Original article

Activity-related typologies and longitudinal change in physical activity and sedentary time in children and adolescents: The UP&DOWN Study

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Abstract

Background: Children and adolescents can be distinguished by different typologies (clusters) of physical activity and sedentary behavior. How physical activity and sedentary behaviors change over time within different typologies is not known. This study examined longitudinal changes in physical activity and sedentary time among children and adolescents with different baseline typologies of activity-related behavior.

Methods: In this longitudinal study (3 annual time points) of children ($n = 600$, age = 9.2 ± 0.4 years (mean ± SD), 50.3% girls) and adolescents ($n = 1037$, age = 13.6 ± 1.7 years, 48.4% girls), participants were recruited in Spain in 2011−2012. Latent class analyses identified typologies based on self-reported screen, educational, social and relaxing sedentary behaviors, active travel, muscle strengthening activity, and sport at baseline. Within each typology, linear mixed growth models explored longitudinal changes in accelerometer-derived moderate-to-vigorous physical activity and sedentary time, as well as time by class interactions.

Results: Three typologies were identified among children ("social screenies", 12.8%; "exercisers", 61.5%; and "non-sporty active commuters", 25.7%) and among adolescents ("active screenies", 43.5%; "active academics", 35.0%; and "non-sporty active commuters", 21.5%) at baseline. Sedentary time increased within each typology among children and adolescents, with no significant differences between typologies. No changes in physical activity were found in any typology among children. In adolescents, physical activity declined within all typologies, with "non-sporty active commuters" declining significantly more than "active screenies" over 3 years.

Conclusion: These results support the need for intervention to promote physical activity and prevent increases in sedentary time during childhood and adolescence. Adolescents characterized as "non-sporty active commuters" may require specific interventions to maintain their physical activity over time.

Keywords: Behavior change; Physical activity; Sedentary behavior; Typologies; Youth

1. Introduction

Lifestyle-related chronic health conditions (e.g., overweight and obesity and cardiovascular disease markers) are becoming more prevalent in children and adolescents, attributable in part to a lack of regular physical activity and excessive sedentary time.[1] Like other youth around the world,[2] national data suggest that youth in Spain have low levels of adherence to physical activity (21%−40%) and sedentary behavior guidelines (21%−40%),[3] which recommend that children and adolescents accumulate at least 60 min of moderate-to-vigorous physical activity (MVPA) daily and spend no more than 2 h/day in screen time.[4] Spanish data from 2016 show that physical activity participation rates among females are particularly low, with as little as 9% of female adolescents meeting both the physical activity and sedentary

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behavior guidelines.[3] Furthermore, there is consistent evidence for age-related declines in the proportion of youth in Spain achieving both the physical activity and sedentary behavior guidelines.[3] However, these results are based on overall averages and fail to consider potential differences between subgroups.

As identified within a recent systematic review, a growing body of research has focused on identifying distinct groups of individuals based on engagement in different types of physical activity and sedentary behavior.[5] Thirteen studies have identified typologies based purely on physical activities and sedentary behaviors, with results suggesting that individuals who undertake more physical activities tend to be younger in age.[5] To date, studies assessing different combinations (typologies) of physical activity and sedentary behavior have primarily done so cross-sectionally.[5] Results from these studies can be used to tailor and target interventions to different groups. However, while it has been shown repeatedly that physical activity generally tends to decline and sedentary time tends to increase during childhood and adolescence,[6] it is unknown how these behaviors change among children and adolescents with diverse baseline activity-related typologies. Because both physical activity and sedentary time could have unique influences on health,[7−11] it is important to look at how these behaviors change concurrently over time. Identifying whether and how these behaviors change over time based on baseline activity typologies may help effectively target interventions to prevent declines in physical activity and increases in sedentary time. To date, no studies have examined the associations between different activity-related behavioral typologies and later behavioral outcomes, such as physical activity and sedentary time. The aim of the current study was to explore changes in physical activity and sedentary time over 3 years according to baseline activity-related typologies.

2. Methods

This study used data from the UP&DOWN study,[12] a longitudinal study of healthy children (6−11 years of age) and adolescents (11−18 years of age) in Spain. Baseline data collection occurred between September 2011 and June 2012. Children <8 years old were excluded because they did not complete self-reported questionnaires due to their age (limited ability to provide reliable and valid information). The study involved 2 annual follow-ups (3 time points, including baseline). Ethical approval for the UP&DOWN study was obtained from the Bioethics Committee of the National Research Council (Madrid, Spain), the Ethics Committee of the Hospital Puerta de Hierro (Madrid, Spain), and the Committee for Research Involving Human Subjects at the University of Cádiz (Cádiz, Spain). Clustering of lifestyle behaviors have previously been identified in this dataset, with cross-sectional associations with physical fitness[10] and prospective associations with fatness.[11] The present study examined activity-related typologies (excluding diet and sleep).

2.1. Sample

Participants were recruited from primary and secondary schools within the Cádiz and Madrid regions of Spain, respectively. Information about the study and an invitation to

participate were sent to headmasters or physical education teachers at each school, of which 23 primary schools (24 invited, 96% response rate) and 22 secondary schools (46 invited, 48% response rate) provided consent to participate. A flyer describing the study was provided to all parents of students in the 1st and 4th grades (primary school) and in the 7th and 10th grades (secondary school). The flyer provided inclusion criteria (no physical disability or health problems that might limit levels of physical activity) and an invitation to parents to attend an information evening at their child's school. Following the information evening, written parental informed consent and child written assent was obtained for 1188 children and 1038 adolescents. Response rates for this component of the study were not calculated because the number of parents present at the information evenings was not recorded. Further details regarding recruitment have been published elsewhere.[12]

2.2. Measures

2.2.1. Self-reported physical activity and sedentary behaviors at baseline

Children aged 8−11 years and adolescents aged 11−18 years completed self-report questionnaires, indicating their age, sex, and participation in a range of activity-related behaviors. Participants were asked to record how many days during the last 7 days they exercised to strengthen their muscles. This was re-coded as 1 (≥2 times/week) *vs.* 0 (<2 times/week) to provide an indication of whether participants regularly engaged in muscle-strengthening activities sufficient for strength benefits.[13,14] Participation in organized sport was determined from the Finnish Physical Activity Index.[15] Participants were asked to indicate whether they were currently involved in sport at the local, regional, national, or international level (coded as 1) or not currently participating in any sport (coded as 0). Active travel to and from school was determined based on a question asking participants to choose their usual mode of transport to and from school from a list of options.[16] This item was dichotomized based on reported walking or cycling to and from school as the usual mode (coded as 1) *vs.* other modes (coded as 0).

The Youth Leisure-time Sedentary Behaviour Questionnaire was used to indicate time spent in 12 different sedentary behaviors across both weekdays and weekend days in the week prior to completing the survey.[16] Participants were asked to recall the average time spent in each behavior during the previous week, reporting weekdays, and weekend days, separately. Response options were 0 min, 30 min, 1 h, 2 h, 3 h, 4 h, and ≥5 h. The average time per day spent on each behavior was calculated using the following method: ((weekday-time × 5) + (weekend-time × 2))/7. These values were adjusted to account for the participants' sleep and school time to give an indication of their leisure-time sedentary behaviors. The adjustments followed a protocol that has been detailed previously.[16] Overall screen time was categorized as ≥2 h/day (coded as 1) *vs.* <2 h/day (coded as 0), which was consistent with the guidelines.[4] Time spent in "educational sedentary behaviors" (homework/study with a computer and homework/study without a computer),

"social sedentary behaviors" (sitting and talking with family or friends, listening to music, talking on the telephone, and sending messages), and "relaxation sedentary behaviors" (reading for fun, sitting to rest, and cognitive hobbies) were each dichotomized as ≥ 1 h/day (coded as 1) and <1 h/day (coded as 0), based on previous research protocols.[17,18]

2.2.2. Objectively assessed physical activity and sedentary time at baseline, Year 2, and Year 3

Physical activity and sedentary time were also assessed objectively using reliable ActiGraph accelerometer models GT1M, GT3X, and GT3X+ (Actigraph TM LLC., Fort Walton Beach, FL, USA) at each time point. The GT1M accelerometers collected data at 2-s epochs, and the GT3X and GT3X+ collected data at 30 Hz. However, all data were subsequently transformed into a 10-s epoch prior to analysis to increase sensitivity to sporadic movement behaviors typical of children and adolescents.[19] Furthermore, the use of 3 models did not imply any methodological problems because estimates across the 3 models show strong agreement among children and adolescents.[20,21] Participants were asked to wear the device on their hip during all waking hours (with the exception of water-based activities) for 7 consecutive days, which is consistent with established procedures.[22] Non-wear time was defined as 60 min of consecutive 0 count, allowing for up to 2 min of <100 counts per minute (cpm), with a small window of 30 min of consecutive 0 count for detection of artifactual movements based on the algorithm proposed by Choi et al.[23] Inclusion criterion was based on a minimum 3 days of recording with at least 10 h/day.[19] Average duration per day of sedentary time and MVPA were determined using the cut-point values of <100 cpm[19] and ≥ 2000 cpm,[24] respectively. The data-processing procedures used to estimate sedentary time and physical activity are consistent with previous studies among children and adolescents.[25,26]

2.3. Data analyses

Analyses were stratified by age (children and adolescents). Latent class analysis (LCA) was conducted in MPlus (Version 8.0; Múthen & Múthen, Los Angeles, CA, USA)[27] to generate baseline activity profiles (typologies) based on 7 self-reported activity-related behaviors described above (screen time, educational sedentary behaviors, social sedentary behaviors, relaxing sedentary behaviors, active travel to and from school, muscle strengthening activities, and sport). Although valid data were not obtained from all participants for each of these self-report variables ($n = 10-24$ missing on muscle strengthening and sport variables), LCA conducted in MPlus handles missing data using maximum likelihood estimation. Therefore, the LCA was based on the full sample. After excluding children aged between 6 and 8 years, the final baseline analytical sample included 600 children and 1037 adolescents. Five LCA models were conducted with class sizes of $1-5$, and the statistical indicators used to identify the optimal class solution were Akaike information criterion (lower = better model fit),[28] Bayesian information criterion (lower = better model fit),[29] entropy (higher = greater precision of model fit),[30] and

Lo-Mendel Rubin ($p < 0.05$ indicates $n - 1$ class is better than n class model).[31] Class sizes within each solution were also compared to ensure they were sufficient for further analyses. Once the optimal class solution was determined, linear mixed growth models for continuous repeated measures with random intercept were performed using STATA (Version 15.1; Stata Corp., College Station, TX, USA) to determine change in MVPA and sedentary time over 3 years within each baseline typology, as well as time by class interactions. The statistical approach used to identify longitudinal change in MVPA and sedentary time was chosen because it has the ability to (a) adjust for missing data points, (b) model nonlinear, individual characteristics between participants, and (c) account for non-independence of each participant's residuals.[32] Significance was set as $p < 0.05$ (two-tailed) for all tests.

3. Results

3.1. Participants

The mean age of child participants was 9.2 ± 0.4 years (mean $\pm$ SD), and 50.3% were girls. The mean age of adolescent participants was 13.6 ± 1.7 years, with 48.4% girls.

3.2. Baseline typologies of activity-related behaviors

Three typologies of activity-related behaviors were identified for children and for adolescents. This was based on the best model fit indices across each of the LCA models explored (Supplementary Table 1). The item−response probability plots for these 3-class solutions are shown in Fig. 1, and the distribution of activity-related behaviors within each typology are shown in Table 1.

Among children, the 3 typologies can be described as "social screenies" (Class 1; $n = 77$, 12.8%), "exercisers" (Class 2; $n = 369$, 61.5%), and "non-sporty active commuters" (Class 3; $n = 154$, 25.7%). Children in the "social screenies" typology self-reported the highest amount of all sedentary behaviors, with all participants reporting ≥ 2 h/day of screen time and >1 h/day of educational, social, and relaxing sedentary time. Compared to the other 2 typologies, the smallest proportion of these children reported participation in sport and regular active travel to and from school. Children classified within the "exercisers" typology all self-reported meeting the muscle strengthening guidelines of ≥ 2 sessions/week, and the highest proportion of these children engaged in organized sport. Sedentary time and active travel were similar to the "non-sporty active commuters" typology (Class 3). Children classified within the "non-sporty active commuters" typology were similar to "exercisers" on all activity-related behaviors, with the exception of muscle strengthening exercise and organized sport. None of these children achieved muscle strengthening exercise guidelines, and less than one-quarter reported any participation in sport. Overall, objectively measured MVPA and sedentary time did not differentiate the 3 typologies (Fig. 1 and Table 1).

The 3 adolescent typologies can be described as "active screenies" (Class 1; $n = 451$, 43.5%), "active academics" (Class 2; $n = 363$, 35.0%), and "non-sporty active commuters" (Class 3; $n = 223$, 21.5%). The male-dominated "active screenies"
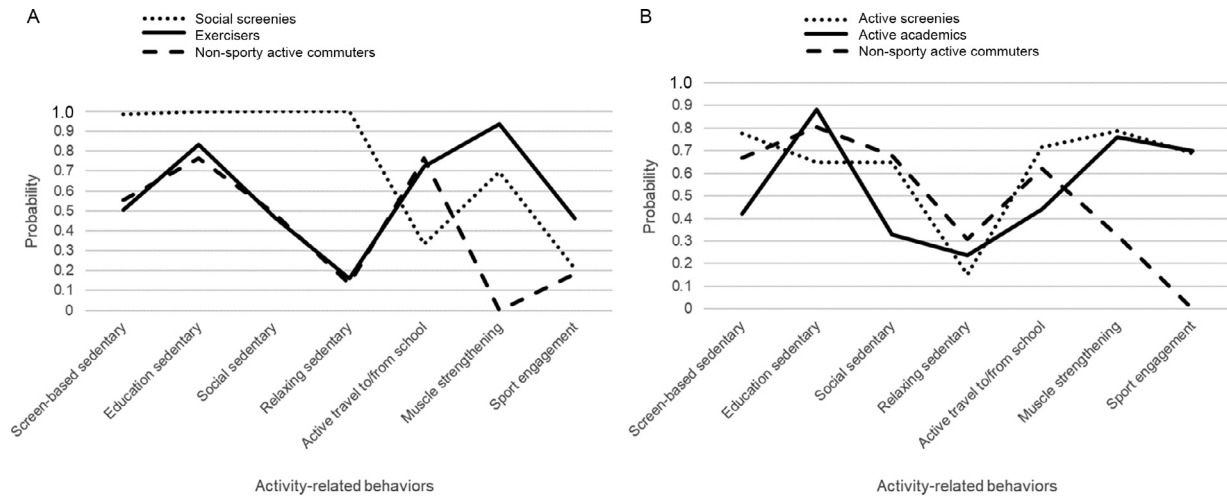
Fig. 1. Typologies item-response probability plot for (A) children and (B) adolescents.

typology had the highest proportion of adolescents who self-reported ≥2 h/day of screen time, regular active transport to and from school and muscle-strengthening activities, and the lowest proportion engaging in ≥1 h/day of sedentary time for relaxation. They also had the highest MVPA across the 3 typologies. The "active academics" typology comprised the youngest adolescents with almost all reported spending ≥1 h/day in educational sedentary time and the lowest proportion reported engaging in ≥2 h/day in screen time and ≥1 h/day in social sedentary time compared to the other 2 typologies. The "non-sporty active commuters" typology was composed mostly of females, less than 20% of those classified in this typology reported ≥2 sessions/week of muscle strengthening exercise, and none reported engaging in sport. The majority of adolescents in this typology also reported excessive screen time and ≥1 h/day of educational and social sedentary. This typology had the highest proportion of adolescents engaging in ≥1 h/day of relaxing sedentary time compared to the other 2 typologies, and overall

engaged in significantly higher sedentary time compared to the "active academics" (Fig. 1 and Table 1).

3.3. Change in physical activity and sedentary behavior

Results of the linear mixed growth models (Fig. 2) revealed no significant differences in average minutes per day of MVPA over the 3 time points among children ($p = 0.13$); however, each year was associated with an increase of 19.71 min/day of sedentary time (95% confidence interval (95%CI): 7.70−31.72, $p = 0.001$). There were no significant differences in change in MVPA over time between the "exercisers" ($p = 0.23$) or "non-sporty active commuters" ($p = 0.89$) compared to the "social screenies" typology, nor were there any significant differences for sedentary time ("exercisers", $p = 0.80$; "non-sporty active commuters", $p = 0.46$) compared to the "social screenies" typology. There was no evidence of an interaction between class membership

Table 1

Characteristics and activity-related behavior participation of children's and adolescents' typologies at baseline.

	Children				Adolescents			
	n	Class 1: Social screenies ($n = 77$)	Class 2: Exercisers ($n = 369$)	Class 3: Non-sporty active commuters ($n = 154$)	n	Class 1: Active screenies ($n = 451$)	Class 2: Active academics ($n = 363$)	Class 3: Non-sporty active commuters ($n = 223$)
Age (year, mean ± SD)	600	9.25 ± 0.59	9.12 ± 0.42	9.17 ± 0.39	1037	14.35 ± 1.51	12.15 ± 0.54*	14.30 ± 1.67#
Sex (%, female)	600	55.8	48.0	53.3	1037	40.8	46.0	67.7
Screen-based sedentary (%, ≥2 h/day)	600	100.0	49.6	53.3	1037	80.0	39.9	68.2
Education sedentary (%, ≥1 h/day)	600	100.0	82.9	77.3	1037	61.6	91.7	78.9
Social sedentary (%, ≥1 h/day)	600	100.0	46.3	47.4	1037	69.4	27.3	70.0
Relaxing sedentary (%, ≥1 h/day)	600	100.0	14.9	11.7	1037	11.5	23.1	38.1
Active travel to/from school (%, ≥1 times/week)	600	35.1	72.6	76.0	1037	74.5	40.8	68.7
Muscle strengthening (%, ≥2 sessions/week)	590	67.6	100.0	0.0	1027	85.7	78.2	14.3
Sport engagement (%, involved)	576	17.9	47.3	23.0	1018	69.4	69.4	0.0
SED (min/day, mean ± SD)	491	545.64 ± 90.30	545.23 ± 65.32	544.63 ± 66.85	943	661.99 ± 110.11	641.86 ± 105.09*	677.50 ± 88.18#
MVPA (min/day, mean ± SD)	491	71.51 ± 25.57	72.93 ± 25.16	70.01 ± 25.21	948	66.16 ± 23.35	63.00 ± 24.00	53.76 ± 19.27*,#

* $p < 0.05$, compared with adolescents Class 1.
# $p < 0.05$, compared with adolescents Class 2.
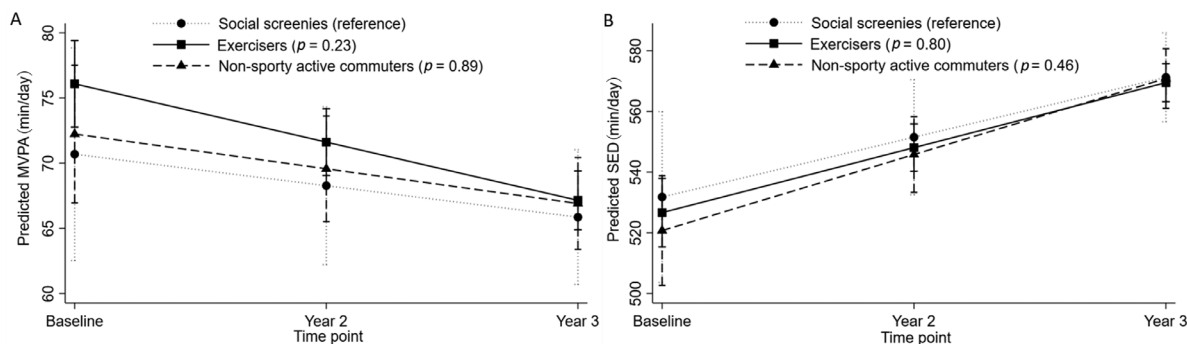Abbreviations: MVPA = moderate-to-vigorous physical activity; SED = sedentary behavior.

Fig. 2. Activity-related typologies and changes (mean ± SD) in children's (A) MVPA and (B) sedentary behavior. MVPA = moderate-to-vigorous physical activity; SED = sedentary time.

and time for physical activity ($p = 0.20$) or sedentary time ($p = 0.66$), with a similar minimal magnitude of change in the same direction across each of the 3 typologies.

There was a significant change in MVPA for adolescents (Fig. 3), with a 2.26-min (95%CI: -3.52 to -0.99, $p < 0.001$) decrease per year. This trajectory differed between classes, with MVPA among the "non-sporty active commuters" typology declining significantly more than the "active screenies" (coefficient = -12.94, 95%CI: -18.18 to -7.71, $p < 0.001$). No significant differences were evident between the "active academics" and "active screenies" ($p = 0.07$). Additionally, as can be seen in Fig. 3, there were no class by time interaction effects seen for MVPA among adolescents ($p = 0.56$) across the 3 time points. Sedentary time significantly increased by 11.73 min with each year of the study (95%CI: 5.47–17.99, $p < 0.001$). However, no significant differences were seen between "active academics" ($p = 0.74$) or "non-sporty active commuters" ($p = 0.43$) compared to "active screenies". There were also no significant interaction effects between class membership and time ($p = 0.69$) for sedentary time among adolescents.

4. Discussion

Our study explored changes in physical activity and sedentary time of children and adolescents over 3 years dependent on baseline typologies of activity-related behaviors. Because the study is the first of its kind, it is difficult to draw comparisons with other studies. Results revealed 3 independent, homogeneous typologies of children ("social screenies", "exercisers", and "non-sporty active commuters") and adolescents ("active screenies", "active academics", and "non-sporty active commuters") at baseline. Overall, for each age group and regardless of typology, sedentary time followed a similar increase across the 3 years. Sedentary time in this sample of youth tended to increase by 11–20 min/day with each consecutive year of the study. This sedentary time is less than the sedentary time found in a systematic review of 10 longitudinal studies, which reported that accelerometer-derived sedentary time tends to increase by approximately 30 min/day with each consecutive year in school-age children and adolescents from Western countries.[33] These differences may be due to variation in the follow-up period (1–10 years), baseline age (3.8–13.2 years), population group (no previous studies focused on youth from Spain), or differences in accelerometer data processing methods.[33]

Among children, typologies were defined by unique combinations of self-reported individual activity-related behaviors; however, there were no differences in overall MVPA or sedentary time between these groups at baseline. Furthermore, the magnitude of change in MVPA and in sedentary time was similar between the groups over the 3 years. In adolescents,
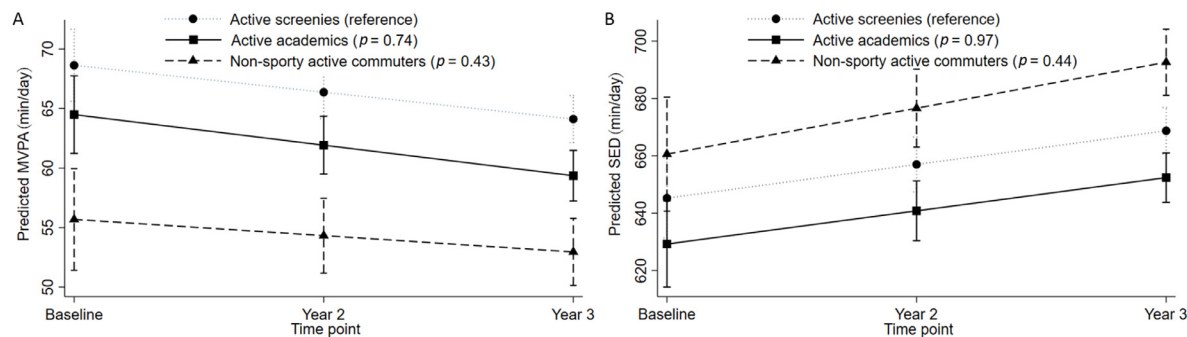

Fig. 3. Activity-related typologies and changes (mean ± SD) in adolescent's (A) MVPA and (B) sedentary behavior. MVPA = moderate-to-vigorous physical activity; SED = sedentary time.

however, declines in physical activity were significant among all typologies, with "non-sporty active commuters" declining significantly more than "active screenies" over the 3 years. Although not a direct comparison of methods used, these findings differ from those of Farooq et al.,[34] who identified 4 negative trajectories of MVPA over 8 years (baseline age = 7 years) with no indication that the declines were greater during adolescence than childhood. In the current study sample, the differences in physical activity change seen between children (no change over time) and adolescents (significant decline) may be due to youth facing other additional pressures during adolescence, such as school examinations, employment, and increasing social interactions outside of school time compared to during childhood.[35] Further research is needed to identify these predictors of change.

The findings that the adolescent "non-sporty active commuters" typology were majority female suggests that female adolescents may be most in need of physical activity interventions. Specifically, the consistency of the current results with previous literature[5] highlights the need for intervention targeting female adolescents engaging in high levels of sedentary behaviors and low physical activity participation. More research is needed to identify potential intervention strategies for this target group. Additionally, while no significant changes in overall MVPA were seen with time, we found that children identified as "social screenies" were the least likely to report regular active travel to and from school and sport engagement at baseline. Active travel to school has long been suggested as a way to increase daily physical activity in all youth.[36] This finding suggests that existing successful school initiatives aimed at increasing active travel (e.g., Safe Routes to School, Walking School Bus, TravelSmart initiatives)[37] could be potential ways to help these children increase their physical activity.

Almost all children and adolescents in the "non-sporty active commuters" typologies self-reported no muscle strengthening exercise or sport engagement, combined with one-half to three-quarters indicating high levels of all sedentary behaviors (except social sedentary behaviors). This combination of unhealthy baseline behaviors and the changes in their physical activity and sedentary time over the 3 years suggests that these youth in particular should be of high priority to target in health promotion initiatives. More specifically, given their lack of participation in organized sport and muscle strengthening activities, interventions could be tailored to include sport and muscle strengthening exercises. Future research should explore the individual, social, and environmental factors that predict the likelihood of youth engaging in such combinations of behavior combinations and changes over time to determine strategies that may be most appropriate for intervention. Given the difference in activity-related behavior typologies and physical activity changes over time between children and adolescents, it is possible that influencing factors may also differ between children and adolescents.

Few studies examining typologies of activity-related behaviors have used longitudinal study designs. While this study was unique in examining changes in physical activity and sedentary time among children and adolescents according to activity typologies, future studies should examine changes in behavioral typologies over time. Little is known about whether these typologies (patterns of sedentary behaviors and physical activities) remain stable over time or whether they are disrupted. In addition, the current study examined changes in physical activity and sedentary time separately using group means. However, it is possible that other trajectories of change were masked using this approach. Future research should consider using group-based trajectory analysis to identify different groups of individuals based on patterns of behavior change.

The strengths of this study include the use of a large cohort of children and adolescents, including a relatively even distribution of boys and girls, and the longitudinal study design. The subjective nature of the activity-related behavior variables used to determine the baseline typologies means that these variables were open to social-desirability and recall biases. However, objective measures of MVPA and sedentary time were used to examine changes in behavior over time.

5. Conclusion

This study was the first to examine longitudinal change in physical activity and sedentary time among children and adolescents with different baseline typologies of activity-related behavior. Findings revealed relatively similar baseline typologies between both children and adolescents. Sedentary time increased over time, irrespective of baseline typology, indicating the constant need to target a reduction in sedentary behaviors during childhood and adolescence. Physical activity declined among adolescents (but not children), with the majority female "non-sporty active commuters" declining significantly more than "active screenies" over the 2 years. These findings suggest that different physical activity interventions are needed targeting adolescents compared to children, as well as targeting adolescent females and sport engagement or muscle strengthening exercise specifically. However, for tailored interventions to be developed, more research is needed to determine group-based trajectories of change in physical activity and sedentary time, as well as the individual, social, and environmental determinants associated with potential changes.

Authors' contributions

KP contributed to the conceptualization of the focus of this paper, conducted all statistical analyses, drafted the manuscript, and prepared the manuscript for publication; AT, JS, KV, and HB contributed to the conceptualization of the focus of this paper, provided critical feedback on draft versions of the manuscript; IEC,

VCS, JCP, DSO, and OLV contributed to the initiation of the UP&DOWN study, the conceptualization of the focus of this paper, provided critical feedback on draft versions of the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jshs.2020.02.004.

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