Changes in physical activity, sedentary behaviour and sleep across the transition from primary to secondary school: A systematic review

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Abstract
Objectives: To describe how children's time spent in the 24-h movement behaviours of physical activity (PA), sedentary behaviour (SB) and sleep change, individually and collectively, across the transition from primary to secondary school. Design: Systematic review. Methods: Six electronic databases were searched from January 1990 to May 2019. Eligibility criteria included longitudinal studies reporting time spent in PA, SB and/or sleep, with baseline assessments conducted during the last two years of primary school and at least one follow-up during the first two years of secondary school. For studies reporting only SB, this review considered those published from November 2015 onwards to update a previous systematic review. Results: The present review identified six articles that reported changes in PA (n = 5) or PA and SB concurrently (n = 1). Most articles had a high risk of bias (n = 4/6). There was limited but consistent evidence of a change in PA over the school transition period, in particular a decrease in total daily PA and during specific time periods (i.e., in-school, after-school and leisure time). A concurrent but opposite change was observed in SB. No studies were identified that assessed changes in sleep, or all three movement behaviours concurrently. Conclusions: Further research exploring concurrent changes in all movement behaviours (PA, SB and sleep) and associated factors is warranted to inform future behavioural interventions and policies for promoting an optimal 24 h movement behaviour pattern during this critical developmental period.

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Abstract

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Methods: Six electronic databases were searched from January 1990 to May 2019. Eligibility criteria included longitudinal studies reporting time spent in PA, SB and/or sleep, with baseline assessments conducted during the last two years of primary school and at least one follow-up during the first two years of secondary school. For studies reporting only SB, this review considered those published from November 2015 onwards to update a previous systematic review.

Results: The present review identified six articles that reported changes in PA (n = 5) or PA and SB concurrently (n = 1). Most articles had a high risk of bias (n = 4/6). There was limited but consistent evidence of a change in PA over the school transition period; in particular a decrease in total daily PA and during specific time periods (i.e., in-school, after-school and leisure time). A concurrent but opposite change was observed in SB. No studies were identified that assessed changes in sleep, or all three movement behaviours concurrently.

Conclusions: Further research exploring concurrent changes in all movement behaviours (PA, SB and sleep) and associated factors is warranted to inform future behavioural interventions and policies for promoting an optimal 24-hour movement behaviour pattern during this critical developmental period.

Keywords:
child; adolescent; longitudinal studies; human development; movement behaviours
1. Introduction

From a movement perspective, a 24-hour day comprises a sequence of time periods spent in movement behaviours that fall on a no/low-high intensity continuum, ranging from sleep to sedentary behaviour (SB) and physical activity (PA). While evidence supports how each of these behaviours is associated with child and adolescent health and wellbeing, new research suggests potential synergistic health benefits through achieving certain combinations of movement behaviours within a 24-hour period. This has prompted a paradigm shift where an integrated approach focusing on all behaviours across the movement continuum has been adopted in public health research and promotion. Several countries (Canada, New Zealand and Australia) have recently released national integrated movement guidelines that provide recommendations for PA, SB and sleep across a hypothetical 24-hour day. Current international evidence indicates that less than 20% of school-aged children and adolescents meet the 24-hour integrated guidelines, which include: i) the accumulation of at least 60 minutes of moderate-to-vigorous PA (MVPA), ii) no more than 2 hours of recreational screen time, and iii) obtaining uninterrupted sleep of 9 to 11 hours for ages 5-13 years and 8 to 10 hours for ages 14-17 years.

To promote the concept that the “whole day matters” in achieving optimal health and wellbeing, it is vital to understand the time-use composition of all movement behaviours and identify the ideal setting(s) and time for interventions.

Schools are recognised as an important setting for promoting and establishing healthy time-use behaviours in children given the large proportion of waking time children spend in school. The transition from primary to secondary school has attracted particular attention because of its accompanying changes in the physical and social environment, psychological well-being, and pubertal development that may influence children’s movement behaviours. A recent systematic review on SB found that both overall and screen-based sedentary time (e.g., television viewing and computer use) increase substantially across the school transition. However, little is known about changes in the remaining movement-related time-use components of PA and sleep, although studies have shown age-related declines in these behaviours during childhood and/or adolescence. As the duration of a day is finite (i.e., 24 hours), a change in time spent in one behaviour will result in an equal and opposite change in at least one other behaviour. Understanding how 24-hour movement behaviours change, individually
(i.e., changes within each individual movement behaviour) and collectively (i.e., changes in the composition or the combinations of 24-hour movement behaviours), over the school transition period will help inform the development of intervention strategies for promoting optimal movement behaviour patterns among school children.

The purpose of this study was to systematically identify and review studies reporting changes in time spent in PA, SB and sleep, individually and collectively, across the transition from primary to secondary school to promote further understanding of changes in children’s 24-hour movement behaviours during this critical developmental period.
2. Methods

The present review was registered with PROSPERO (CRD42018095573) and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

Six electronic databases (PsycINFO, PubMed, Scopus, SPORTDiscus, Web of Science and China Academic Journal Network Publishing) were searched from January 1990 until 31 May 2019. No language restrictions were applied at the searching stage. The search strategy is provided in Supplementary Appendix A. A secondary search was performed by screening the reference lists of the included articles. For studies reporting only SB outcomes, this review considered those that had not been included in a previous systematic review (i.e., published from November 2015 onwards). Search records were extracted from the databases and imported into Endnote X7 (Thomson Reuters, San Francisco, USA), where duplicate records were removed. Two independent reviewers (KHC and BK/ZZ) screened titles and abstracts of the remaining records against the eligibility criteria. Full-text articles for studies meeting the criteria in the initial screening (by at least one reviewer) were retrieved and assessed for final inclusion. Any discrepancies were resolved by discussion between the two reviewers, with a third reviewer (AP, DC or AO) consulted when necessary.

Studies were eligible for inclusion if they fulfilled the following criteria: 1) longitudinal, observational studies with repeated objective/subjective measurements of time/duration spent in PA, SB and or/sleep; 2) inclusion of participants in their last two years of primary/elementary school (referred to hereafter as primary school) at baseline (or Time 1) and first two years of secondary/middle/high school (referred to hereafter as secondary school) at follow-up (or Time 2); 3) full-text journal articles or short reports (excluding published abstracts) that were written in English, Chinese, Portuguese, Spanish, Polish or Malay; and 4) published or accepted/in-press in a peer-reviewed journal at the time of review. Intervention studies were considered for inclusion if they had reported results for a control group, or combined control and intervention groups where non-significant intervention effects were observed on the behaviours of interest. For studies that did not clearly report the school grade/level of the participants, the lead or corresponding author was contacted for clarification or the protocol paper/relevant publications cited in each study were examined.
Studies were excluded if they were conducted in special populations (e.g., participants with specific health condition) or did not report data for the same participants at all the time points of interest. Reviews, conference proceedings, dissertations and non-scholarly sources were also excluded from the review. Where multiple articles were identified for the same study, those that had no overlap in the reported outcomes of interest were considered for inclusion.

A pre-standardized form was used to extract data from included studies by one reviewer (KHC) and checked by a second reviewer (BK or ZZ). Extracted information included: bibliographic details (lead author, year of publication, country of study), details of the study sample (size, percentage with complete data, age and/or school grade), the follow-up period (frequency and length), the behaviour domain assessed (e.g., daily MVPA), the method of measurement (objective or subjective), study instrumentation (e.g., accelerometer or self-report questionnaire) and results summary.

Included studies were assessed for risk of bias (ROB) using three adapted items from Cliff et al.:

(i) were the participants representative of the target population? (selection bias); (ii) did an adequate percentage of participants (≥ 70%) have complete data? (attrition bias); and (iii) did the measure of behaviour demonstrate adequate reliability and/or validity in children or adolescents? – ICC ≥ 0.4, Kappa ≥ 0.4, r ≥ 0.5 or ROC-AUC ≥ 0.7 (detection bias). For studies that used accelerometry, the validity of cut-point definitions for each behavioural domain was determined by consulting relevant studies and reviews or examining the supporting evidence cited in each study. These items were independently coded by two reviewers (KHC and BK/ZZ) as ‘low’, ‘unclear’ or ‘high’ ROB, and an overall rating of ‘low’ ROB was applied for studies with at least two out of three items coded as ‘low’ ROB. Where studies reported more than one type of behaviour (or different domains), the ROB was evaluated for each domain. Discrepancies between the two reviewers were resolved through discussion or consultation with a third reviewer (AP, DC or AO). The reviewers (KHC and BK) reported 86% agreement with independent criterion assessments conducted on the included studies (18 out of 22 items).

Studies were not excluded from the review based on ROB.

A narrative synthesis focusing on the significance and direction of change was conducted to evaluate evidence on behavioural changes over the school transition period. The change was categorised as ‘increase’ or ‘decrease’ if it was statistically significant (p-value < 0.05); otherwise ‘no change’ (p-value...
≥ 0.05). The statistical significance data were extracted from the articles or manually calculated using paired-samples t-test based on the reported mean changes. For articles that did not provide statistical significance data nor mean changes, the descriptive results were presented in this review. Whenever possible, subgroup analyses were performed to examine if the changes were moderated by sex or by types of measures/domains of the behaviour.
3. Results

The database searches identified 9,539 articles; 5,977 articles remained after duplicates were removed (Fig. 1). Following the title and abstract screening, 112 articles were retrieved for full-text review. Of these, six articles\(^{15,16,32-35}\) met the inclusion criteria and were included in this review.

The six articles analysed data from four studies conducted in the United Kingdom\(^{32,33}\), Belgium\(^{15,34}\), Australia\(^{16}\) and the United States\(^{35}\) (Table 1). In all studies, the baseline measurements were conducted during the last year of primary school. The follow-up periods ranged from five months to two years, with measurements conducted during the first and/or second year of secondary school. Five articles\(^{15,32-35}\) reported changes in 10 different PA outcomes (four accelerometer and six self-report), and one article\(^{16}\) reported changes in PA-SB combined including four PA outcomes (two accelerometer and two self-report) and five SB outcomes (one accelerometer and four self-report). The analytic samples varied from 127 to 810 participants. Most articles (n = 4/6)\(^{16,32,33,35}\) had a high ROB as a result of attrition (i.e., 36-62% of data missing) and selection bias (i.e., inclusion of participants from a specific population segment e.g., urban areas or low socio-economic strata) (see Supplementary Appendix B). Notably, this review did not identify any studies that examined changes in sleep duration, nor studies that assessed changes in the time-use composition of all three behaviours.

Table 2 presents a summary of changes in individual and combined movement behaviour components by time segments across the school transition (see Supplementary Appendix C for full results of all studies).

Based on the studies reporting only PA\(^{15,32-35}\), most outcomes assessed (n = 7/10) showed significant changes, with four (one accelerometer and three self-report outcomes) decreasing over the transition period, depending on the time-segment of the day or week. Two studies assessed changes in daily total PA. One study reported a significant decrease in total PA (self-report) over a two-year period\(^{15}\). Another reported that total PA (accelerometer) decreased with the initial transition to secondary school but
remained stable from the first to second year of secondary school across all ethnic groups and parental education levels\textsuperscript{36}; however, it was not possible to determine if the changes were significant as neither p-values nor mean changes were reported.

Two studies assessed changes in weekday PA; both showed an increase in MVPA (accelerometer) over time\textsuperscript{15,33}. One study also reported an increase in MVPA (accelerometer) during weekends but a decrease during the after-school period among boys and girls\textsuperscript{34}.

One study reported a decrease in self-report participation in extracurricular PA at school\textsuperscript{15} and sports during leisure time (for both boys and girls)\textsuperscript{35}. This study also showed no changes in active transport to and from school\textsuperscript{15}, and cycling for transport during leisure time (for both boys and girls)\textsuperscript{35}. However, mixed results emerged for walking for transport during leisure time where a decrease in time was observed among boys but no change among girls\textsuperscript{35}.

Only one study\textsuperscript{16} reported changes in two movement behaviours (i.e., PA and SB) concurrently during the school transition period. On an average daily basis, light PA and MVPA (accelerometer) significantly decreased while overall sedentary time (accelerometer) increased. There was an increase in time spent being ‘very active’ (self-report) during the after-school period, but no change during weekends. On the other hand, significant increases were observed in screen time measures (self-report) on both weekdays (for leisure only) and weekends.

[Insert Table 2 approximately here]

4. Discussion

This study reviewed evidence on individual and collective changes in movement behaviours including time spent in PA, SB and sleep across the transition from primary to secondary school. Based on the findings of the included studies, there was limited but consistent evidence of a change in PA over the school transition period; however, the direction of the change was dependent on the time segments of the day or week. In particular, significant decreases were observed in total daily PA and for specific time periods (i.e., in-school, after-school and leisure time). There also appeared to be a concurrent but opposite change in SB, as suggested by the single study that explored combined behaviours (PA-SB)\textsuperscript{16}. This review, however, did not retrieve any studies that examined changes in sleep duration, nor studies that assessed the time-use composition of all three behaviours.
The findings of a decrease in daily PA outcomes is consistent with the literature reporting age-related decreases in PA levels during childhood and adolescence\textsuperscript{21,36,37}. Interestingly, this review found consistent evidence from two studies for an increase in PA outcomes (accelerometer) during weekdays\textsuperscript{15,32}, but conflicting results for weekends where one study reported an increase (accelerometer)\textsuperscript{34} and another no change (self-report)\textsuperscript{16}. However, Brooke et al.\textsuperscript{38} found significant decreases in accelerometer-measured PA (MVPA and total PA) on both weekdays and weekends over a 4-year period spanning the transition from childhood to adolescence. The discrepancy could be attributed to differences in the duration of follow-up assessments, which may have reflected behaviours at different developmental stages (i.e., within childhood versus childhood-to-adolescence); or the variation between schools in their approach to providing support for PA (e.g., provision of sports and PA during lunch break and after school)\textsuperscript{15,16}. However, this may simply indicate that the school transition has a differential impact on children’s PA, particularly during weekdays.

This review found some evidence to suggest that PA decreases not only while in school\textsuperscript{15} but also after-school\textsuperscript{33} or during the leisure time period\textsuperscript{34} when children move from primary to secondary school. This is similar to longitudinal observations showing an age-related decrease in PA during the in-school\textsuperscript{38} and out-of-school periods\textsuperscript{38,39} across childhood and adolescence. Such decreases in PA may be due to a concurrent increase in SB, as shown in previous research\textsuperscript{16,17,40}. Further, literature shows that the after-school period (typically defined as end-of-school to 6pm\textsuperscript{41}) makes a substantial contribution to the accumulation of children’s daily PA\textsuperscript{39,42}, particularly as children enter adolescence\textsuperscript{39}. These data suggest that the decrease in after-school or leisure time PA may be the major contributor to the overall decline in daily PA levels during the transition to secondary school, as identified in this review. Further studies are warranted to explore changes in accumulation of PA across different time segments and their associations with changes in overall PA that accompany this school transition.

Only one study in this review reported changes in active transportation over the school transition period, where the time spent in active school travel increased\textsuperscript{15} but no change for active travel during leisure time (except among boys where walking for transport decreased)\textsuperscript{34}. However, most active travel studies to date have reported a stable trend in participation rate between childhood and adolescence\textsuperscript{43}. According to Cooper et al.\textsuperscript{32}, children’s school travel mode was associated with their PA across the
school transition; a change from active to passive transportation was associated with a reduction in MVPA, and vice versa. Promoting active school travel may therefore be an important approach to increase, or at least, maintain children’s PA levels throughout the transition period.

No additional studies reporting data on SB were found since the previous systematic review\(^{20}\). In that review, the authors identified 11 articles (n = 9 studies) that assessed changes and/or tracking of SB across the school transition. There was consistent evidence demonstrating an increase in screen-based (e.g., television viewing, video games use) and overall SB over time, with accelerometer-based studies showing an increase of approximately 10-20 minutes per day per year in overall sedentary time. Screen-based SB also tracked moderately (tracking coefficients \(r\) were mostly in the range of 0.3 to 0.5) from primary to secondary school, suggesting the direction and magnitude of the behavioural change is relatively consistent within each study population\(^{20}\). The present review provides further evidence to suggest that an increase in SB may be at least partly attributed to the decrease in PA during specific time periods (e.g., after-school and leisure time); although it remains debatable whether there is a direct displacement of time spent among these two behaviours (also referred as the “displacement hypothesis”)\(^{44}\). Further research that explore concurrent changes in PA and SB across different time segments are required to confirm the inter-relationships between these behaviours.

This review did not identify any studies reporting changes in sleep duration during the school transition. One study in this review\(^{16}\) found concurrent but opposite changes in accelerometer-measured PA and SB; however, their changes were not equal in magnitude (PA: -27 vs. SB: +16 minutes/day). Such discrepancy in time could be due to a concurrent change in sleep duration, given the compositional nature of time-use data\(^8\). A recent study also reported the existence of bi-directional associations between nocturnal sleep duration with daytime PA and SB in schoolchildren; although the observed effect sizes were subtle and the associations varied between sexes and countries\(^{45}\).

The largest knowledge gap identified in this review is the absence of research investigating the time-use composition of all movement behaviours (PA, SB and sleep) during a 24-hour day. The challenge of measuring the full movement spectrum in free-living conditions and the lack of standardised classification criteria for different behaviours may be the reason for the lack of evidence in this field\(^8,46\). However, with recent advances in wearable accelerometry-based technology (e.g., wrist-worn,
waterproof devices) and time-use data processing and analysis methods, more studies are now collecting objective behavioural data using a continuous (24-hour) monitor wear protocol. This protocol has demonstrated high levels of compliance in children and adolescents, and thus, producing more reliable estimates of intensity-specific behaviours. Nevertheless, current objective measures still do not provide contextual information of the behaviours (e.g., domain of activity), which may be useful in identifying more specific behaviours to prioritise in intervention and public policy. To address the gap, future research is recommended to use both objective and self-report tools to provide a greater depth of understanding of children’s 24-hour movement behaviours. Additionally, it would be worthwhile to characterise changes in time allocations between different movement behaviours during the school transition period (e.g., using time flow analytics), which could have distinct influences on health and wellbeing.

There is considerable uncertainty about the exact influence of the school transition on children’s movement behaviours. A recent longitudinal study in the United States found that there were significant but non-linear declines in children’s in-school PA over a three-year period, where declines were greater during the transition from primary to secondary school compared to the first two years of secondary school; indicating that the school transition period may have immediate impacts on children’s behaviours. This may be due, in part, to the differences in primary and secondary school environmental characteristics (e.g., policies, programmes and facilities for PA), which have been shown to be associated with changes in PA and SB over this transition period. Another study comparing children’s activity patterns between two different school transition systems in Australia (i.e., transitioning to a new secondary school vs. remaining in the same school) also found that changes in children’s activity patterns may be moderated by the level of disruption in school environment, where a change of school during this transition period was associated with a greater change in the type/context of behaviours (e.g., participation in active school travel and recreational screen time). While these findings seem to confirm the influence of a change in school environment on children’s movement behaviours, recent research highlights the importance of considering multiple levels of influence (e.g., individual, social, community) and their cross-level interaction effects to understand the change in these behaviours during the school transition. For example, having both parental support and a supportive
neighbourhood environment for PA may assist in addressing the decrease in children’s total PA as they transition to secondary school\textsuperscript{57}. Further studies are required to examine which of the previously identified factors/determinants\textsuperscript{8} are associated with most changes in children’s 24-hour movement behaviours to inform the development of effective interventions.

This study extended the scope of previous work by Pearson et al.\textsuperscript{20} with an aim to provide a detailed and systematic understanding of how children’s time-use in all three movement behaviours (PA, SB and sleep) may change during the transition from primary to secondary school. This approach aligns with the Framework for Viable Integrative Research in Time-Use Epidemiology (VIRTUE)\textsuperscript{8} framework which acknowledges the importance of adopting an integrated approach when studying movement-related time-use patterns in populations. This review also employed more stringent inclusion criteria using studies that reported data for the same participants within a 4-year period covering the pre-, during, and post-school transition phases, enabling a more nuanced understanding of the intra-individual behavioural changes that occur over this school transition period.

The results of this review, however, should be interpreted with caution given the paucity of studies identified. Most articles in this review had a high ROB (n = 4/6), although the findings were relatively consistent across all studies. It was not feasible to conduct a meta-analysis for quantifying behavioural changes due to considerable heterogeneity between studies (e.g., variation in behaviour domains assessed and measurement methodology). While most studies used measures that appeared to be valid, the findings may not be directly comparable due to discrepancies in the definitions of the measures or some methodological decisions, such as the accelerometer data inclusion criteria and cut-points employed for defining PA intensity. Finally, all studies were conducted in high-income developed countries; thus, the findings may not be generalizable to the populations of low/middle-income countries.
5. Conclusion

Despite a limited number of studies, the present review found some important evidence describing the changes in children’s 24-hour movement behaviours across the transition from primary to secondary school. Findings from the included studies in this review suggest that changes in PA are largely dependent on the time segments of the day or week, indicating the need for targeted period-specific intervention strategies. Specifically, the after-school or leisure time period was identified as a potential target for delivering interventions to prevent a decrease in PA and increase in SB across the school transition. On the other hand, there appeared to be a concurrent but opposite change in SB; with existing evidence indicating a substantial increase in individual and overall SB over the transition from primary to secondary school\(^2\). No studies investigated changes in sleep duration, or concurrent changes in the overall time-use composition (i.e., time spent in PA, SB and sleep combined). Additional high-quality studies using an integrated approach\(^8\) are required to explore the changes in children’s overall movement behaviour patterns and associated factors that accompany the school transition. Such information would facilitate the development of effective interventions by identifying and prioritising the ‘at-risk’ behaviour(s) to be addressed during this critical developmental period, and subsequently promote the importance of practising an optimal 24-hour movement behaviour pattern for overall health and wellbeing in children and adolescents.
Practical implications

- Significant decreases were observed in total daily physical activity and for specific time periods (i.e., in-school, after-school and leisure time) across the transition from primary to secondary school. This highlights the importance of targeting this transition period for promoting healthy time-use behaviours in children.

- The findings of time-segment specific decreases in physical activity indicate the need for targeted period-specific intervention strategies to prevent a decrease in overall physical activity over the school transition period.

- The existing studies focused primarily on physical activity and/or sedentary behaviour components. Therefore, it remains unknown how sleep or the 24-hour composition of all three movement behaviours change during this critical developmental period.
References

1. Pedišić Ž. Measurement issues and poor adjustments for physical activity and sleep undermine sedentary behaviour research—the focus should shift to the balance between sleep, sedentary behaviour, standing and activity. *Kinesiology* 2014; 46(1): 135-146.


34. D’Haese S, De Meester F, Cardon G et al. Changes in the perceived neighborhood environment in relation to changes in physical activity: a longitudinal study from childhood into adolescence. *Health Place* 2015; 33: 132-141. [https://doi.org/10.1016/j.healthplace.2015.03.004](https://doi.org/10.1016/j.healthplace.2015.03.004).

35. Barr-Anderson DJ, Flynn JI, Dowda M et al. The modifying effects of race/ethnicity & socioeconomic status on the change in physical activity from elementary to middle school. *J Adolesc Health* 2017; 61(5): 562-570. [https://doi.org/10.1016/j.jadohealth.2017.05.007](https://doi.org/10.1016/j.jadohealth.2017.05.007).


580. Grgic J, Dumuid D, Bengoechea EG et al. Health outcomes associated with reallocations of time between sleep, sedentary behaviour, and physical activity: a systematic scoping review of...


<table>
<thead>
<tr>
<th>Author; Year; Country</th>
<th>Age (years)<em>; School grade</em></th>
<th>Length of follow-up (year)</th>
<th>Method</th>
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<tr>
<td><strong>Individual behaviour: PA</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Cooper et al.32.a; 2012; United Kingdom</td>
<td>10-11y; 7th grade</td>
<td>1</td>
<td>Accel</td>
<td>Weekday MVPA (469)</td>
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<tr>
<td>Jago et al.33.a; 2012 United Kingdom</td>
<td>10-11y; 7th grade</td>
<td>1</td>
<td>Accel</td>
<td>After-school MVPA (810) Weekend MVPA (458)</td>
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<tr>
<td>De Meester et al.15,b; 2014; Belgium</td>
<td>M: 11.1y M: 13.4y</td>
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<td>Accel</td>
<td>Weekday MVPA (140)</td>
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<tr>
<td>D’Haese et al.34,b; 2015; Belgium</td>
<td>M: 11.1y M: 13.4y</td>
<td>2</td>
<td>SR</td>
<td>Active transport to and from school (420) Extracurricular PA at school (420) Total PA (420)</td>
</tr>
<tr>
<td>Barr-Anderson et al.15; 2017; United States</td>
<td>5th grade 6th grade: 7th grade</td>
<td>2*</td>
<td>Accel</td>
<td>Total PA (643)</td>
</tr>
</tbody>
</table>

**Combined behaviours: PA – SB**
Marks et al.\textsuperscript{16}; M: 12.2y; M: 12.8y; 5 – 8 months

2015; 6\textsuperscript{th} grade 7\textsuperscript{th} grade Australia

Accel Daily MVPA (127)

Daily LPA (127)

Daily SedT (127)

SR Being ‘very active’ after school (237)

Being ‘very active’ during weekend (242)

Weekday leisure ST (240)

Weekend leisure ST (239)

Weekday homework ST (241)

Weekend homework ST (239)

\textsuperscript{a,b}References with the same superscript letter analysed data from the same study.

\textsuperscript{*}Two annual follow ups at secondary school: One at 6\textsuperscript{th} grade and another at 7\textsuperscript{th} grade.

M = mean; PA = physical activity; MVPA = moderate-to-vigorous PA; LPA = light PA; SB = sedentary behaviour; SedT = sedentary time; ST = screen time; Accel = accelerometer; SR = self-report.

\textsuperscript{*}where reported; n = sample size for paired analysis.
Table 2 Changes in individual and combined movement behaviours (by time segments) across the transition from primary to secondary school

<table>
<thead>
<tr>
<th>Time segments</th>
<th>Outcome assessed (method)</th>
<th>Direction of change (from primary to secondary school)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Individual behaviour: PA</strong></td>
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<td>Average daily</td>
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<td>Unknown\textsuperscript{#}</td>
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<td>MVPA (Accel)\textsuperscript{15,32}</td>
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<td></td>
<td>Active transport to and from school (SR)\textsuperscript{15}</td>
<td>Increase</td>
</tr>
<tr>
<td>In-school</td>
<td>Extracurricular PA (SR)\textsuperscript{15,c}</td>
<td>Decrease</td>
</tr>
<tr>
<td>After-school</td>
<td>MVPA (Accel)\textsuperscript{33}</td>
<td>B: Decrease; G: Decrease</td>
</tr>
<tr>
<td>Weekend days</td>
<td>MVPA (Accel)\textsuperscript{33}</td>
<td>B: Increase; G: Increase</td>
</tr>
<tr>
<td>Leisure time</td>
<td>Waking for transport (SR)\textsuperscript{34}</td>
<td>B: Decrease; G: No change</td>
</tr>
<tr>
<td></td>
<td>Cycling for transport (SR)\textsuperscript{34}</td>
<td>B: No change; G: No change</td>
</tr>
<tr>
<td></td>
<td>Participation in sports (SR)\textsuperscript{34}</td>
<td>B: Decrease; G: Decrease</td>
</tr>
<tr>
<td><strong>Combined behaviours: PA – SB\textsuperscript{16}</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average daily</td>
<td>PA: MVPA (Accel)</td>
<td>Decrease</td>
</tr>
<tr>
<td></td>
<td>PA: LPA (Accel)</td>
<td>Decrease</td>
</tr>
<tr>
<td></td>
<td>SB: SedT (Accel)</td>
<td>Increase</td>
</tr>
<tr>
<td>Weekdays</td>
<td>SB: Leisure ST (SR)</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td>SB: Homework ST (SR)</td>
<td>Increase</td>
</tr>
<tr>
<td>After-school</td>
<td>PA: Being ‘very active’ (SR)\textsuperscript{d}</td>
<td>Increase</td>
</tr>
<tr>
<td>Weekend days</td>
<td>PA: Being ‘very active’ (SR)\textsuperscript{d}</td>
<td>No change</td>
</tr>
<tr>
<td></td>
<td>SB: Leisure ST (SR)</td>
<td>No change</td>
</tr>
<tr>
<td></td>
<td>Homework ST (SR)</td>
<td>Increase</td>
</tr>
</tbody>
</table>

PA = physical activity; MVPA = moderate-to-vigorous PA; LPA = light PA; SB: sedentary behaviour; ST: screen time; Accel = accelerometer; SR = self-report; B = boys; G = girls.
Data on statistical significance and mean changes were not provided.

Defined as the sum of participation in active transport, physical education, extracurricular PA at school and sports during leisure time\textsuperscript{15}.

Defined as the sum of time spent in light PA and MVPA\textsuperscript{35}.

Defined as the sum of participation in PA during playtime, lunch break, after-school hours or at class or school tournaments\textsuperscript{15}.

Defined as participation in sports, dance or play games in which children were very active\textsuperscript{16}. 

\textsuperscript{a}Data on statistical significance and mean changes were not provided.
Fig. 1 Flowchart of study selection process

1. Records identified through database searching (n = 9539)
2. Records after duplicates removed (n = 5977)
3. Records screened (n = 5977)
4. Full-text articles assessed for eligibility (n = 112)
5. Articles included in qualitative synthesis (n = 6)
6. Full-text articles excluded (n = 106)
   - Did not measure or report time/duration data (n = 30)
   - Not within the specified time frame (n = 55)
   - Did not report data for the same participants at all time points of interest (n = 9)
   - Unclear about school grade (n = 3)
   - Cross-sequential/cross-sectional study (n = 8)
   - Conference abstract (n = 1)
**Article title:** Changes in physical activity, sedentary behaviour and sleep across the transition from primary to secondary school: A systematic review

**Journal:** Journal of Science and Medicine in Sport

### Table A.1 Search strategy

<table>
<thead>
<tr>
<th>#</th>
<th>Search terms</th>
<th>Date Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>child* OR adolescen* OR youth</td>
<td>1990 – May 2019</td>
</tr>
<tr>
<td>2</td>
<td>“primary school” OR “elementary school” OR “secondary school” OR “middle school” OR “high school”</td>
<td>1990 – May 2019</td>
</tr>
<tr>
<td>3</td>
<td>longitudinal OR follow-up OR cohort OR tracking OR transition</td>
<td>1990 – May 2019</td>
</tr>
<tr>
<td>4</td>
<td>“physical activit*” OR sport OR exercise OR sedentar* OR “sedentary behavio*” OR computer* OR “TV viewing” OR “video gam*” OR “electronic gam*” OR internet OR tablet OR smartphone OR “social media” OR television OR screen-time OR screen-based OR “screen based” OR “non-screen-based” OR sitting OR sleep*</td>
<td>1990 – May 2019</td>
</tr>
<tr>
<td>5</td>
<td>1 AND 2 AND 3 AND 4</td>
<td></td>
</tr>
</tbody>
</table>
**Article title:** Changes in physical activity, sedentary behaviour and sleep across the transition from primary to secondary school: A systematic review

**Journal:** Journal of Science and Medicine in Sport

### Table B.1 Risk of bias assessment of included articles

<table>
<thead>
<tr>
<th>Lead author &amp; Publication year</th>
<th>Selection bias</th>
<th>Attrition bias</th>
<th>Detection bias</th>
<th>Overall assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper et al. (2012)(^3)</td>
<td>HIGH risk of bias</td>
<td>HIGH risk of bias</td>
<td>LOW risk of bias(^d)</td>
<td>HIGH risk of bias</td>
</tr>
<tr>
<td>Jago et al. (2012)(^4)</td>
<td>HIGH risk of bias</td>
<td>HIGH risk of bias</td>
<td>LOW risk of bias(^d)</td>
<td>HIGH risk of bias</td>
</tr>
<tr>
<td>De Meester et al. (2014)(^5)</td>
<td>LOW risk of bias</td>
<td>Accelerometer measure</td>
<td>Accelerometer measure</td>
<td>LOW risk of bias</td>
</tr>
<tr>
<td>D’Haese et al. (2015)(^6)</td>
<td>LOW risk of bias</td>
<td>HIGH risk of bias</td>
<td>LOW risk of bias</td>
<td>LOW risk of bias</td>
</tr>
<tr>
<td>Marks et al. (2015)(^7)</td>
<td>HIGH risk of bias</td>
<td>Accelerometer measure</td>
<td>Accelerometer measure</td>
<td>HIGH risk of bias</td>
</tr>
<tr>
<td>Barr-Anderson et al. (2017)³⁶</td>
<td>HIGH risk of bias</td>
<td>HIGH risk of bias</td>
<td>LOW risk of bias</td>
<td>HIGH risk of bias</td>
</tr>
</tbody>
</table>

- **a** Were the participants likely to be representative of the target population?
- **b** Did an adequate percentage of participants (≥70%) have complete data?
- **c** Did the measure of behaviour demonstrate adequate reliability and/or validity in children or adolescents? - ICC≥0.4²⁷, Kappa≥0.4²⁷, r≥0.5²⁸ or ROC-AUC≥0.7²⁹
- **d** The validity of cut-point definition was determined based on the results of a comparative validity study³¹.
- **e** An overall rating of ‘LOW’ ROB was applied for studies with at least two out of three items coded as ‘LOW’ ROB.

**References (cited in main article)**


### Table C.1 Changes in individual movement behaviour (physical activity) across the transition from primary to secondary school

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Outcome assessed (minutes/day, unless otherwise stated)</th>
<th>Primary school(^a)</th>
<th>Secondary school(^a)</th>
<th>Mean change (secondary minus primary)(^a)</th>
<th>Direction of change</th>
<th>Analysis of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper et al., 2012</td>
<td>Weekday MVPA (Accel)</td>
<td>60.6 (21.6)</td>
<td>63.1 (23.6)</td>
<td>2.6 (95%CI: 0.5 - 4.7)(^*)</td>
<td>Increase</td>
<td>Paired sample t-test</td>
</tr>
<tr>
<td>Jago et al., 2012</td>
<td>After-school MVPA (Accel)</td>
<td>n/a</td>
<td>n/a</td>
<td>B: -4.60 (17.21)***</td>
<td>Decrease</td>
<td>Paired sample t-test (^b)</td>
</tr>
<tr>
<td></td>
<td>Weekend MVPA (Accel)</td>
<td>n/a</td>
<td>n/a</td>
<td>G: -2.63 (13.08)***</td>
<td>Decrease</td>
<td></td>
</tr>
<tr>
<td>De Meester et al., 2014</td>
<td>Weekday MVPA (Accel)</td>
<td>27.69 (19.15)</td>
<td>31.74 (23.97)</td>
<td>n/a*</td>
<td>Increase</td>
<td>Cross-classified multilevel regression models</td>
</tr>
<tr>
<td></td>
<td>Active transport to and from school (SR)</td>
<td>11.35 (13.35)</td>
<td>17.23 (17.83)</td>
<td>n/a***</td>
<td>Increase</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Extracurricular PA at school (SR)(^c)</td>
<td>23.12 (18.67)</td>
<td>10.72 (15.09)</td>
<td>n/a***</td>
<td>Decrease</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total PA (SR)(^d)</td>
<td>80.62 (41.62)</td>
<td>69.49 (40.42)</td>
<td>n/a**</td>
<td>Decrease</td>
<td></td>
</tr>
<tr>
<td>D’Haese et al., 2015</td>
<td>Walking for transport during leisure time (SR)</td>
<td>B: 9.11 (12.58)</td>
<td>B: 5.93 (10.21)</td>
<td>B: -3.18 (16.20)(^*)</td>
<td>Decrease</td>
<td>Cross-classified multilevel regression models (adjusted for educational level of mother and father)</td>
</tr>
<tr>
<td></td>
<td>Sports during leisure time (SR)</td>
<td>B: 12.79 (14.12)</td>
<td>B: 11.06 (14.22)</td>
<td>B: -1.73 (20.04)</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>G: 7.60 (10.09)</td>
<td>G: 6.92 (9.34)</td>
<td>G: -0.68 (13.75)</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B: 33.43 (25.15)</td>
<td>B: 29.85 (27.14)</td>
<td>B: -3.58 (37.00)(^*)</td>
<td>Decrease</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>G: 25.23 (23.43)</td>
<td>G: 18.46 (21.00)</td>
<td>G: -6.77 (31.46)***</td>
<td>Decrease</td>
<td></td>
</tr>
<tr>
<td>Barr-Anderson et al., 2017</td>
<td>Total PA(^c) (minutes/hour) (Accel)</td>
<td>Overall 23.3 (SE 0.18)</td>
<td>Overall 24.3 (0.19)</td>
<td>Overall 22.7 (0.19)</td>
<td>n/a</td>
<td>“Minutes/hour of total PA declined from fifth to sixth grade and NS</td>
</tr>
<tr>
<td>Parent education</td>
<td>Hispanic</td>
<td>White</td>
<td>Hispanic</td>
<td>White</td>
<td>Parent education</td>
<td>Hispanic</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>-------</td>
<td>----------</td>
<td>-------</td>
<td>------------------</td>
<td>----------</td>
</tr>
<tr>
<td>&lt;=High school</td>
<td>28.7 (SE 0.27)</td>
<td>24.0 (SE 0.27)</td>
<td>28.7 (SE 0.27)</td>
<td>24.0 (SE 0.27)</td>
<td>&lt;=High school</td>
<td>22.9 (SE 0.29)</td>
</tr>
<tr>
<td>&gt;High school</td>
<td>28.1 (SE 0.24)</td>
<td>24.0 (SE 0.24)</td>
<td>28.1 (SE 0.24)</td>
<td>24.0 (SE 0.24)</td>
<td>&gt;High school</td>
<td>22.4 (SE 0.25)</td>
</tr>
</tbody>
</table>

PA = physical activity; MVPA = moderate-to-vigorous PA; LPA = light PA; Accel = accelerometer; SR = Self-report questionnaire; B = boys; G = girls; n/a = data not given/stated; SE = standard error; CI = confidence interval; Statistical significance: * p < 0.05; ** p < 0.01; *** p < 0.001.

aData presented in mean (standard deviation), unless otherwise stated.

bManual calculation based on the reported mean changes.

cDefined as the sum of participation in PA during playtime, lunch break, after-school hours or at class or school tournaments.

dDefined as the sum of participation in active transport, physical education, extracurricular PA at school and sports during leisure time.

eDefined as the sum of time spent in light PA and MVPA.
Table C.2 Changes in combined movement behaviours across the transition from primary to secondary school

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>Movement behaviours</th>
<th>Outcome assessed (minutes/day, unless otherwise stated)</th>
<th>Primary school&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Secondary school&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean change (secondary minus primary)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Direction of change</th>
<th>Analysis of change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marks et al., 2015&lt;sup&gt;16&lt;/sup&gt;</td>
<td>PA</td>
<td>Daily MVPA (Accel)</td>
<td>Final year: 51 (18)</td>
<td>First year: 48 (17)</td>
<td>-4 (13)*</td>
<td>Decrease</td>
<td>Paired sample t-test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daily LPA (Accel)</td>
<td></td>
<td></td>
<td>-23 (33)*</td>
<td>Decrease</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Being ‘very active’ after school (SR)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>219 (39)</td>
<td>196 (40)</td>
<td>10 (66)*</td>
<td>Increase</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Being ‘very active’ during weekend (SR)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>64 (56)</td>
<td>75 (67)</td>
<td>-1 (106)</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>Daily sedentary time (Accel)</td>
<td>84 (82)</td>
<td>83 (85)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weekday leisure screen time (SR)</td>
<td>476 (69)</td>
<td>492 (86)</td>
<td>16 (76)*</td>
<td>Increase</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weekend leisure screen time (SR)</td>
<td>135 (111)</td>
<td>152 (114)</td>
<td>17 (126)*</td>
<td>Increase</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weekday homework screen time (SR)</td>
<td>143 (121)</td>
<td>158 (160)</td>
<td>16 (164)</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weekend homework screen time (SR)</td>
<td>36 (49)</td>
<td>61 (64)</td>
<td>25 (67)*</td>
<td>Increase</td>
<td></td>
</tr>
</tbody>
</table>

PA = physical activity; MVPA = moderate-to-vigorous PA; LPA = light PA; SB = Sedentary behaviour; Accel = accelerometer; SR = Self-report questionnaire

Statistical significance: * p < 0.05.

<sup>a</sup>Data presented in mean (standard deviation), unless otherwise stated.

<sup>b</sup>Defined as participation in sports, dance or play games in which children were very active.
References (cited in main article)


34. Barr-Anderson DJ, Flynn JI, Dowda M et al. The modifying effects of race/ethnicity & socioeconomic status on the change in physical activity from elementary to middle school. *J Adolesc Health* 2017; 61(5): 562-570. [https://doi.org/10.1016/j.jadohealth.2017.05.007](https://doi.org/10.1016/j.jadohealth.2017.05.007).