting to school might make to children's overall PA [21].

1.3 ActivityStat hypothesis

PA promotion serves as a preventive health strategy [22, 23]. To succeed the health benefits of PA, it is essential to fully understand the PA determinants. Most research has thus far focused on the psychosociological, social, and environmental issues that affect PA levels [24]. In contrast, the potential effect of intrinsic biological control on regular activity has received little attention [25]. With Rowland’s “ActivityStat” hypothesis [26], the research on biological control that underpins PA and energy expenditure has gained momentum in the literature [27]. Briefly, the ActivityStat hypothesis suggests that an imposed increase or decrease in PA in one domain might induce a compensatory change in the opposite direction in another domain in order to maintain a level of PA or energy expenditure that is overall stable over time [27]. Thus, based on the ActivityStat concept, human beings maintain their total PA at a constant level by adapting various mechanisms, such as increasing or decreasing the frequency, intensity, or duration of time spent engaged in PA [28]. By such adapting mechanisms, their actual energy expenditure can either be increased or decreased so that the overall energy expenditure is stable over a certain period of time. For example, on a day when a child has physical education (PE) classes at school, the child may experience an increase in PA in the morning. However, the child may subsequently increase the time that it spends being sedentary in the afternoon, resulting in an overall PA level that is not increased for this day.

1.4 Compensatory changes for imposed physical activity in the scientific literature
A review of school-based PA programs has concluded that there is solid evidence that school-based interventions have a positive impact on the duration of PA with generally no effects on leisure time PA [15]. The review implies no substantial evidence that there is compensation being made for the PA imposed through interventions by having the PA decrease in another domain [15]. However, the studies included in that review rarely analyzed the occurrence of compensatory mechanisms. Generally, for studies with subjective PA measuring methods, potential compensation mechanisms are hardly ever identified [29]. Other research has found that school-based interventions demonstrate small or moderate effects on increasing PA within the school setting and that PA interventions result in little to no change in terms of overall PA levels as a result of compensatory mechanisms employed outside of the school setting [30-37].

A systematic review of active commuting to school and children's PA levels has revealed, in 50% of the studies included, that children who actively commute to school exhibit higher PA levels in all analyzed domains (commuting to school itself, active commuting to other destinations, recreational physical activities, organized sports, or in-school PA) [19]. However, most of the studies included in this review did not analyze the changes in overall PA due to an increase in PA in a specific context or did not perform analyses in different domains or time-spans [19]. Nevertheless, in order to obtain evidence regarding the general effectiveness of interventions on overall PA levels (which are essential for growing up healthy), a holistic approach is important—one that analyzes different domains and time periods of a day in children and adolescents (e.g., physical activities in school and outside of school) in addition to overall PA. Such analysis could provide insights into the potential compensatory mechanisms and rearrangements mentioned in the ActivityStat hypothesis.

In contrast, the ActivityStat hypothesis has been significantly less often investigated in children and adolescents in comparison to adults. A recent study has examined the compensation effect in accelerometer-measured occupational and non-occupational PA in adults. The findings reveal that adults who increase their occupational moderate-to-vigorous PA (MVPA) do not compensate for this increase by reducing their non-occupational MVPA. However, adults who perform more occupational light PA (LPA) do compensate by reducing their non-occupational LPA [38]. In another study, adults are found to compensate for acute physical exercises by decreasing their MVPA and LPA, while increasing their sedentary time in the days following physical exercise [39]. These two studies show how equivocal the findings tend to be in the context of PA and compensation, indicating a need for further investigation in order to understand the reasons and potential mechanisms behind this phenomenon.

1.5 Displacement hypothesis

The original displacement hypothesis postulates a mechanism that opposes the ActivityStat hypothesis, stating that television watching and other sedentary behaviors may displace PA [40]. Different studies have suggested that an increased amount of time spent being sedentary is the primary factor contributing to the current increase in obesity seen in adolescents [41-45]. Due to its inverse relationship, this original hypothesis can also be used to justify the displacement of inactivity with PA. However, little evidence exists that supports this assumption in children and adolescents under 18 years of age [46].

1.6 Aims of the present review

Little is known about how PA varies in children and adolescents within intervals of one and multiple days [47]. Additionally, the question arises whether and how inactive or sedentary time can be displaced by PA within a day or over a period of several days in children and adolescents. For children and adults, a systematic review by Gomersall et al. [27] has found inconclusive results with regards to the ActivityStat hypothesis. This review was limited in its scope because it exclusively considered studies that made explicit reference to compensation. Thus, the term compensation had to be mentioned in the title or abstract of a study in order for it to be included in this review. Overall, to the best of our knowledge, no review has yet analyzed PA compensation in children and adolescents within intervals of one and multiple days.

Consequently, this systematic review aims to provide a synthesis of studies that analyzed changes in overall PA among children and adolescents within the context of PA interventions. Specifically, the present review aims: (i) to provide an overview and analysis of studies that examined changes in (overall) PA, assessed with objective measurements, in children and adolescents and (ii) to identify whether compensatory mechanisms follow PA increases or decreases in one domain or during a time-span of the day (e.g., at school, in the morning) or in terms to the amount at a specific intensity level (e.g., light, moderate, or vigorous PA).

2 Methods

This systematic review was performed and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Additional file 1) [48].

2.1 Eligibility criteria

Studies were deemed to be eligible if they met the following criteria: (1) PA or energy expenditure was objectively measured; (2) changes in (overall) PA or (overall) energy expenditure caused by an increase in PA in a specific domain or during a specific time-span (e.g., at school; in the morning) were investigated and statistically analyzed; (3) participants in the study were healthy children and adolescents (3 to 18 years of age or their mean age was in this range); (4) the study was published in a peer-reviewed journal in the English or German language; and (5) the article was published in the year 2000 or later.
We included interventional as well as non-interventional studies. Interventional studies offered the opportunity to obtain information about "ActivityStat" by investigating intra-individual changes in PA levels in response to an intervention stimulus. Non-interventional studies were included if they investigated PA levels of individuals during different time-spans or in different domains over a period of several days.

2.2 Search strategy

The search was performed on 31 March 2020 using the electronic databases PubMed, Scopus, Web of Science, and SportDiscus. The search strategy included using a combination of terms related to children and youth (child* OR youth* OR adolescen* OR boy* OR girl* OR student* OR pupil*), terms related to PA compensation (increas* OR decreas* OR *more activ* OR improve* OR "less activ*" OR compensat* OR replace* OR change* OR activitystat), terms related to measurement methods ("objective* measure*" OR acceleromet* OR pedomet* OR "heart rate monitor*" OR "doubly labeled water" OR calorimet* OR "direct* observ*"), and outcome-related terms ("physical activ*" OR "energy expenditure"). Two filters were used to refine the results and to obtain the final reference sample for screening. In accordance with the set inclusion criteria, studies "published between 2000–2020" were selected. The publication type was filtered for journal articles (PubMed: "journal article"; SportDiscus: "academic journal", "peer reviewed"; Scopus: "articles"; Web of Science: "Article"). In accordance with recommendations for systematic reviews [49], we screened the reference lists and citations of included articles in order to identify additional relevant studies.

2.3 Study selection

Identified references were imported into Endnote X9, a reference management software [50]. Subsequently, the citations were imported into Covidence, a systematic review software [51]. Within this program, all duplicates were removed. This step was followed by a three-step study selection process, comprising (1) title-screening, (2) abstract-screening, and (3) full-text-screening for inclusion criteria by two independent reviewers (FB, trained student assistant). During each step of the screening process, all references that could not conclusively be excluded were kept for further screening in the next step. Disagreements between the two reviewers in relation to final inclusion were resolved through discussion with a third researcher (AKR).

2.4 Data extraction

The following data were extracted from each article: author(s); country; study design; sample description (number of participants, age, sex); aim/purpose of the study; measurement and instrument of measurement as well as duration of measurement; context of PA, main study results on the relationship between PA in one domain and PA in another domain/overall PA; statistical indicators for compensation.

Studies were also classified by taking into consideration different settings or contexts in which PA was measured. In relation to the main objectives of the study, six settings were defined (school-based PA, physical education, active commuting to school, daily pattern, sport clubs, and others). All included studies were allocated to one of these categories.

2.5 Quality assessment

The methodological quality of the included studies was rated by two independent reviewers (FB, trained student assistant). To assess the quality of each study, criteria for evaluating primary research articles, developed by Kmet et al. [52], were applied. We decided to use this tool because it is appropriate for a variety of different study designs. The "QualSyst" scoring system is based on existing tools and particularly relies upon the instruments developed by Cho and Bero [53] and Timmer et al. [54] for quantitative studies. A series of 14 items was used to assess quality. These items included questions related to study design, methods of participant selection, random allocation procedure, blinding, outcome measures, sample size, estimate of variance, confounding, reporting of results, and the evidence base for the conclusion. The items were scored depending on the degree to which each criterion was met ("yes" = 2, "partial" = 1, "no" = 0). If an item was not applicable to a particular study design, it was coded with "N/A" and was excluded from the calculation of the summative score. Randomization was scored only in interventional studies. The following equation was applied for estimating quality scores: 28 – (number of N/A × 2). Consequently, 28 was the maximum score that could be obtained for the 14 questions. The risk of bias was evaluated with its summary score (range 0–1), whereas higher scores indicated better methodological quality.

2.6 Synthesis of results

It was anticipated that the studies included in this systematic review would exhibit a diverse range of research methods (e.g., study design, intervention characteristics, setting, measurements, participant characteristics, outcome measures). Therefore, it was not appropriate to use meta-analysis to integrate and summarize the included studies. Instead, a narrative synthesis of results was performed. Summary tables describing the detailed characteristics of included studies and the visualization of statistical indicators, describing the probability for compensation related to these characteristics, were provided. The included studies and their findings were grouped according to study design, sample size, target group, dependent variable, geographic origin, PA context, measurement instrument, duration of intervention (if this information was provided), intervention type, and time-span in which compensation was measured. Analyses of compensatory mechanisms were performed for different categories, which seemed to be helpful for understanding compensation. In this respect, the aim was to determine which study design, target group, measurement instrument, PA context, time-span, and intervention duration, as well as type, was susceptible to compensation. A study was voted to be "supporting
compensation” if overall PA did not change with respect to different time points, or if it did not differ between intervention group(s) and control group(s), or if there was a significant increase in PA in one domain or time-span and a significant decrease in PA in another domain or time-span.

3 Results

3.1 Flow chart

A total of 5,917 potentially relevant articles (or 10,946 including duplicates) were identified through database searches and their titles and abstracts were screened. In the next step, the full texts of 95 studies were retrieved for in-depth screening. Since 20 articles were excluded due to inappropriate aims of study, statistical analysis, participants, or multiple reasons, a total of 75 articles were identified as eligible and were included in this systematic review. Two additional relevant publications were identified through backward reference tracking, yielding a total of 77 articles reporting on 74 unique studies included in this systematic review (Figure 1). The PA as Civil Skill Program was published in two studies that focused on LPA [55] and moderate PA (MPA) [56], respectively. The PHASE-Study was also reported in two separate articles. While Ridgers et al. [57] focused on the association between daily PA on two following days, Ridgers et al. [58] analyzed the correlations between the amount of sitting, standing, and stepping time within and between days in primary schoolchildren. Furthermore, two articles included in this review were part of the TEACHOUT-Study and investigated general effects of education outside the classroom [59] and effects of education outside the classroom in different domains [60].

3.2 Characteristics of included studies

A complete data extraction table for each included study can be found in Additional file 2. A synthesis of the characteristics of the included articles is presented in Table 1. The majority of included articles (N = 49; 64%) presented non-interventional studies and 36% presented interventional studies. The sample size ranged from 13 [61] to 6,916 participants [28] with the mean sample size of 532 participants. The geographical origin of the studies was as follows: n = 40 Europe, n = 21 North/Mid America, n = 10 Australia/New Zealand, and n = 6 Asia. Most studies (76%) were published between 2011 and 2020 with the earliest being published in 2000. The main focus of 65 studies (84%) were schoolchildren, while 12 (16%) studies focused on preschoolers. There were 4 studies that targeted only girls [28, 62-64] and 2 only boys [65, 66]. Only 10 studies explicitly stated that their aim was to test compensation [28, 67-75] and, of these studies, 2 specifically mentioned the ActivityStat hypothesis [71, 74]. There were 63 studies that used accelerometry to objectively assess PA, 13 used pedometers, and 1 used a heart rate monitor. A SenseWear Armband was used in 2 studies, in addition to an accelerometer, to assess energy expenditure [74, 76]. Included studies were assigned to one of six contexts/settings: school-based PA in children and adolescents (N = 28), active commuting to school (N = 9), daily PA pattern (N = 15), physical education lessons (N = 16), organized sports (N = 5), or others (N = 4). With respect to interventional studies, the duration of the intervention varied from one week [66, 74] to two years [36, 55, 56, 77, 78]. The average duration of the interventions was 36 weeks (standard deviation (SD) = 37 weeks). Investigation of 3 intervention types found that 50% (N = 14) were educational, 29% (N = 8) were environmental, and 21% (N = 6) were multicomponent. Regardless of their study design (interventional or non-interventional), most studies (85%) examined changes in PA within a one day period.

A total of 39 of the 77 studies, representing 16,297 (40%) children and adolescents, reported statistical indicators that emphasize the probability of compensation. From these 39 studies, 5 reported inconsistent findings in relation to compensation within the sample [64, 69, 77, 79, 80]. Furthermore, some studies indicated compensation in one interventional group (higher amount of PA during intervention) but not in the other [37, 75] —in girls but not in boys [59, 67, 81, 82] or in boys but not in girls [83]. In Table 1, an overview of all studies supporting compensation (N = 39) is presented. With respect to study design, interventional studies indicated compensatory behavior in 75% of studies (representing 76% of participants; N = 6,477), whereas non-interventional studies supported compensation in only 30% of studies (representing 30% of participants; N = 9,820) [57, 58, 67, 69, 71, 76, 80-91]. Furthermore, 42% of preschoolers and 40% of schoolchildren showed indicators for compensatory behavior. Measurements conducted with a pedometer indicated compensation in 6,938 participants (72%), whereas accelerometer measurements showed indicators for compensation in 9,309 participants (30%). In relation to the PA context, school-based PA revealed compensation indicators in 5,350 participants, which corresponds to 72% of all participants in this context, followed by active commuting to school (6,095 participants; 56%). No compensation was indicated in the sport clubs context (0%). With respect to intervention duration, in studies with a duration ≥ 1 year, 100 % of participants indicated compensatory behavior. Compensation was supported in all multicomponent interventions (N = 2,074 participants) and in 64% of all educational interventions (N = 2,295 participants).

3.4 Results of methodological quality assessment

For quality assessment, we applied the “QualSyst” scoring system with a scoring range of 0–1 [52]. The mean quality score of the included articles was rated as high by both raters (mean = 0.87, SD = 0.10, range 0.5–1). The methodological quality criteria and the proportion of studies fulfilling the criteria are presented in Table 2; more detailed quality assessment of each included article is presented in Additional file 3. Items 5, 6, and 7 were only scored for randomized controlled trials (RCTs).

In RCTs, the mean quality score was 0.76 (SD = 0.11) (range 0.5–0.89). In all RCTs, poor blinding of the treatment was evident for both investigators and participants. Overall, included studies revealed a high quality and only few studies exhibited a higher risk of bias [67, 68, 89, 92].

4 Discussion
The present systematic review aims to provide a synthesis of studies that have analyzed changes in overall PA, assessed using objective measurements, or compensatory behavior caused by PA increases or decreases in a specific PA domain or during the time-span of a day in children and adolescents.

A total of 77 articles were included that investigated compensation or displacement across various contexts in children and adolescents. Overall, approximately 50% of the included articles found indicators suggesting compensation and 50% refuted compensational behavior and supported displacement of inactive time with bouts of activity. Detailed analyses based on study design, target group, instruments, context, intervention duration, and measurement duration were performed, revealing differences in compensation depending on categories. The analyses showed tendencies toward compensation in school interventions (especially with durations lasting longer than 1 year) and tendencies of displacement in the context of weekly-organized participation in sport clubs.

It is hypothesized that when PA in one domain or time-span increases, PA in another domain or time-span decreases in order to maintain the PA level constant, as postulated by the ActivityStat hypothesis [27]. In the present analysis, 38 of 77 articles, including 24,532 participants, refuted the ActivityStat hypothesis and showed an increase in overall PA that resulted from imposed PA in one domain or time-span and absence of a reduction in PA in other domains or time-spans. Sustained displacement of inactivity with PA led to an overall increased PA level, as described in the displacement hypothesis. One possible explanation for these increases in overall PA could be that imposed PA stimuli serve as some kind of trigger: PA opportunities in different contexts may stimulate children and adolescents to engage more in physical activities during the entire day [67, 73, 81, 93-95].

In our review, we distinguished between interventional and non-interventional studies. A total of 21 interventional studies (N = 6,477 participants) showed indicators for compensation, whereas only 18 non-interventional studies (N = 9,820 participants) indicated compensatory behavior. This suggests that when PA of children and adolescents is promoted in an intervention, the participants tend to compensate for the additional bouts of PA within the intervention by decreasing their activity levels during other parts of the day or in other domains so that they maintain their overall PA at a stable level. On the other hand, when children increase their PA levels on their own, without participating in an intervention program (in non-interventional studies), it seems that they do not compensate for this and ultimately increase their overall PA level. This could be due to the fact that, in these cases, their PA is more likely based on intrinsic motivation that external influences. Furthermore, interventions were mostly offered and performed in (pre)school contexts. Improvements in (pre)school PA can be compensated for by less PA outside of (pre)school [36, 37, 55, 56, 59, 62, 64, 66, 77-79, 96-103]. "It is possible that school-based interventions are too focused on school setting and children and adolescents do not translate the health message on the importance of physical activity at home or in the community” [15]. For school interventions, it has been suggested that the focus should also be placed on changing parental behaviors and awareness for the sake of adopting a sustainable active lifestyle. In addition, multicomponent interventions or interventions that include schools together with families or communities are most effective in changing PA levels [15, 35]. In general, interventions are most efficient when they operate on multiple levels [104]. "According to ecological models, the most powerful interventions should (a) ensure safe, attractive, and convenient places for physical activity, (b) implement motivational and educational programs to encourage use of those places, and (c) use mass media and community organization to change social norms and culture.” [105]. Since intrapersonal, interpersonal, organizational, community, and public policy factors can influence health behaviors, they consequently counteract compensatory behavior. Despite the fact that the literature suggests that multicomponent interventions have been shown to be useful for changing PA behavior, our results contradict this assumption by the findings of compensatory behavior in all multicomponent studies [36, 37, 77, 79, 102, 103].

Analysis of interventions pointed out a wide range in terms of intervention duration. All six studies (N = 2,541 participants) in which interventions lasted for over one year supported compensation behavior in children and adolescents [36, 55, 56, 64, 77, 78]. Nevertheless, compensatory behavior in children and adolescents was also identified in interventions that had a duration between one month and one year [37, 62, 68, 75, 79, 96-98, 100, 101, 103]. A possible explanation for this finding could be that interventions that last for a shorter period of time may have no or less effect in changing the PA behavior of children and adolescents due to a lack of time needed to progress through the six stages of change, according to the trans-theoretical model [106]. This means that children and adolescents who accumulate more MVPA during an intervention might continue to be as physically active in their leisure time as they were before the intervention. The longer an intervention lasts, the greater the probability that children and adolescents would adapt their PA and become less active in their leisure time—hence, maintaining their overall PA at a stable level.

Almost all studies included in our review captured PA data using pedometers or accelerometers. Six pedometer studies (N = 6,938 children and adolescents) reported compensatory behavior in 32 accelerometer studies [36, 55-59, 62, 64, 66-69, 71, 76-78, 80, 81, 83, 85-87, 89, 91, 96-103]. One explanation for this finding could be that pedometers only capture step counts—an index of the number of steps a person took—whereas the overall PA levels for participating individuals remained unknown. Hence, it is likely that compensation is diagnosed through a measured reduction in steps, while other shifts in PA levels (e.g., overall MVPA) remain unconsidered. Furthermore, only one study out of the 77 analyzed studies investigated energy expenditure using a heart rate monitor and indicated compensation [107].

Besides interventions in a school context, there are two other settings in which children and adolescents are physically active. Only 57% of children and adolescents who actively commute to school showed indicators for compensation [81, 83, 84, 86]. Active commuting and independent mobility
of children provide additional opportunities for spontaneous play [95] and enable other active behaviors [108, 109]. This can lead to an increase in overall PA and, therefore, supports the displacement theory.

In the PE context, only 32% of the participants indicated compensatory behavior [67, 71, 82, 88, 89, 91]. PE classes should provide an opportunity for children and adolescents to engage in PA and to develop knowledge about and attitudes toward developing an active lifestyle [110], which could lead to displacing inactivity with active behavior. Interestingly, two articles, involving 365 participants, investigated the impact of different amounts of PE per week on overall PA levels in children and adolescents. From their findings, it can be summarized that more PE per week is not necessarily effective for increasing total PA because the PA in PE classes is often compensated for by less activity outside of the school setting [71, 89]. Consequently, future studies should assess what the right amounts and intensities of PA during PE classes would be in order to avoid compensation outside of school.

Finally, our detailed analyses reveal one PA domain in which an increase of activity levels was not found to lead to compensation but, instead, to displacement: when engaging in organized sport clubs, children and adolescents do not compensate their PA levels by being less active after the training sessions [61, 63, 111-113]. Sport clubs represent a health-promoting setting and support children and adolescents in living an active lifestyle outside sport clubs [114]. Furthermore, sport programs can provide beneficial access to and resources for recreational activities [112]. Thus, participation in sport clubs serves as an additional factor for increasing overall PA and can displace sedentary behavior.

Compensatory behavior occurs after a PA increase or decrease in one domain or time-span in order to maintain a stable overall PA level. Almost all studies in this review revealed that a PA increase in one domain or time-span is followed by a PA decrease in another domain or time-span, which is negatively connoted. Nevertheless, there exists one study [82] in our review, where compensatory behavior was found to occur after a PA reduction—leading to compensation being positively connoted.

4.1 Implications

This review of compensation for PA in children and adolescents provides inconsistent results relating to compensation. Consequently, further research is needed for better understanding of compensatory mechanisms and a recommendation is made for future studies to investigate PA behavior over a period of a few days using an objective measurement method. In addition, participants should complete a questionnaire or keep a diary in order to terminate and locate their activities and to obtain information about the reasons for their PA behavior. Social support plays an important role for sufficient PA in children and adolescents. Thus, PA behavior and attitude of family and friends can influence one's own PA and determine compensatory behavior. Additional subgroup analyses, including an examination of differences in PA by gender, age, weight status, socioeconomic status (SES), and ethnicity, could provide more information about compensatory behavior. Gender differences have already been seen in a few of the included studies with inconclusive results [59, 67, 81, 83]. Additionally, various SES analyses indicate different environmental, social, and educational circumstances [115, 116]. Hence, SES is an important predictor of PA in children and adolescents [115] and can influence compensatory behavior. Unfortunately, none of the included studies investigated compensatory behavior separately for different SES. It is hypothesized that children and adolescents with lower SES compensate more often than individuals with higher SES. It would also be interesting to further investigate the setpoint for “ActivityStat” or possible differences depending on age, season, or energy intake. With the help of an experimental design, future studies could investigate when this setpoint is reached and whether there are differences. Furthermore, there are currently no existing theories that deal with the timeframe for compensation. It is hypothesized that the timeframe for compensation is unlikely to be day-to-day [27]. Currently, the timeframes in the studies examined in our review are random. Finally, combined measurement of energy expenditure and PA should be used to obtain more detailed and reliable information about compensatory mechanisms.

Practical implications refer to interventional studies: besides active PA promotion, it is important to improve the awareness in children and adolescents, as well as in their parents, regarding the importance of PA as well as to enable them to be physically active at home during their leisure time. This is necessary in order to avoid compensation that occurs when PA at home and/or in the family environment is reduced after increases in PA levels take place during interventions in, for example, the school setting.

4.2 Strengths and limitations

The main strength of this review is that we exclusively included studies that objectively measured PA, including measures that directly assessed one or more PA dimension (e.g., frequency, intensity, time, type) and captured a variety of measures, such as step counts, activity minutes, and PA intensity [117]. An additional strength lies in the fact that the systematic search of relevant primary studies employed several electronic databases and a comprehensive list of search strings. Furthermore, the reference lists of all included studies were manually checked in the search for additional relevant studies. Our search strategy was broad enough to allow us to identify relevant studies as well as to include those studies that did not analyze PA compensation as their main objective. In contrast to Gomersall et al. [27], we did not only include studies that made explicit reference to compensation. Instead, we analyzed studies investigating changes in overall PA and in different domains or time segments for compensatory mechanisms. Another strength is the inclusion of a wide range of different settings in which PA plays an important role.

A limitation of this review relates to the variety of the study designs of the included studies, which made a comparison of the results difficult. Additionally, some studies only allowed between-subject analyses, which, in turn, only enabled conclusions about compensation to be obtained from
a comparison of PA levels between two groups. For better understanding of compensatory mechanisms, within-subject analyses provided stronger results. Another limitation is that there were different PA segments in the reviewed studies, which made it difficult to compare them all.

5 Conclusion

Based on Rowland’s ActivityStat hypothesis [26], this systematic review provided inconclusive results regarding potential compensatory activity behavior after changes in PA levels in one domain or during a time-span in children and adolescents. Overall, 39 studies (n = 16,297 children and adolescents) that were included in this review did exhibit indicators of compensation. In summary, the synthesis of the included studies revealed a tendency for compensatory behavior in the context of interventions, especially in interventions with a long duration (< 1 year). Furthermore, children and adolescents who regularly participated in organized sports showed no indicators for compensatory behavior. In order to verify the results of the present review, further investigations are needed.

List Of Abbreviations

LPA light physical activity
MPA moderate physical activity
MVPA moderate-to-vigorous physical activity
PA physical activity
PE physical education
RCT randomized controlled trial
SD standard deviation
WHO World Health Organization

Declarations

Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Availability of data and materials
Data generated and/or analyzed during the current study are mainly included in the published article and its supplementary information files. Additional data (e.g., details of the screening process) are available on request from the corresponding author.

Conflict of interests/Competing interests
The authors declare that they have no conflicts of interests or competing interests.

Funding
This study was supported by the Federal and State Program for Women Professors (Professorinnenprogramm) (third phase; 2018–2022) that is funded by the Federal Ministry of Education and Research (BMBF) together with the German states.

Author's contribution
All authors developed the concept of the study. FB drafted the manuscript, performed the review, and synthesized the findings. AKR supervised the project. AKR and FE provided edits to the manuscript. All authors read and approved the final manuscript.

Acknowledgements
The authors thank student assistants, Susan Faizy and Ralf Winderl, for their assistance in the processes of literature screening and methodological quality rating.
References

1. Poitras VJ, Gray CE, Borghese MM, Carson V, Chaput JP, Janssen I, 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):S197-S239.

2. Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Cooper A, et al. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA. 2012;307(7):704-12.

3. Biddle SJ, Asare M. Physical activity and mental health in children and adolescents: a review of reviews. Br J Sports Med. 2011;45(11):886-95.

4. Rodrigues-Ayllon M, Cadenas-Sanchez C, Estevez-Lopez F, Munoz NE, Mora-Gonzalez J, Migueles JH, et al. Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: a systematic review and meta-analysis. Sports Med. 2019;49(9):1383-410.

5. Committee PAGAA. Physical Activity Guidelines Advisory and Committee Report. 2008.

6. World Health Organization. Global Health Risks. Mortality and burden of disease attributable to selected major risk. 2009.

7. Hong I, Coker-Bolt P, Anderson KR, Lee D, Velozo CA. Relationship between physical activity and overweight and obesity in children: findings from the 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey. Am J Occup Ther. 2016;70(5):7005180060p1-8.

8. Telama R, Yang X, Leskinen E, Kankaanpaa A, Hirvensalo M, Tammelin T, et al. Tracking of physical activity from early childhood through youth into adulthood. Med Sci Sports Exerc. 2014;46(5):955-62.

9. World Health Organization. Global recommendations of physical activity for health. 2010.

10. World Health Organization. Guidelines on physical activity, sedentary behavior and sleep for children under 5 years of age. 2019.

11. Van Hecke L, Loyen A, Verloigne M, van der Ploeg HP, Lakerveld J, Brug J, et al. Variation in population levels of physical activity in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. Int J Behav Nutr Phys Act. 2016;13.

12. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. The Lancet. 2012;380(9838):247-57.

13. Tremblay MS, Baines JD, Gonzalez SA, Katzmarzyk PT, Onywera VO, Reilly JJ, et al. Global matrix 2.0: report card grades on the physical activity of children and youth comparing 38 countries. J Phys Act Health. 2016;13(11 Suppl 2):S343-S66.

14. Messing S, Rutten A, Abu-Omar K, Ungerer-Rohrich U, Goodwin L, Burlacu I, et al. How can physical activity be promoted among children and adolescents? A systematic review of reviews across settings. Front Public Health. 2019;7:55.

15. Dobbins M, Husson H, DeCorby K, LaRocca RL. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. Cochrane Database Syst Rev. 2013(2):Cd007651.

16. Owen MB, Curry WB, Kerner C, Newson L, Fairclough SJ. The effectiveness of school-based physical activity interventions for adolescent girls: a systematic review and meta-analysis. Prev Med. 2017;105:237-49.

17. Gorga E, Regazzoni V, Bansilal S, Carubelli V, Trichaki E, Gavazzoni M, et al. School and family-based interventions for promoting a healthy lifestyle among children and adolescents in Italy: a systematic review. J Cardiovasc Med (Hagerstown). 2016;11(3):A202-A.

18. Story M, Nanney MS, Schwartz MB. School and obesity prevention: creating school environments and policies to promote healthy eating and physical activity. Milbank Q. 2009;87:71-100.

19. Lee MC, Orenstein MR, Richardson MJ. Systematic review of active commuting to school and children's physical activity and weight. J Phys Act Health. 2008;5:930-49.

20. Olden K. Urban Sprawl and Public Health: Designing, planning, and building for healthy communities. Environ Health Perspect. 2005;113(3):A202-A.

21. Tudor-Locke C, Ainsworth BE, Popkin BM. Active commuting to school: an overlooked source of children's physical activity? Sports Med. 2001;31(5):309-13.

22. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act. 2010;7:40.

23. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. CMAJ. 2006;174(6):801-9.

24. Sallis JF, Hovell MF. Determinants of exercise behavior. Exerc Sport Sci Rev. 1990;18:307-30.

25. Thorburn AW, Proietto J. Biological determinants of spontaneous physical activity. Obes Rev. 2000;1:87-94.

26. Rowland TW. The biological basis of physical activity. Med Sci Sports Exerc. 1998;30:392-9.

27. Gomersall SR, Rowlands AV, English C, Maher C, Olds TS. The ActivityStat hypothesis: the concept, the evidence and the methodologies. Sports Med. 2013;43(2):135-49.

28. Baggett CD, Stevens J, Catellier DJ, Evenson KR, McMurray RG, He K, et al. Compensation or displacement of physical activity in middle-school girls: the Trial of Activity for Adolescent Girls. Int J Obes (Lond). 2010;34(7):1193-9.
29. Reilly JJ. Can we modulate physical activity in children. Int J Obes (Lond). 2011;35(10):1266-9.
30. Baranowski T, Anderson CAM, Carmack C. Mediating variables framework in physical activity interventions. How are we doing? How might we do better? Am J Prev Med. 1998;15:266-97.
31. Gortmaker SL, Peterson K, Wiecha J, Sobol AM, Dixit S, Fox MK, et al. Reducing obesity via a school-based interdisciplinary intervention among youth: Planet Health. Arch Pediatr Adolesc Med. 1999;153(4):409-18.
32. Kelder SH, Perry CL, Klepp KI. Community-wide youth exercise promotion: long-term outcomes of the Minnesota Heart Health Program and the Class of 1989 Study. J Sch Health. 1993;63(5):218-23.
33. Killen JD, Telch MJ, Robinson TN, Maccoby N, Taylor CB, Farquhar JW. Cardiovascular disease risk reduction for tenth graders. A multiple-factor school-based approach. Jama. 1988;260(12):1728-33.
34. Saunders RP, Ward D, Felton GM, Dowda M, Pate RR. Examining the link between program implementation and behavior outcomes in the lifestyle education for activity program (LEAP). Eval Program Plann. 2006;29(4):352-64.
35. van Sluijs EM, McMinn AM, Griffin SJ. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. BMJ. 2007;335(7622):703.
36. Haapala HL, Hirvensalo MH, Kulmala J, Hakonen H, Kankaanpaa A, Laine K, et al. Changes in physical activity and sedentary time in the Finnish Schools on the Move program: a quasi-experimental study. Scand J Med Sci Sports. 2017;27(11):1442-53.
37. Aburto NJ, Fulton JE, Safdie M, Duque T, Bonvechio A, Rivera JA. Effect of a school-based intervention on physical activity: cluster-randomized trial. Med Sci Sports Exerc. 2011;43(10):1898-906.
38. Gay JL, Buchner DM, Smith J, He C. An examination of compensation effects in accelerometer-measured occupational and non-occupational physical activity. Prev Med Rep. 2017;8:55-9.
39. Goncin N, Linares A, Lloyd M, Dogra S. Does sedentary time increase in older adults in the days following participation in intense exercise? Aging Clin Exp Res. 2020;32(12):2517-27.
40. Mutz DC, Roberts DF, Van Vuuren DP. Reconsidering the displacement hypothesis: television’s influence on children’s time use. Communication Research. 1993;20:51-75.
41. Gortmaker SL, Must A, Sobol AM, Peterson K, Colditz GA, Dietz WH. Television viewing as a cause of increasing obesity among children in the United States, 1986–1990. Arch Pediatr Adolesc Med. 1996;150(4):356-62.
42. Dietz WJ, Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. Pediatrics. 1985;75:807-12.
43. Klesges RC, Shelton ML, Klesges LM. Effects of television on metabolic rate: potential implications for childhood obesity. Pediatrics. 1993;91:281-6.
44. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. Physical activity, sedentary time, and obesity in an international sample of children. Med Sci Sports Exerc. 2015;47(10):2062-9.
45. Jago R, Salway R, Emm-Collison L, Sebire SJ, Thompson JL, Lawlor DA. Association of BMI category with change in children's physical activity between ages 6 and 11 years: a longitudinal study. Int J Obes (Lond). 2020;44(1):104-13.
46. Marshall SJ, Biddle SJ, Gorely T, Cameron N, Murdey I. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. Int J Obes Relat Metab Disord. 2004;28:1238-46.
47. Wilkin TJ, Mallam KM, Metcalf BS, Jeffery AN, Voss LD. Variation in physical activity lies with the child, not his environment: evidence for an "activitystat" in young children (EarlyBird 16). Int J Obes (Lond). 2006;30(7):1050-5.
48. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.
49. Briscoe S, Bethel A, Rogers M. Conduct and reporting of citation searching in Cochrane systematic reviews: a cross-sectional study. Res Synth Methods. 2020;11(2):169-80.
50. Analytics Clarivate. Endnote X9. Philadelphia: Clarivate Analytics; 2020.
51. Veritas Health Innovation. Covidence systematic review software Melbourne. Melbourne, Australia.
52. Kmet LM, Lee RC, Cook LS. Standard quality assessment criteria for evaluating primary research paper from a variety of fields. Edmonton: Alberta Heritage Foundation for Medical Research (AHFMR). AHFMR-HTA Initiative #13; 2004.
53. Cho MK, Bero LA. Instruments for assessing the quality of drug studies published in the medical literature. Jama. 1994;272(2):101-4.
57. Ridgers ND, Timperio A, Cerin E, Salmon J. Compensation of physical activity and sedentary time in primary school children. Med Sci Sports Exerc. 2014;46(8):1564-9.

58. Ridgers ND, Timperio A, Cerin E, Salmon J. Within- and between-day associations between children's sitting and physical activity time. BMC Public Health. 2015;15.

59. Schneller MB, Duncan S, Schipperijn J, Nielsen G, Mygind E, Bentsen P. Are children participating in a quasi-experimental education outside the classroom intervention more physically active? BMC Public Health. 2017;17.

60. Schneller MB, Schipperijn J, Nielsen G, Bentsen P. Children's physical activity during a segmented school week: results from a quasi-experimental education outside the classroom intervention. Int J Behav Nutr Phys Act. 2017;14.

61. Pelclova J, El Ansari W, Vasickova J. Is participation in after-school physical activity associated with increased total physical activity? A study of high school pupils in the Czech Republic. Int J Environ Res Public Health. 2010;7(7):2853-65.

62. Alhassan S, Nwoakemele O, Greever CJ, Burkart S, Ahmadi M, St Laurent CW, et al. Effect of a culturally-tailored mother-daughter physical activity intervention on pre-adolescent African-American girls' physical activity levels. Prev Med Rep. 2018;11:7-14.

63. Fromel K, Pelclova J, Skalik K, Novakova Lokvencova R, Mitas J. The association between participation in organised physical activity and level of physical activity and inactivity in adolescent girls. Acta Gymnica. 2012;42(1):7-16.

64. Harrington DM, Davies MJ, Bodicoat DH, Charles JM, Chudasama YV, Gorely T, et al. Effectiveness of the 'Girls Active' school-based physical activity programme: a cluster randomised controlled trial. Int J Behav Nutr Phys Act. 2018;15.

65. Aljuhani O, Sandercock G. Contribution of physical education to the daily physical activity of schoolchildren in Saudi Arabia. Int J Environ Res Public Health. 2019;16(13).

66. Wilson AN, Olds T, Lushington K, Parvazian S, Dollman J. Active school lesson breaks increase daily vigorous physical activity, but not daily moderate to vigorous physical activity in elementary school boys. Pediatr Exerc Sci. 2017;29(1):145-52.

67. Alderman BL, Benham-Deal T, Beighle A, Erwin HE, Olson RL. Physical education's contribution to daily physical activity among middle school youth. Pediatr Exerc Sci. 2012;24(4):634-48.

68. Alhassan S, Sirard JR, Robinson TN. The effects of increasing outdoor play time on physical activity in Latino preschool children. Int J Pediatr Obes. 2007;2(3):153-8.

69. Carlson JA, Mitchell TB, Saelens BE, Staggs VS, Kerr J, Frank LD, et al. Within-person associations of young adolescents' physical activity across five primary locations: is there evidence of cross-location compensation? Int J Behav Nutr Phys Act. 2017;14(1):50.

70. Dale D, Corbin CB, Dale KS. Restricting opportunities to be active during school time: do children compensate by increasing physical activity levels after school? Res Q Exerc Sport. 2000;71:240-8.

71. Fremeaux AE, Mallam KM, Metcalf BS, Hosking J, Voss LD, Wilkin TJ. The impact of school-time activity on total physical activity: the activitystat hypothesis (EarlyBird 46). Int J Obes (Lond). 2011;35(10):1277-83.

72. Long MW, Sobol AM, Cradock AL, Subramanian SV, Blendon RJ, Gortmaker SL. School-day and overall physical activity among youth. Am J Prev Med. 2013;45(2):150-7.

73. Morgan CF, Beighle A, Pangrazi RP. What are the contributory and compensatory relationships between physical education and physical activity in children? Res Q Exerc Sport. 2007;78(5):407-12.

74. Ridgers ND, Lamb KE, Timperio A, Brown H, Salmon J. Investigating children's short-term responses to imposed or restricted physical activity. J Phys Act Health. 2018;15(4):239-46.

75. Stylianou M, van der Mars H, Kulinka PH, Adams MA, Mahar M, Amazeen E. Before-school running/walking club and student physical activity levels: an efficacy study. Res Q Exerc Sport. 2016;87(4):342-53.

76. Ridgers ND, Barnett LM, Lubans DR, Timperio A, Cerin E, Salmon J. Potential moderators of day-to-day variability in children's physical activity patterns. J Sports Sci. 2018;36(6):637-44.

77. Magnusson KT, Sigurgeirsson I, Sveinsson T, Johannsson E. Assessment of a two-year school-based physical activity intervention among 7–9-year-old children. Int J Behav Nutr Phys Act. 2011;8.

78. Toftager M, Christiansen LB, Ersboll AK, Kristensen PL, Due P, Troelsen J. Intervention effects on adolescent physical activity in the multicomponent SPACE study: a cluster randomized controlled trial. PLoS One. 2014;9(6).

79. Eyre ELJ, Cox VM, Birch SL, Duncan MJ. An integrated curriculum approach to increasing habitual physical activity in deprived South Asian children. Eur J Sport Sci. 2016;16(3):381-90.

80. Goodman A, Mackett RL, Paskins J. Activity compensation and activity synergy in British 8–13 year olds. Prev Med. 2011;53(4-5):293-8.

81. Cooper AR, Page AS, Foster LJ, Qahwaji D. Commuting to school. Am J Prev Med. 2003;25(4):273-6.

82. Tudor-Locke C, Lee SM, Morgan CF, Beighle A, Pangrazi RP. Children's pedometer-determined physical activity during the segmented school day. Med Sci Sports Exerc. 2006;38(10):1732-8.

83. Jago R, Wood L, Sebire SJ, Edwards MJ, Davies B, Banfield K, et al. School travel mode, parenting practices and physical activity among UK Year 5 and 6 children. BMC Public Health. 2014;14.
84. Bin Tan S, Zegers PC, Wilhelm E, Arcaya MC. Evaluating the effects of active morning commutes on students’ overall daily walking activity in Singapore: Do walkers walk more? J Transp Health. 2018;8:220-43.
85. Bringolf-Iser B, Grize L, Maeder U, Ruch N, Sennhauser FH, Braun-Fahrländer C. Assessment of intensity, prevalence and duration of everyday activities in Swiss school children: a cross-sectional analysis of accelerometer and diary data. Int J Behav Nutr Phys Act. 2009;6.
86. Ford P, Bailey R, Coleman D, Woolf-May K, Swaine I. Activity levels, dietary energy intake, and body composition in children who walk to school. Pediatr Exerc Sci. 2007;19(4):393-407.
87. Gidlow CJ, Cochrane T, Davey R, Smith H. In-school and out-of-school physical activity in primary and secondary school children. J Sports Sci. 2008;26(13):1411-9.
88. Groff D, Mitas J, Jakubec L, Svozil Z, Fromel K. Adolescents’ physical activity in education systems varying in the number of weekly physical education lessons. Res Q Exerc Sport. 2020.
89. Mallam KM, Metcalf BS, Kirkby J, Voss LD, Wilkin TJ. Contribution of timetabled physical education to total physical activity in primary school children: cross sectional study. BMJ. 2003;327:592-3.
90. Ribeyre J, Fellmann N, Vernet J, Delaître M, Chamoux A, Coudert J, et al. Components and variations in daily energy expenditure of athletic and non-athletic adolescents in free-living conditions. Br J Nutr. 2007;84(4):531-9.
91. Rooney L, McKee D. Contribution of physical education and recess towards the overall physical activity of 8–11 year old children. Journal of Sport and Health Research. 2018;10:302-13.
92. Loucaides CA, Jago R, Charalambous I. Promoting physical activity during school break times: piloting a simple, low cost intervention. Prev Med. 2009;48(4):332-4.
93. Cheung P. School-based physical activity opportunities in PE lessons and after-school hours: Are they associated with children's daily physical activity? Eur Phys Educ Rev. 2019;25(1):65-75.
94. Pesola AJ, Melin M, Vanhala A, Gao Y, Finni T. Does SuperPark make children less sedentary? How visiting a commercial indoor activity park affects 7 to 12 years old children's daily sitting and physical activity time. Int J Environ Res Public Health. 2018;15(8).
95. Smith L, Sahliqvist S, Ogilvie D, Jones A, Corder K, Griffin SJ, et al. Is a change in mode of travel to school associated with a change in overall physical activity levels in children? Longitudinal results from the SPEEDY study. Int J Behav Nutr Phys Act. 2012;9:134-41.
96. Adkins M, Brown GA, Heelan K, Ansorge C. Can dance exergaming contribute to improving physical activity levels in elementary school children? Afr J Phys Educ Recreat Dance. 2013;19:576-85.
97. Alhassan S, Nwaokemehe O, Ghazarian M, Shitole S, Puleo E, Pfeiffer KA, et al. Feasibility and effects of short activity breaks for increasing preschool-age children's physical activity levels. J Sch Health. 2016;86:526-33.
98. Coombes E, Jones A. Gamification of active travel to school: a pilot evaluation of the Beat the Street physical activity intervention. Health Place. 2016;39:62-9.
99. Møller NC, Tarp J, Kamelarczyk EF, Brønd J, Klakk H, Wedderkopp N. Do extra compulsory physical education lessons mean more physically active children—findings from the childhood health, activity, and motor performance school study Denmark (The CHAMPS-study DK). Int J Behav Nutr Phys Act. 2014;11.
100. O'Dwyer MV, Fairclough SJ, Ridgers ND, Knowles ZR, Foweather L, Stratton G. Effect of a school-based active play intervention on sedentary time and physical activity in preschool children. Health Educ Res. 2013;28(6):931-42.
101. Palmer KK, Chinn KM, Robinson LE. The effect of the CHAMP intervention on fundamental motor skills and outdoor physical activity in preschoolers. J Sport Health Sci. 2019;8(2):98-105.
102. Pate RR, Brown WH, Pfeiffer KA, Howie EK, Saunders RP, Addy CL, et al. An intervention to increase physical activity in children: a randomized controlled trial with 4-year-olds in preschools. Am J Prev Med. 2016;51(1):12-22.
103. Sutherland RL, Nathan NK, Lubans DR, Cohen K, Davies LJ, Desmet C, et al. An RCT to facilitate implementation of school practices known to increase physical activity. Am J Prev Med. 2017;53(6):818-28.
104. Sallis JF, Owen N, Fisher EB. Ecological Models of Health Behavior. In: Glanz K, Rimer BK, Viswanath K, editors. Health Behavior and Health Education: Theory, Research and Practice. 4th ed. San Francisco, California: Jossey-Bass; 2008.p.465-586.
105. Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating active living communities. Annu Rev Public Health. 2006;27:297-322.
106. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. Am J Health Promot. 1997;12(1):38-48.
107. Ribeyre J, Fellmann N, Vernet J, Delaître M, Chamoux A, Coudert J, et al. Components and variations in daily energy expenditure of athletic and non-athletic adolescents in free-living conditions. Br J Nutr. 2000;84(4):531-9.
108. Page AS, Cooper AR, Griew P, Jago R. Independent mobility, perceptions of the built environment and children’s participation in play, active travel and structured exercise and sport: the PEACH Project. Int J Behav Nutr Phys Act. 2010;7:17.
109. Wen LM, Kite J, Merom D, Rissel C. Time spent playing outdoors after school and its relationship with independent mobility: a cross-sectional survey of children aged 10–12 years in Sydney, Australia. Int J Behav Nutr Phys Act. 2009;6:15.
110. Hills AP, Dengel DR, Lubans DR. Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. Prog Cardiovasc Dis. 2015;57(4):368-74.

111. Jago R, Macdonald-Wallis C, Solomon-Moore E, Thompson AL, Lawlor DA, Sebire SJ. Associations between participation in organised physical activity in the school or community outside school hours and neighbourhood play with child physical activity and sedentary time: a cross-sectional analysis of primary school-aged children from the UK. BMJ Open. 2017;7(9).

112. Koorts H, Timperio A, Arundell L, Parker K, Abbott G, Salmon J. Is sport enough? Contribution of sport to overall moderate-to-vigorous-intensity physical activity among adolescents. J Sci Med Sport. 2019;22(10):1119-24.

113. Mooses K, Kull M. The participation in organised sport doubles the odds of meeting physical activity recommendations in 7-12-year-old children. Eur J Sport Sci. 2019.

114. Geidne S, Quennerstedt M, Eriksson C. The youth sports club as a health-promoting setting: an integrative review of research. Scand J Public Health. 2013;41(3):269-83.

115. Gidlow C, Johnston LH, Crone D, Ellis N, James D. A systematic review of the relationship between socio-economic position and physical activity. Health Educ J. 2016;65(4):338-67.

116. Schmidt SCE, Anedda B, Burchartz A, Oriwol D, Kolb S, Wasche H, et al. The physical activity of children and adolescents in Germany 2003–2017: The MoMo-study. PLoS One. 2020;15(7):e0236117.

117. Strath SJ, Kaminsky LA, Ainsworth BE, Ekelund U, Freedson PS, Gary RA, et al. Guide to the assessment of physical activity: Clinical and research applications: a scientific statement from the American Heart Association. Circulation. 2013;128(20):2259-79.

118. Brockman R, Jago R, Fox KR. The contribution of active play to the physical activity of primary school children. Prev Med. 2010;51(2):144-7.

119. Brusseau T, Kulina PH, Tudor-Locke C, Van der Mars H, Darst PW. Children's step counts on weekend, physical education and non-physical education days. J Hum Kinet. 2011;27:125-35.

120. Gao Y, Wang J-J, Lau PWC, Ransdell L. Pedometer-determined physical activity patterns in a segmented school day among Hong Kong primary school children. J Exerc Sci Fit. 2015;13(1):42-8.

121. Hardman CA, Home PJ, Rowlands AV. Children's pedometer-determined physical activity during school-time and leisure time. J Exerc Sci Fit. 2009;7:129-34.

122. Kek CC, Bengoechea EG, Spence JC, Mandic S. The relationship between transport-to-school habits and physical activity in a sample of New Zealand adolescents. J Sport Health Sci. 2019;8(5):463-70.

123. Kippe KO, Lagestad PA. Kindergarten: Producer or reducer of inequality regarding physical activity levels of preschool children. Front Public Health. 2018;6.

124. Kobel S, Kettner S, Lammle C, Steinacker JM. Physical activity of German children during different segments of the school day. Z Gesundh Wiss. 2017;25(1):29-35.

125. Mayorga-Vega D, Martinez-Baena A, Viciana J. Does school physical education really contribute to accelerometer-measured daily physical activity and non sedentary behaviour in high school students? J Sports Sci. 2018;36(17):1913-22.

126. Meyer U, Roth R, Zahner L, Gerber M, Puder JJ, Hebestreit H, et al. Contribution of physical education to overall physical activity. Scand J Med Sci Sports. 2013;23(5):600-6.

127. Nielsen G, Bugge A, Hermansen B, Svensson J, Anderson LB. School playground facilities as a determinant of children's daily activity: a cross-sectional study of Danish primary school children. J Phys Act Health. 2012;9:104-14.

128. O'Neill JR, Pfeiffer KA, Dowda M, Pate RR. In-school and out-of-school physical activity in preschool children. J Phys Act Health. 2016;13(6):606-10.

129. Owen CG, Nightingale CM, Rudnicka AR, van Sluijs EMF, Ekelund U, Cook DG, et al. Travel to school and physical activity levels in 9-10 year-old UK children of different ethnic origin; Child Heart and Health Study in England (CHASE). PloS One. 2012;7(2).

130. Sigmund E, Sigmundova D, Hamrik Z, Geckova AM. Does participation in physical education reduce sedentary behaviour in school and throughout the day among normal-weight and overweight-to-obese Czech children aged 9-11 years? Int J Environ Res Public Health. 2014;11(1):1076-93.

131. Stewart T, Duncan S, Schipperijn J. Adolescents who engage in active school transport are also more active in other contexts: a space-time investigation. Health Place. 2017;43:25-32.

132. Trapp G, Giles-Corti B, Christian H, Timperio A, McCormack G, Bulsara M, et al. Driving down daily step counts: the impact of being driven to school on physical activity and sedentary behavior. Pediatr Exerc Sci. 2013;25:337-46.

133. Vale S, Santos R, Soares-Miranda L, Silva P, Mota J. The importance of physical education classes in pre-school children. J Paediatr Child Health. 2011;47(1-2):48-53.

134. Van Cauwenbergh E, De Craemer M, De Decker E, De Bourdeaudhuij I, Cardon G. The impact of a teacher-led structured physical activity session on preschoolers' sedentary and physical activity levels. J Sci Med Sport. 2013;16(5):422-6.
135. Herman KM, Paradis G, Mathieu M-E, O’Loughlin J, Tremblay A, Lambert M. Association between accelerometer-measured physical activity intensities and sedentary time in 8- to 10-year-old children. Pediatr Exerc Sci. 2014;26(1):76-85.

136. Adamo KB, Wasenius NS, Grattan KP, Harvey ALJ, Naylor LH, Barrowman NJ, et al. Effects of a preschool intervention on physical activity and body composition. J Pediatr. 2017;188:42-49.e2.

137. Alhassan S, Nwaokelemeh O, Ghazarian M, Roberts J, Mendoza A, Shitole S. Effects of locomotor skill program on minority preschoolers’ physical activity levels. Pediatr Exerc Sci. 2012;24:435-49.

138. Alhassan S, Nwaokelemeh O, Lyden K, Goldsby T, Mendoza A. A pilot study to examine the effect of additional structured outdoor playtime on preschoolers’ physical activity levels. Child Care Pract. 2013;19(1):23-35.

139. Kidokoro T, Shimizu Y, Edamoto K, Annear M. Classroom standing desks and time-series variation in sedentary behavior and physical activity among primary school children. Int J Environ Res Public Health. 2019;16(11).

Tables

**Table 1**: Characteristics and voting of all included articles
| Characteristics          | N studies (% of all studies) | N participants (% of all participants) | N studies to support compensation | N participants to support compensation | N studies to support displacement | N participants to support displacement | All Sources | Compensation Sources |
|--------------------------|-----------------------------|---------------------------------------|-----------------------------------|---------------------------------------|-----------------------------------|--------------------------------------|-------------|----------------------|
| **Study design**         |                             |                                       |                                   |                                       |                                   |                                      |             |                      |
| Non-interventional studies | 32,310 (79%)                | 49 (64%)                              | 18 (37%)                          | 9,820 (30%)                          | 35 (71%)                          | 22,490 (70%)                          | [28, 57, 61, 63, 65, 67, 69-73, 76, 80-91, 93-95, 111-113, 118-135] |             | [57, 58, 67, 69, 71, 76, 80, 82-91] |
| Interventional studies   | 8,519 (21%)                 | 28 (36%)                              | 21 (75%)                          | 6,477 (76%)                          | 10 (36%)                          | 2,042 (24%)                          | [36, 37, 55, 56, 59, 60, 62, 64, 66, 68, 74, 75, 77-79, 92, 96-103, 136-139] |             | [36, 37, 55, 56, 59, 62, 64, 66, 68, 75, 77, 78, 96-103] |
| **Sample Size**          |                             |                                       |                                   |                                       |                                   |                                      |             |                      |
| < 500                    | 57 (74%)                    | 10,980 (27%)                          |                                    |                                       |                                   |                                       |             | [36, 55-59, 61-63, 65-68, 70, 71-73, 77-79, 83, 85, 86, 89-94, 96-98, 100-102, 112, 113, 119-125, 128, 131, 133, 134, 136-139] |             |                      |
| > 500                    | 20 (26%)                    | 29,849 (73)                           |                                    |                                       |                                   |                                       |             | [28, 37, 60, 64, 69, 72, 78, 84, 87, 88, 95, 99, 103, 111, 118, 126, 127, 129, 132, 135] |             |                      |
| **Target group**         |                             |                                       |                                   |                                       |                                   |                                      |             |                      |
| Preschool children (3–6 years) | 12 (16%) | 2,188 (5%) | 5 (42%) | 919 (42%) | 7 (58%) | 38 (58%) | [68, 97, 100-102, 123, 128, 133, 134, 136-138] |             | [68, 97, 100-102] |
| School children          | 65                           | 38,641                                | 34 (52%)                          | 15,378 (40%)                        | 1,269 (58%)                      | 23,263 (60%)                        | [28, 36, 36, 37, 55-59, 111-113, 118-135] |             |                      |
| (> 6 years) | (84%) | (95%) |
|------------|-------|-------|
| 37, 55-67, 69, 96, 98, 99, 103, 111-113, 118-122, 124-127, 129-132, 135, 139 |

Dependent Variable

| Physical Activity | 40,779 (99%) | 76 (96%) |
|-------------------|-------------|---------|
| [28, 36, 55-89, 91-103, 111-113, 118-139] |

Energy Expenditure

| 333 (1%) | 3 (4%) |
|----------|-------|
| [74, 76, 90] |

Geographic origin

| Europe | 40 (52%) | 16,881 (41%) |
|--------|---------|-------------|
| [36, 55, 56, 59-61, 63, 64, 71, 77, 78, 80, 81, 83, 85-92, 94, 95, 98-100, 111, 113, 118, 121, 123-127, 129, 130, 133, 134] |

| North America | 21 (27%) | 14,256 (35%) |
|---------------|---------|-------------|
| [28, 37, 62, 67-70, 72, 73, 75, 82, 96, 97, 101, 102, 119, 128, 135-138] |

| Australia/New Zealand | 10 (13%) | 3,548 (9%) |
|-----------------------|---------|-----------|
| [57, 58, 66, 74, 76, 103, 112, 122, 131, 132] |

| Asia | 6 (8%) | 6,144 (15%) |
|------|-------|------------|
| [65, 79, 84, 93, 120, 139] |

PA measurement instrument

| Accelerometer | 63 (79%) | 31,150 (76%) | 32 (51%) | 9,309 (30%) | 36 (57%) | 21,841 (70%) |
|---------------|---------|-------------|---------|------------|---------|-------------|
| [28, 36, 55-89, 91-103, 111-139] |
### Context of PA measures

| Pedometer | Heart Rate Monitor | School-based PA | Active commuting to school | Daily PA Pattern | Physical Education | Sports Club | Others (Locations/Active play) | Duration of Intervention |
|-----------|--------------------|-----------------|-----------------------------|------------------|-------------------|-------------|-------------------------------|-------------------------|
| 13 (16%)  | 1 (1%)             | 26 (34%)        | 10 (13%)                    | 15 (19%)         | 17 (22%)          | 5 (6%)      | 4 (5%)                        | ≤ one week              |
| 9,629 (23%) | 50 (0.1%)       | 7,392 (18%)     | 10,733 (26%)                | 12,499 (31%)     | 5,814 (14%)       | 2,583 (6%) | 1,808 (4%)                    | 2 (7%)                  |
| 6,938 (72%) | 1 (100%)        | 5,350 (72%)     | 6,175 (58%)                 | 1,677 (13%)      | 2,567 (44%)       | 0 (0%)      | 528 (29%)                     | 207 (2%)                |
| 10 (77%)  | 50 (100%)         | 10 (36%)        | 7 (70%)                     | 8 (53%)          | 12 (75%)          | 5 (100%)    | 3 (75%)                       | 51 (25%)                |
| 2,691 (28%) | 0 (0%)           | 2,042 (28%)     | 4,558 (43%)                 | 10,822 (87%)     | 3,247 (56%)       | 2,583 (100%)| 1,280 (71%)                   | 156 (75%)               |

#### Duration of Intervention

| ≤ one week | ≤ one month | ≤ 1–2 months | ≤ 3–4 months |
|------------|------------|--------------|--------------|
| 2 (7%)     | 1 (4%)     | 6 (21%)      | 3 (11%)      |
| 207 (2%)   | 67 (1%)    | 869 (12%)    | 144 (2%)     |
| 51 (25%)   | 0 (0%)     | 573 (66%)    | 3 (100%)     |
| 156 (75%)  | 1 (100%)   | 296 (34%)    | 144 (100%)   |

**Notes:**
- Numbers in brackets indicate the range of possible values.
- The context of PA measures data includes various activities such as school-based PA, active commuting to school, daily PA pattern, physical education, sports club, and others (locations/active play).
- The duration of intervention data categorizes the intervention periods as ≤ one week, ≤ one month, ≤ 1–2 months, and ≤ 3–4 months.
Table 2: Criteria for methodological quality assessment and the number (%) of studies that scored points or each criterion.

| Time-span measuring compensation | ≤ 5–6 months | ≤ one year | > one year |
|----------------------------------|--------------|------------|-----------|
|                                  |              |            |           |
| Within a day                     | 6 (21%)      | 4 (14%)    | 6 (21%)   |
|                                  | 2,241 (38%)  | 2,450 (28%)| 2,541 (31%)|
|                                  | 3 (50%)      | 3 (75%)    | 6 (100%)  |
|                                  | 1,520 (68%)  | 1,648 (58%)| 2,541 (100%)|
|                                  | 4 (67%)      | 2 (50%)    | 0         |
|                                  | 721 (32%)    | 802 (32%)  | 0         |

| Intervention type                | Educational | Environmental | Multicomponent |
|----------------------------------|-------------|---------------|----------------|
|                                  |             |               |                |
| Educational                       | 14 (50%)    | 8 (29%)       | 6 (21%)        |
|                                  | 3,593 (42%) | 2,393 (28%)   | 2,533 (30%)    |
|                                  | 9 (64%)     | 6 (75%)       | 6 (100%)       |
|                                  | 2,295 (64%) | 2,108 (88%)   | 2,074 (82%)    |
|                                  | 7 (50%)     | 2 (25%)       | 1 (17%)        |
|                                  | 1,145 (32%) | 285 (12%)     | 459 (18%)      |

(numbers of compensation or displacement voting are relative to respective characteristic; studies containing both compensation and displacement results were added to either category)
| No. | Item                                                                 | Yes | Partial | No  | N/A |
|-----|----------------------------------------------------------------------|-----|---------|-----|-----|
| 1   | Question /objective is sufficiently described?                       | 51  | 26      | 0   | 0   |
|     |                                                                     | (66%)| (34%)   |     |     |
| 2   | Study design is evident and appropriate?                            | 75  | 2       | 0   | 0   |
|     |                                                                     | (97%)| (3%)    |     |     |
| 3   | Method of subject/comparison group selection or source of information/input variables is described and appropriate? | 64  | 13      | 0   | 0   |
|     |                                                                     | (83%)| (17%)   |     |     |
| 4   | Subject (and comparison group, if applicable) characteristics are sufficiently described? | 50  | 27      | 0   | 0   |
|     |                                                                     | (65%)| (35%)   |     |     |
| 5   | If interventional and random allocation was possible, was it described? | 7   | 9       | 1   | 60  |
|     |                                                                     | (9%) | (12%)   | (1%)| (78%)|
| 6   | If interventional and blinding of investigators was possible, was it reported? | 4   | 1       | 12  | 60  |
|     |                                                                     | (5%) | (1%)    | (16%)| (78%)|
| 7   | If interventional and blinding of subjects was possible, was it reported? | 0   | 1       | 16  | 60  |
|     |                                                                     |     | (1%)    | (21%)| (78%)|
| 8   | Outcome(s) and (if applicable) exposure measure(s) is/are well defined and robust to measurement/misclassification bias? Means of assessment are reported? | 66  | 11      | 0   | 0   |
|     |                                                                     | (86%)| (14%)   |     |     |
| 9   | Sample size is appropriate?                                         | 70  | 7       | 0   | 0   |
|     |                                                                     | (91%)| (9%)    |     |     |
| 10  | Analytic methods are described/justified and appropriate?           | 75  | 2       | 0   | 0   |
|     |                                                                     | (97%)| (3%)    |     |     |
| 11  | Some estimate of variance is reported for the main results?         | 36  | 41      | 0   | 0   |
|     |                                                                     | (47%)| (53%)   |     |     |
| 12  | Controlled for confounding?                                         | 44  | 31      | 2   | 0   |
|     |                                                                     | (57%)| (40%)   | (3%)|     |
| 13  | Results reported in sufficient detail?                              | 58  | 19      | 0   | 0   |
|     |                                                                     | (75%)| (25%)   |     |     |
| 14  | Conclusions supported by the results?                               | 58  | 19      | 0   | 0   |
|     |                                                                     | (75%)| (25%)   |     |     |

**Figures**
Figure 1
Flow Chart

Supplementary Files
This is a list of supplementary files associated with this preprint. Click to download.

- additionalfile1PRISMA2009checklistReviewcompensation.pdf
- additionalfile2dataextraction.xlsx
- additionalfile3qualityassessment.xlsx