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Public Health

Children's physical activity and sedentary behavior is related between different parts of a day

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Abstract: It is unclear how different day parts are related to each other in terms of children's physical activity (PA) or sedentary behavior (SB) and how moderators (sex, weight status or age) affect this. As many health interventions aim to increase PA and decrease SB, knowledge about same-day PA and SB patterns is important and related to practical implications. Therefore, study aims were to identify: 1) children's PA and SB relationships between parts of a day; and 2) moderators of these relationships. Participants (n = 1,085; 50.14% female; mean age = 8.60 [SD = 1.75] years; mean BMI%ile = 61.31 [31.57] kg/m2) wore a GENEActiv accelerometer for six days. Correlations between school-day and out of school (after school plus evening) moderate-vigorous PA (MVPA) and SB percent were calculated. Analyses were further stratified by sex, weight status, and age. There were strong negative correlations between MVPA % in school with SB % in school ($r = -0.92$, $p < 0.01$) as well as between MVPA % out of school with SB % out of school ($r = -0.94$, $p < 0.01$). Moderate positive correlations were found between MVPA % in school with MVPA % out of school ($r = 0.40$, $p < 0.01$) as well as between SB % in school with SB % out of school ($r = 0.39$, $p < 0.01$). This was similar across sex, weight status and age. Children's PA and SB is related between different day parts, independent of sex, weight status and age. Thus, promoting more PA and less SB for children at any part of the day is likely to positively affect PA and SB at other day parts.

Keywords: compensation effects, transfer effects, physical activity, sedentary behavior, child, health.

Introduction

Physical activity (PA) in children and adolescents is associated with several physical health benefits such as cardiovascular health, healthy weight, improved fitness, and bone strength (Janssen & Leblanc, 2010; Poitras et al., 2016), as well as mental and cognitive health benefits, including fewer psychological disorders and improved cognitive functions (Alvarez-Bueno et al., 2017; Herman et al., 2015; Janssen & Leblanc, 2010; Poitras et al., 2016). However, only 22% of US youth

between 6 and 19 years meet the recommendations of 60 minutes of moderate to vigorous PA (MVPA) a day (Katzmarzyk et al., 2016). Therefore, it is important to understand daily PA patterns of youth to design effective PA promotion interventions.

According to the activitystat hypothesis, PA is controlled by an individual's intrinsic activity center that regulates the total amount of PA to a set point and, based on that set point, controls future activity (Eisenmann & Wickel, 2009; Gomersall et al., 2016; Rowland, 1998). Therefore if an individual engages in a lot of PA one day it would be hypothesized that PA would be reduced the following day. Connected to this hypothesis, some evidence shows that children with high PA on one day have less activity the next day (Ridgers et al., 2017). In one study, children (average age 10 years) wore an ActiGraph accelerometer continuously for 8 days (Ridgers et al., 2017). In this sample, every additional 10 minutes spent in MVPA on one day lead to about 9 minutes less of MVPA and 17 minutes less of light PA (LPA) the next day (Ridgers et al., 2017). Similar results were found in another study that investigated children's PA patterns in the same age using an ActiGraph accelerometer for seven consecutive days. Each additional minute of children's MVPA on one day was related with about 5 minutes less of MVPA and 25 minutes less of LPA the next day (Ridgers et al., 2014). Looking at these patterns, this might explain why PA interventions are not successful in enhancing PA levels, as children seem to engage in less PA on other days (Van Sluijs et al., 2007).

However, there is also evidence against the activitystat hypothesis. In a school-randomized controlled trial, children wore accelerometers for two consecutive school weeks. One of the following conditions was applied at each school on one occasion: additional LPA, additional MVPA, and restricted LPA and MVPA. Comparing the activity levels the day after the additional or restricted conditions to the same day at baseline showed no significant differences for any group (Ridgers et al., 2018). Furthermore, a review of 28 studies on the activitystat hypothesis among all ages showed that there is still inconclusive evidence, with about half of the studies supporting and half of them opposing this hypothesis. This was also the case for the eight studies where the participants were children (Gomersall et al., 2013). Thus, a generalization hypothesis – high PA on one day is related to high PA the next day – seems to be plausible.

Additionally, when looking at PA behavior, there is still a lack of knowledge regarding the timeframe when these hypothesized patterns occur in relation to PA behavior (Gomersall et al., 2013). Only two studies were found that investigated same day PA patterns in children, also with mixed findings (Frémeaux et al., 2011). In a study comparing children's PA levels at three different schools, children in the active school had less activity outside of school, whereas children at the two less active schools had more activity after school (Frémeaux et al., 2011). However, in a study evaluating a before-school exercise intervention, children did not show a decrease in behavior during school-time during the days they participated in the exercise program (Stylianou et al., 2016).

Additionally, there is increasing evidence for the activity generalization (or synergy) hypothesis, proposing that active children are more active at other times. In a sample of 8-13 year old British children, PA was measured with accelerometers, diaries and GPS-(global positioning systems) on four consecutive days. Each extra 1% of time that a child spent in structured sports and play, physical education and games, or active travel per day was related to a 0.21% - 0.60% MVPA increase that day (Goodman et al., 2011). Baggett and colleagues (2010) found similar evidence in adolescent girls: each 10 minutes of MVPA were related to about 20 fewer minutes of inactivity the same day and 10 more minutes of LPA. This points to the possibility that if children are active for part of a day they are likely to be active for other parts also.

In studies exploring the school day, higher school-day PA generalized to higher outside-school PA (Dale et al., 2000; Long et al., 2013). The same results could be observed for LPA in- and out of PE-classes (Matthews-Ewald et al., 2014). Dale et al. (2000) also found evidence for same day "inactivity" synergy hypothesis. In an experimental condition, children in third and fourth grade wore accelerometers on four nonconsecutive schooldays with two days of restricted PA and two days of increased PA. On restricted PA days, children did not adjust for inactivity during the school day with PA in the after-school period (Dale et al., 2000). Looking at the relationship between PA and inactivity or sedentary behavior (SB), two meta-analyses found a small negative relationship between PA and either inactivity or SB (r's ~ -.1; Marshall et al., 2004; Pearson et al., 2014), indicating that both variables behave either in a healthy pattern or an unhealthy pattern.

In summary, it is not clear if or how the different times of day are related to each other in terms of children's PA or SB. Beyond that, there is a research gap regarding how PA and SB generalization patterns might be influenced by social-demographic characteristics. Comparing PA between different demographic groups, it has been shown that more boys (26%) than girls (17%) meet the World Health Organization (WHO)-PA guidelines, and that 43% of US six to eleven year olds, but less than 8% of US 12 to 19 year olds meet the WHO guidelines (Katzmarzyk et al., 2016). Another study comparing school-aged youth from 34 countries showed that overweight children have lower PA levels compared to children with a healthy weight (Janssen et al., 2005). However, so far, there is a lack of research on how sex, age, and weight status may moderate same-day PA and SB generalization in youth, although different groups might show different patterns. Many health interventions targeting youth aim to increase PA during specific periods of the day (Dale et al., 2000; Long et al., 2013), but it is crucial to know about same day PA patterns to assess the impact of the intervention on overall daily PA. This rationale also applies to SB. Therefore, the primary aim of this study is to identify the PA and SB generalization patterns of youth during the day. Given what is currently known in children, the following hypotheses were made:

- Youth with high PA rates during the school day also have high PA levels during out of school period

Youth with high rates of SB during the school day also have high SB rates during out of school period

The second aim of this study is to identify patterns stratified by sex, weight status, and age. Due to the exploratory nature:

- Non-directional hypotheses were put forth for sex, weight status, and age stratification.

Methods

Participants

One class of first (6-year olds), third (8-year olds) and fifth grade (10-year olds) students from eight different Denver public schools participated in the spring of each year, with separate samples selected yearly from 2010-2013 (. = 1,085; aged 7-12). Demographics are presented in Table 1.

Table 1

Table 1
Participants demographics (n = 1,085)

Demographic		Mean	*SD*
Age (yrs)		8.60	1.75
Weight (kg)		35.11	15.80
BMI (z-score)		0.47	1.25
BMI%ile		61.31	31.57
		n	%
Female		544	50.14
Grade	1	371	34.19
	3	370	34.10
	5	344	31.71
OW/OB BMI*		376	34.65

OW = overweight
OB = obese
BMI = Body Mass Index
* Overweight or Obese BMI ≥ 85%ile

Study Design

Data from this study come from the Intervention for PhysicaL Activity in Youth (IPLAY) study. The study was approved by the Colorado Multiple Institutional Review Board (IRB), Colorado State University IRB, and the University of Hawaii IRB. IPLAY was a multi-year intervention trial exploring the impacts of schoolyard renovations and/or a recess curriculum (SPARK) on PA levels among elementary aged students (Nigg et al., 2019). Importantly, no significant differences were found among the groups within the intervention, thereby allowing the use of the full dataset to be explored without concern about intervention effects.

PA measurement

PA was measured using wrist-mounted accelerometry. For a detailed description of the device specifications and processing decisions, see Nigg et al. (2019). Briefly, the data were collected using GENEActiv accelerometers (Activinsights Limited, Cambridgeshire, UK), which are tri-axial waterproof devices that have been validated for use in children (Schaefer et al., 2014). Classification accuracies for children's MVPA with these cut-points were 70%, sensitivity >.90 and specificity >.85 (Schaefer et al., 2014). Data were mostly collected at 75 Hz and a subset (data collected in three schools during the spring of 2011) at 30 Hz. Data revealed no significant differences by frequency ($p > .05$), thus were combined.

Data Collection

On the first day of data collection, devices were attached to each student's non-dominant wrist, and were left on for six consecutive days including weekend days (Ettienne et al., 2016) without removing them. Devices were attached using semi-non-removable hospital bands (MedTech Wristbands, Orlando FL). Teachers were asked to keep detailed class schedules for the week, so that before school, class time, lunch, recess, Physical Education (PE) times and end of school day would be identifiable by the researchers when downloading and analyzing the data. At the end of the six-day period, researchers returned to the schools to collect the devices and provide compensation (gift card for school supplies) valued at US$ 100 to the participating classes. Students received part of their incentive at the beginning of the data collection period, and the other part of it upon returning the devices.

Data Processing

Upon collecting the accelerometers from students, data was immediately downloaded from the devices so devices could be re-charged and provided to the next school. A custom Matlab software script (Mathworks, Inc.,

v12.0, Natick, MA) was created to clean the data and assess for non-wear. The first day of data was discarded to account for novelty effects. To assess completeness of the data file, periods of time with greater than 60 minutes or more of values below the nonwear threshold (< 0.06 g s) were summed over the day to assess completeness of each data file. In order to be considered a valid data file, a minimum of 10 hours of wear time each day for a minimum of four days was required (Matthews et al., 2012). Thirty-one (2.78%) datasets did not meet this criterion. Once data were cleaned, custom time intervals were created based on schedules provided by teachers in order to identify when specific activities happened throughout the day. These intervals included the full day (6 a.m. - 11 p.m.), before school (6 a.m. to school-specific start time), school day (school-specific start and end time), after-school (school-specific end time to 5 p.m.), evening (5 p.m. – 9 p.m.) and weekend (6 a. m. – 11 p.m.). Once time intervals were created, the Matlab script then applied cutpoints. The following cut-points were applied to distinguish between sedentary (SED = 0 – 0.0935), light (LPA = 0.0936 – 0.1846), moderate (MPA = 0.1847 – 0.4531), vigorous (VPA = 0.4532+), and moderate-vigorous PA (MVPA; sum of MPA and VPA = 0.1847+; Schaefer et al., 2014) during each of the custom intervals. Moderate and vigorous data were combined to create a single MVPA variable. Before school had negligible PA and thus was excluded in further analyses.

Data análisis

For hypotheses 1 and 2 correlations between school-day and out of school (after school plus evening) MVPA were calculated for PA and SB. Percent within the specified time interval were used in the analysis to standardize the comparisons. The averages of multiple measurements (days) within the same individuals were first calculated and then the resulting averages were used for the correlation analyses. Correlations can be interpreted as weak (~ .2), moderate (~ .5), or strong (~ .8; Cohen, 2013). For moderation, analyses were stratified by sex, weight status (BMI percentile for age < 85 vs. BMI >/= 85), and age (grade).

Results

Means and standard deviations in minutes per day of MVPA in school and out of school along with the corresponding percent were calculated, in addition to the Pearson correlation coefficients among the variables in percent (see Table 2). There were strong negative correlations between MVPA % in school with SB % in school ($r = -0.92$; $p < 0.01$) as well as between MVPA % out of school with SB % out of school ($r = -0.94$, $p < 0.01$).

Moderate positive correlations were found between MVPA % in school with MVPA % out of school ($r = 0.40$, $p < 0.01$) as well as between

SB % in school with SB % out of school ($r = 0.39$, $p < 0.01$). This was similar across sex, weight status and age.

Table 2

Minutes and percent of MVPA and SB in school and out of school and their correlación (all correlations are significant at $p < 0.01$; total $n = 1,085$).

Table 2

Minutes and percent of MVPA and SB in school and out of school and their correlación (all correlations are significant at $p < 0.01$; total n = 1,085).

OVERALL (n = 1,085)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
59.64	*16.00*	*14.53*	*3.88*	*MVPA% in School (1)*	*0.396*	*-0.921*	*-0.348*
64.77	*20.61*	*19.16*	*6.03*	*MVPA% Out of School (2)*	*1*	*-0.352*	*-0.936*
290.86	*24.65*	*70.88*	*5.84*	*Sedentary% in School (3)*		*1*	*0.392*
221.46	*33.85*	*65.29*	*7.96*	*Sedentary% Out of School (4)*			*1*
SEX							
Girls (n = 544)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
55.75	*14.92*	*13.58*	*3.61*	*MVPA% in School (1)*	*0.382*	*-0.934*	*-0.342*
61.08	*17.81*	*18.08*	*5.18*	*MVPA% Out of School (2)*	*1*	*-0.357*	*-0.921*
295.29	*23.96*	*71.94*	*5.72*	*Sedentary% in School (3)*		*1*	*0.411*
223.00	*32.02*	*65.81*	*7.25*	*Sedentary% Out of School (4)*			*1*
Boys (n=541)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
63.55	*16.10*	*15.49*	*3.91*	*MVPA% in School (1)*	*0.361*	*-0.907*	*-0.345*
68.48	*22.50*	*20.25*	*6.61*	*MVPA% Out of School (2)*	*1*	*-0.313*	*-0.957*
286.40	*24.55*	*69.81*	*5.76*	*Sedentary% in School (3)*		*1*	*0.371*
219.91	*35.55*	*64.77*	*8.60*	*Sedentary% Out of School (4)*			*1*
WEIGHT STATUS							
Normal Weight, BMI < 85% (n = 709)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
59.25	*15.93*	*14.45*	*3.86*	*MVPA% in School (1)*	*0.400*	*-0.927*	*-0.353*
65.52	*21.36*	*19.38*	*6.25*	*MVPA% Out of School (2)*	*1*	*-0.360*	*-0.949*
291.38	*24.24*	*71.06*	*5.73*	*Sedentary% in School (3)*		*1*	*0.378*
221.19	*34.33*	*65.22*	*8.18*	*Sedentary% Out of School (4)*			*1*
OW/OB, BMI >= 85% (n = 376)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
60.38	*16.12*	*14.69*	*3.92*	*MVPA% in School (1)*	*0.397*	*-0.911*	*-0.341*
63.36	*19.05*	*18.74*	*5.58*	*MVPA% Out of School (2)*	*1*	*-0.349*	*-0.909*
289.89	*25.40*	*70.54*	*6.02*	*Sedentary% in School (3)*		*1*	*0.425*
221.97	*32.95*	*65.43*	*7.55*	*Sedentary% Out of School (4)*			*1*
AGE (GRADE)							
Grade 1 (n = 371)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
63.16	*14.40*	*15.38*	*3.50*	*MVPA% in School (1)*	*0.369*	*-0.948*	*-0.333*
69.04	*19.94*	*20.35*	*5.77*	*MVPA% Out of School (2)*	*1*	*-0.328*	*-0.957*
284.25	*22.17*	*69.22*	*5.06*	*Sedentary% in School (3)*		*1*	*0.333*
216.37	*31.89*	*63.57*	*7.36*	*Sedentary% Out of School (4)*			*1*
Grade 3 (n = 370)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
60.09	*15.77*	*14.64*	*3.82*	*MVPA% in School (1)*	*0.316*	*-0.863*	*-0.250*
65.40	*19.88*	*19.36*	*5.88*	*MVPA% Out of School (2)*	*1*	*-0.228*	*-0.900*
289.88	*25.47*	*70.62*	*5.96*	*Sedentary% in School (3)*		*1*	*0.333*
220.20	*33.66*	*64.89*	*7.81*	*Sedentary% Out of School (4)*			*1*
Grade 5 (n = 344)							
Min./Day		*%*		*Variable*	*Pearson's Correlations*		
Mean	*SD*	*Mean*	*SD*		*2*	*3*	*4*
55.37	*16.90*	*13.50*	*4.11*	*MVPA% in School (1)*	*0.432*	*-0.954*	*-0.376*
59.49	*20.97*	*17.67*	*6.17*	*MVPA% Out of School (2)*	*1*	*-0.413*	*-0.948*
299.04	*24.01*	*72.95*	*5.87*	*Sedentary% in School (3)*		*1*	*0.407*
228.30	*35.04*	*67.59*	*8.23*	*Sedentary% Out of School (4)*			*1*

Discussion

The primary aims of this study were to identify if youth PA during the school day was related to PA out of school and if youth SB during the school day was related to SB out of school. These hypotheses were confirmed as both behaviors had a moderately strong correlation between in-school and out of school, possibly indicating generalization or synergy between the different parts of the day within the same behavior. Relatedly, there is also evidence of generalization between more PA in school with less SB out of school as well as more SB in school with less PA out of school (evidenced by moderate negative correlations). So, the more PA in one part of the day the more PA and less SB in another part of the day. Similarly for SB, the higher the SB in one part of the day the higher SB and the lower the PA during the other part of the day. Regarding PA and SB, these findings support previous findings on PA and SB generalization as active children during school are also more active outside of school and more sedentary children during school are also more sedentary out of school (Dale et al., 2000; Long et al., 2013). This however is counter previous research suggesting that environment matters as educational settings decrease PA levels (Gidlow et al., 2008). It may be that children who are more active in one environment are able to find opportunities to be active in other environments.

The secondary purpose was to explore these relationships stratified by sex, weight status or age. Across all subgroups analyzed, there were within-behavior and across-behavior generalizations between the different parts of the day. These subgroup analyses have not been performed in other studies so far (Dale et al., 2000; Long et al., 2013). This underlines the importance and robustness of these findings in our sample of elementary students. A remarkable finding was that within the same part of the day there was a stronger than expected inverse relationship, between PA and SB which was true for all subgroups analyzed ($r \sim -0.9$). These results are substantially stronger compared to the ones in two meta-analysis, showing relationships of – 0.096 (Marshall et al., 2004) and – 0.108 (Pearson et al., 2014) between PA and SB. A possible explanation could be that the meta-analyses included studies that had mostly proxy- or self-report measures about PA and SB (Marshall et al., 2004; Pearson et al., 2014). While self-report allows reporting of PA and SB simultaneously, using accelerometers only allows children to be either active or sedentary at any given time point, thus leading to stronger dependent relationships.

Although we are not able to discern whether these relationships indicating generalization happen consciously, with intentional effort, or whether they occur at a lower level of control, these findings have several implications. Interventions targeting PA or SB at one part of the day may be beneficial for increasing overall daily PA levels. While some studies have already explored synergy effects and possible mechanisms for different health behaviors (Lippke, 2014; Nigg et al., 2009), synergy mechanisms for same-day health behavior should be further investigated

to increase our understanding and to potentially provide guidance on how to strengthen this relationship. In addition, it should be investigated if different settings are related to possible generalization mechanisms in youth, as children's in- and out of school settings differ and both the physical and social environment have been shown to be related to youth's PA (Remmers et al., 2019; Sullivan et al., 2017). The different parts of the day should be further divided (e.g., before school, school, recess, after school, evening) to investigate the part of the day associated with the strongest generalization and to investigate the shortest part of the day where generalization still occurs.

The opposite side is even more important to consider as the individuals with lower PA will likely have higher SB. In other words, the high-risk children tend to be high-risk throughout the whole day (and importantly, this did not depend on weight status). It is strongly recommended to research how to address this subgroup which is most at risk for future health problems, such as children who are currently lacking effective PA interventions (Nooijen et al., 2017). Based on our results, targeting interventions in any part of the day for those who are most sedentary could have positive outcomes. Therefore, interventions aiming to increase PA or decrease SB in one specific part of the day may have important generalization within that same part of the day and importantly, to other parts of the day, strengthening the intervention's health impact.

Strengths and Limitations

This study exploring within-day PA and SB relationships among a sample of elementary students has various strengths worth mentioning. The use of accelerometry removed some of the bias that can result from self-report. Additionally, the large sample size and the heterogeneous sample allowed for exploring our hypotheses by sex, weight status and age. The biggest limitation to this investigation is the cross-sectional nature limiting causal inferences. In addition, the after-school settings of the children are unknown. These findings need to be investigated and replicated longitudinally and optimally with randomized controlled trials and field trials. It also should be investigated where light intensity activity fits in (which there was not much of in this study, possibly due to the short epochs used enabling the detection of short bouts of MVPA, which highlighted that elementary aged students may not actually spend all that much time in light PA); and how light activity is related to same-day PA as recent guidelines underline the importance of light PA as "every move counts" (WHO, 2020).

Conclusión

This study adds to the body of evidence suggesting that children may generalize PA and SB from one part of the day to another part of the day. This is also the first study of its kind to explore the question of

PA and SB relationship within the same day by sex, weight status and age, finding no differences between the groups. The implications of our findings are that promoting PA and reducing SB for children at any part of the day likely positively affects PA and SB at other parts of the day. Practical implications are that children who are active during the school day are also active outside of school, and that children who are sedentary during the school day are also sedentary outside of school. Future research should be done to confirm within-day generalization for children's PA, to investigate within-day generalization in older children and adolescents, and to explore the weekday-weekend relationships.

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