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The effect of a school-centered multicomponent intervention on daily physical activity and sedentary behavior in primary school children: The Active Living study

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ABSTRACT

The aim of the current study was to examine the effectiveness of a school-centered multicomponent PA intervention, called 'Active Living', on children's daily PA levels.
A quasi-experimental design was used including 9 intervention schools and 9 matched control schools located in the Netherlands. The baseline measurement took place between March–June 2013, and follow-up measurements were conducted 12 months afterwards. Accelerometer (ActiGraph, GT3X+) data of 520 children aged 8–11 years were collected and supplemented with demographics and weather conditions data. Implementation magnitude of the interventions was measured by keeping logbooks on the number of implemented physical environmental interventions (PEIs) and social environmental interventions (SEIs). Multilevel multivariate linear regression analyses were used to study changes in sedentary behavior (SB), light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA) between baseline and follow-up. Finally, effect sizes (ESs) were calculated using Cohen's *d*.
No pooled effects on PA and SB were found between children exposed and not exposed to Active Living after 12 months. However, children attending Active Living schools that implemented larger numbers of both PEIs and SEIs engaged in 15 more minutes of LPA per weekday at follow-up than children in the control condition (ES = 0.41; $p < .05$). Moreover, children attending these schools spent less time in SB at follow-up (ES = 0.33), although this effect was non-significant. No significant effects were found on MVPA.
A school-centered multicomponent PA intervention holds the potential to activate children, but a comprehensive set of intervention elements with a sufficient magnitude is necessary to achieve at least moderate effect sizes.

1. Introduction

Increased physical inactivity (Kohl et al., 2012) is a global threat to health and contributes to multiple diseases throughout the lifespan (Andersen et al., 2006; Ekelund et al., 2012; Saunders et al., 2014). Childhood physical activity (PA) and sedentary patterns track into adulthood (Parsons et al., 1999; Singh et al., 2008; Telama, 2009), indicating a necessity to stimulate physical activity at an early age and for early prevention of sedentary behaviors (SB). Low PA and high levels of SB are independent risk factors for health, rather than opposite behaviors in a continuum, and have their own independent determinants (Saunders et al., 2014; Pearson et al., 2014). Primary schools are suitable settings for preventive health activities, since children spend a substantial amount of time in schools during weekdays (Story et al., 2009). A healthy, PA-supportive school environment has the potential to influence childhood PA levels (Escalante et al., 2014; Ridgers et al., 2012). Despite their important position in reaching out to and educating children, schools are only one setting within a broader system in which children operate (Koplan et al., 2005; Pate et al., 2006). Another setting affecting childhood PA patterns is the neighborhood children reside in. A PA-supportive neighborhood is positively associated with children's outdoor play behavior (Aarts et al., 2012). For instance, social safety and traffic safety affect both outdoor play and active transport to school

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(De Vries et al., 2010; Carver et al., 2008; Timperio et al., 2006). A third setting children operate in is the home environment. Parental behaviors and decisions influence children's PA and SB, especially those of young children (Carver et al., 2013; Faulkner et al., 2010). Interactions between activity-inducing physical environmental factors (e.g. the availability of playgrounds in the neighborhood) and social environmental factors (e.g. supportive parental practice towards child's PA behavior) in each setting are assumed to strengthen each other's impact on child behaviors (Gubbels et al., 2014). In other words, the implementation of supportive actions within multiple types of environment, i.e. physical and social, is assumed to have a synergetic effect on child's PA (Gubbels et al., 2011).

Many school-based PA interventions have been implemented (Broekhuizen et al., 2014; Dobbins et al., 2013), but studies found that their effectiveness differs greatly. Generalizability of these studies is limited due to the variety of types, numbers and intensities of interventions. The challenge of generalizing results may be met by performing an implementation-focused process evaluation for each type of environmental intervention (Elder et al., 1994). In addition, school-based interventions tend to focus only on the school setting, e.g. schoolyards, and pay little or no attention to other settings such as the local neighborhood and the home environment. In order to connect the school setting with other settings, the Active Living study has been developed and implemented as a school-centered PA intervention (Van Kann et al., 2015). To increase PA and decrease SB in primary school children, the Active Living study implemented multicomponent PA interventions at or around school to enhance PA in three domains; (1) in school, (2) during active school transport, and (3) during leisure time (Van Kann et al., 2015). In all three PA domains, both physical and social environmental interventions (PEIs and SEIs) were implemented.

The aim of the current study was to test the effectiveness of 'Active Living' in terms of children's daily PA and SB levels, while taking exposure to PEIs and SEIs into account. We hypothesized that children who were exposed to more PEIs and SEIs would increase their PA levels and decrease their SB more than children who were less exposed to these interventions and than children who were not at all exposed to Active Living interventions (control condition).

2. Methods

2.1. Study design and protocol

To test the effectiveness of the Active Living study, a longitudinal, quasi-experimental design was used. The study was conducted among 21 primary schools located in deprived areas (low SES) in the Southern-Limburg region of the Netherlands. A detailed description of the study design, methods, and implementation strategies has been published elsewhere (Van Kann et al., 2015). The Active Living study received ethical approval from the Medical Ethics Committee of the University Hospital Maastricht (METC 12-4-077) and is registered as a Current Controlled Trial (ISCTRN25497687).

2.2. Study sample

For the purpose of the current study, grade 6 and 7 children (aged 8–11 years) from 21 schools were included; 10 Active Living intervention schools and 11 matched control schools. In one case, an intervention school was matched to two control schools, due to unexpected environmental changes in the control school between the feasibility test in the autumn of 2012 and the baseline measurement in the spring of 2013. After the baseline measurement, no further changes were noticed in this control school, making both control schools eligible for inclusion in this study. The baseline measurement (T0) took place between March and June 2013. The follow-up measurement was conducted between March and June 2014 (T1). Schools consented filling out a questionnaire in the classroom. At baseline, all children (N = 1343) filled out a questionnaire, and 791 of them were fitted with an accelerometer (58.9%). Written parental consent to wear an accelerometer, however, was obtained prior to the baseline measurement. To correct for potential seasonal effects (Rich et al., 2012), every intervention-control school pair was assessed on the same dates. Moreover, a minimum number of 10 children per school providing valid accelerometer data at both baseline (T0) and follow-up (T1) was defined as an inclusion criterion. If a school in a pair (intervention-control) did not meet the inclusion criterion, the pair was deleted from the data analyses.

2.3. Intervention packages

Implemented PEIs and SEIs were all intended to stimulate PA or reduce SB (Table 1). An overview of all activities is provided per school in Supplemental Table 1 (Table S1). All interventions were implemented at school or within an 800 m radius around the school. In the Netherlands, the majority of the primary school children lives within 800 m distance from school (Centraal Bureau voor de Statistiek (CBS), 2014). No additional activities were implemented at control schools during the intervention period. A working group at each intervention school was responsible for choosing, designing and implementing intervention elements. All working groups received an intervention budget of 2000 euros at the start of the project. Although sharing an overall scope, the intervention packages could differ in magnitude and design across schools. Working groups defined local needs and designed interventions accordingly. Implementation magnitude was measured by keeping logbooks on the number of implemented PEIs and SEIs. The number of implemented interventions was dichotomized (high/low) using median split (PEI ≥ 4 = high; SEI ≥ 6 = high), and a 'set of interventions' variable was defined as 'high magnitude set' if both the dichotomized PEIs and SEIs variable were high. Other combinations were defined as 'low magnitude set', while the number of implemented interventions in control schools was set to zero.

2.4. Measures

Primary outcome variables of this effectiveness study were changes in PA and SB on weekdays after 12 months. PA data were collected using accelerometers (ActiGraph GT3X+; 30 Hz, 10-second epochs) and data were processed using ActiLife version 6.10.4 (ActiGraph, Pensacola, USA). Wear time validation was assessed using Choi's classification criteria (Choi et al., 2011) and minimal wear time was defined as 480 min per day during waking hours between 6 am and 11 pm (Jago et al., 2013). In view of the focus of the intervention packages of the Active Living study (see Table S1), only weekdays were included in the analyses. The first day of measurement was excluded to prevent reactivity (Dössegger et al., 2014). Valid weekdays, with a minimum of 1 after excluding the first measurement day, were aggregated per child to be included in the statistical models. Evenson's cut-offs (Evenson et al., 2008) were used to classify PA data into sedentary behavior (SB;

Table 1
Examples of implemented interventions.

PA domain	Example of physical environmental intervention (PEI)	Example of social environmental intervention (SEI)
1. PA in school	Providing (portable and fixed) play equipment at schoolyard; Providing playground markings	Introducing sports clinics during recess; Specifying the potential activating role of teachers during recess
2. PA during active school transport	Creating safer parking situation around school (school zones); Providing bicycle racks	Initiating a walk/cycle-to-school day; Running an active transport sticker competition
3. PA during leisure time	Upgrading local playgrounds; Redesigning local playgrounds	Establishing out-of-school activity program; Connecting local sports clubs with schools

Table 2
Characteristics of study population (Baseline March–June 2013).

	Total (N = 520)	Intervention (N = 301)	Control (N = 219)
Demographics			
Age; mean (SD)	10.13 (.69)	10.13 (.68)	10.13 (.70)
Gender			
Boys; N (%)	231 (44.4)	143 (47.5)	88 (40.2)
Girls; N (%)	289 (55.6)	158 (52.5)	131 (59.8)
Ethnicity			
Dutch; N (%)	490 (94.2)	282 (93.7)	208 (95.0)
Non-Dutch; N (%)	30 (5.8)	19 (6.3)	11 (5.0)
PA levels at baseline			
SB; % (SD)	65.4 (6.7)	65.7 (7.1)	64.9 (6.2)
LPA; % (SD)	27.4 (5.2)	27.0 (5.5)	27.9 (4.8)
MVPA; % (SD)	7.2 (2.8)	7.3 (2.8)	7.2 (2.9)
CPM (X-axis); mean (SD)	528.1 (197.9)	521.9 (191.9)	536.6 (206.0)
CPM (vector magnitude); mean (SD)	1007.5 (291.6)	999.6 (289.1)	1018.3 (295.4)
Implemented interventions			
Physical environment (PEI); mean (SD)		4.1 (1.8)	Not applicable
Social environment (SEI); mean (SD)		4.8 (1.9)	Not applicable

SB = sedentary behavior; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; CPM = counts-per-minute.

≤100 counts-per-minute), light PA (LPA; 101–2295 counts-per-minute), and moderate-to-vigorous PA (MVPA; ≥2296 counts-per-minute). Time spent in SB, LPA, and MVPA was divided by wear time to calculate a proportion of time per day spent in SB, LPA, and MVPA, respectively.

Demographic variables were collected using questionnaires completed by the children. Child's age was calculated by subtracting the self-reported date of birth from the first date of measurement at baseline. Other demographic variables were gender and ethnicity (based on country of birth of the child and both parents). Mean temperature, sun exposure and precipitation between 6 am and 11 pm were calculated for every single measurement day before aggregating data (Royal Dutch Meteorological Institute (KNMI)). Individual change scores (Δ) for weather condition between baseline and follow-up measurement were calculated by subtracting the values of aggregated baseline data from those of aggregated follow-up data.

2.5. Statistical analyses

Statistical analyses used SPSS version 21.0 (IBM, USA) and significance was defined as $p < .05$. Various multilevel linear regression analyses were used to study the effectiveness of interventions regarding change in PA and SB. We first tested the pooled effectiveness of the experimental versus control condition. For this purpose, we constructed three two-level regression models with the proportion of time spent in SB, LPA, and MVPA, respectively, as dependent outcome variables while correcting for potentially confounding factors such as demographic variables and weather conditions. School was entered as a level-one independent variable, while baseline proportions of time spent in SB, LPA, and MVPA, respectively; gender; age; ethnicity; change scores for temperature, sun exposure, and precipitation; and condition (intervention/control) were entered as independent variables at level two.

Subsequently, we restructured our models by replacing the condition variable by the dichotomized PEI variable, setting the number of PEIs at control schools at zero. A third model contained the same predictors of change, but included the dichotomized SEI variable. The final model included the same predictors as previous models, but now included the 'set of interventions' variable. These three models were corrected for the similar confounding factors as included in the pooled effectiveness analyses. Finally, effect sizes (ESs) were calculated using Cohen's *d* (1988) and ESs were interpreted using Lipsey's cut-off values, indicating a small effect for ESs ≤0.32, a moderate effect for ESs between 0.33–0.55 and a large effect for ESs ≥0.56 (Lipsey, 1990).

3. Results

3.1. Demographics and intervention implementation

In total, nine (intervention-control) school pairs were included in the analyses. One school pair was excluded for not meeting the criterion on the minimum number of children providing valid accelerometer data. At the 18 included schools, 520 children (74.2%) provided valid accelerometer data both at T0 and T1. Fifty-eight percent of these children were enrolled at an intervention school. Slightly more girls (56%) than boys provided valid data, and the mean age of children at baseline was 10.1 years. The majority of the children had been born in the Netherlands (N = 490; 94%) (Table 2).

At baseline, children spent 65.4% of their time in SB, whereas the proportions of time spent in LPA and MVPA were 27.4% and 7.2%, respectively with no significant differences between children attending intervention and control schools. The proportion of daily time spent in MVPA corresponds to 56.3 min (SD ± 22.6). After 12 months, children spent on average 2.2% (SD ± 7.4) more daily time in SB, while they spent 1.7% (SD ± 5.5) less daily time in LPA and 0.5% (SD ± 1.2) less in MVPA. These proportions correspond to 17.0 additional minutes of SB a day and 13.2, and 3.9 fewer minutes of LPA and MVPA a day, respectively. At follow-up, the temperature was on average 0.4 °C higher than at T0. The sun exposure had increased by an additional 2.6 h a day at T1, and on average 0.6 fewer h of precipitation a day were measured at T1.

On average, 4.1 PEIs were implemented at the intervention schools, ranging from a minimum of 2 to a maximum of 8 per school. The average number of implemented SEIs was 4.8, ranging from 3 to 10 per intervention school (Table 2).

3.2. Predicting change in SB, LPA, and MVPA by intervention condition, demographics, and weather conditions

Overall, a multilevel regression model including the condition variable, i.e. intervention or control condition, showed no significant pooled effect on time spent in either of the three PA categories (Table 3). Baseline proportion of time spent in each activity category strongly predicted the proportion of time spent in the same activity category after 12 months. Moreover, SB increased and LPA and MVPA decreased between T0 and T1. Being older at baseline and being a girl significantly predicted increased time spent in SB and decreased time spent in MVPA and LPA after 12 months. Neither ethnicity nor the difference in

Table 3
Predictors of proportion of time spent in SB, LPA, and MVPA after 12 months (Follow-up March–June 2014).

(N = 520)	SB		LPA		MVPA	
	Beta (95% C.I.)	*p*	Beta (95% C.I.)	*p*	Beta (95% C.I.)	*p*
Baseline % PA	.38 (.30–.46)	<.01	.39 (.32–.47)	<.01	.36 (.28–.45)	<.01
Age	1.09 (.33–1.85)	<.01	−.65 (−1.22–−.08)	.02	−.43 (−.77–−.09)	.01
Gender (male)	−1.98 (−3.03–−.93)	<.01	.76 (−.02–1.54)	.06	1.25 (.77–1.74)	<.01
Ethnicity (Dutch)	.09 (−2.73–2.90)	.95	−.04 (−2.13–2.05)	.97	−.00 (−1.25–1.25)	.99
Δ Temperature (°C)	.01 (−.01–.03)	.52	−.01 (−.02–.01)	.44	−.00 (−.01–.01)	.87
Δ Sun exposure	−.23 (−.69–.22)	.31	.17 (−.15–.49)	.33	.06 (−.15–.28)	.54
Δ Precipitation	.18 (−.52–.88)	.60	−.23 (−.74–.27)	.38	.03 (−.30–.35)	.87
Condition (Intervention)	**.02 (−2.17–2.21)**	**.99**	**.58 (−.93–2.10)**	**.43**	**−.58 (−1.64–.49)**	**.26**
Number of PEIs						
Control = ref						
Low	**0.93 (−1.61–3.47)**	**.44**	**−.21 (−1.86–1.45)**	**.79**	**−.71 (−2.04–.59)**	**.25**
High	**−1.23 (−4.06–1.60)**	**.37**	**1.67 (−.19–3.52)**	**.08**	**−.35 (−1.81–1.11)**	**.61**
Number of SEIs						
Control = ref						
Low	**1.10 (−1.20–3.40)**	**.31**	**−.14 (−1.74–1.47)**	**.85**	**−.92 (−2.15–.31)**	**.13**
High	**−1.51 (−4.08–1.07)**	**.23**	**1.67 (−.14–3.48)**	**.07**	**−.10 (−1.45–1.26)**	**.88**
Package PEIs * SEIs						
Control = ref						
Low	**1.01 (−1.16–3.18)**	**.33**	**−.08 (−1.59–1.42)**	**.91**	**−.87 (−2.04–.30)**	**.13**
High	**−2.04 (−4.88–.80)**	**.15**	**2.06 (.08–4.04)**	**.04**	**.05 (−1.47–1.57)**	**.95**

Note: Multilevel structure applied in analyses to correct for nested structure of data within schools; estimates of covariates are based on the model with condition; covariates did not change substantially in other models; Bold = p < .05. SB = sedentary behavior; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; C.I. = confidence interval.

weather conditions between the two time points was a significant predictor of change in time spent in SB, LPA or MVPA (Table 3).

3.3. Predicting change in SB, LPA, and MVPA by type of intervention

As regards the number of PEIs, a trend towards a significant positive effect ($p = .08$) on the time spent in LPA, with a medium effect size (ES = 0.34), was found for implementing a large number (≥4) of PEIs. As regards the other two PA classifications, no statistically significant effects of implementing PEIs were found. A small non-significant trend with a medium effect size (ES = 0.34) towards an increase in LPA was found in the group that implemented a large number (≥6) of SEIs. Neither PEIs nor SEIs were found to have effects on MVPA, although estimates showed a slight (non-significant) decrease in MVPA over time. All models yielded outcomes comparable to those in the condition model with regard to covariates that predicted the changes in time spent in SB, LPA, and MVPA (Table 3).

As regards the 'set of interventions' variable (combining PEIs and SEIs), a significant positive effect on LPA, with a medium effect size (ES = 0.41), was found for the high magnitude set of interventions. Children attending these schools spent on average 15.4 min more in LPA during a weekday after 12 months, which reflects a medium effect size (Fig. 1). A non-significant decrease in SB was found, with a medium effect size (ES = 0.33). This is likely the result of a switch from SB to LPA, based on the estimates in the model (Table 3). No significant effects on changes in SB, LPA, or MVPA were found in the low magnitude groups.

4. Discussion

The aim of the current study was to test the effectiveness of the Active Living intervention on children's time spent in SB and PA. Children exposed to Active Living did not differ from those at control schools with regard to PA and SB after 12 months.

In line with results from the SPEEDY study in the UK (Corder et al., 2010), we found a general reduction in PA and increase in SB at follow-up. This reduction could most likely be explained by the increase in age. In addition, female gender predicted a decline in PA and increase in SB. Older children and (especially) girls became less active over time,

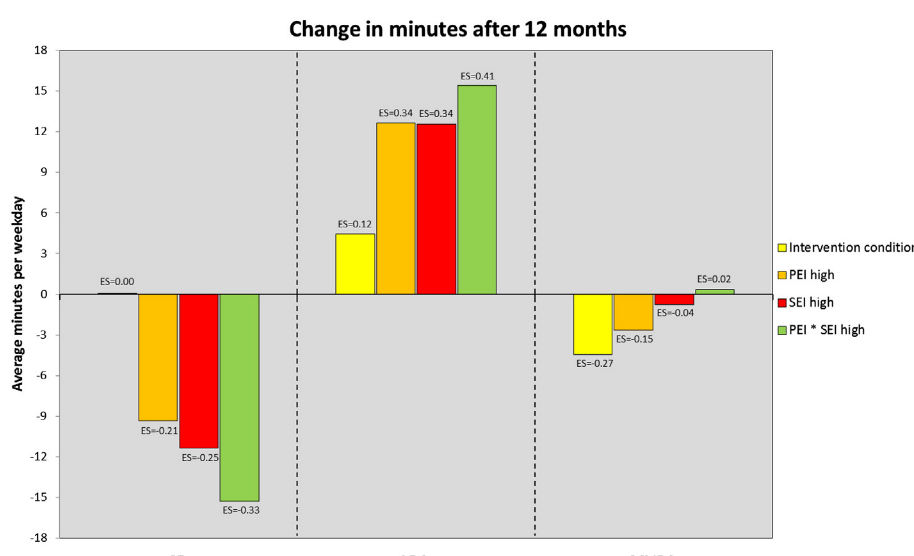

Fig. 1. Intervention effects on SB, LPA, and MVPA expressed in average minutes per weekday and Cohen's *d*.

in line with previous studies, which often found that girls during early adolescence tend to reduce their time spent in PA (Craggs et al., 2011). Exposure to the Active Living project did not prevent this reduction in PA.

A large variation in the number of implemented interventions per school led to different levels of exposure to intervention elements of the children. A more in-depth analysis of the PEIs and SEIs showed that if a substantial number of interventions was implemented, the proportion of time spent in LPA increased non-significantly (Fig. 1), although this increase indicated a trend towards significance ($p < .10$). In line with Gubbels' recommendations (Gubbels et al., 2014), the activating effect of these types of intervention was optimal when a combination of multiple PEIs as well as SEIs were implemented. Children exposed to a substantial number of both types of environmental interventions spent 15 min more time a day in LPA and 15 min less in SB than children in the control condition. Although the reduction in time spent in SB was not significant, the effect size was medium. This finding underlines the importance of implementing a comprehensive package, including multiple types of environmental interventions, rather than 'single shots', to increase PA levels and subsequently reduce overweight (Kriemler et al., 2011; Sobol-Goldberg et al., 2013). The set of interventions, although small in terms of size and budget, resulted in a substantial increase in the level of LPA and a decrease of time spent in SB. Basically, this may be reformulated as 'do it well or don't do it at all'. The recommendation to implement sufficient numbers of both PEIs and SEIs could imply that there might be a certain threshold effect of the number of combined stimuli that should be implemented to activate children in primary school interventions. Further research on this threshold hypothesis is needed.

Irrespective of the level of specification of effect analyses, i.e. taking into account the level of exposure, no effect was found on MVPA. Although this study was initially designed to activate children, the lack of an effect on MVPA contradicts findings of some other (setting-specific) school-based PA interventions (Ridgers et al., 2012; Kriemler et al., 2011). There might be several explanations for the lack of effect on MVPA. Firstly, we studied MVPA on a daily basis and as a proportion of time per day spent in MVPA. Small changes resulting from the interventions within a short period of time, such as an increase in MVPA during recess periods, could be obscured or compensated by activities over the rest of the day, as has been suggested by the 'activitystat' hypothesis (Rowland, 1998). In line with this hypothesis, Metcalf and colleagues (Metcalf et al., 2012) found a limited effect of PA interventions on whole-day MVPA. Combined time-specific and location-specific analyses would potentially be helpful to guide future intervention development and evaluation (Brooke et al., 2014). The limited intensity of the implemented PEIs and SEIs specifically aimed at MVPA (e.g. optimizing PE classes) might be another possible explanation for the lack of effects regarding this outcome. Moreover, the implemented interventions targeted mostly the school setting and hardly (if at all) concerned other MVPA-affecting settings such as the local neighborhood (Klinker et al., 2014; van Sluijs et al., 2011), leading to less exposure to PEIs and SEIs in the leisure time domain. Additionally, the home environment received little attention. The home environment has been reported to be an important setting for health-promotion activities, especially for younger children (van Sluijs et al., 2011). The suboptimal reach of other settings than the school setting might also explain the lack of pooled effectiveness of Active Living. Focusing on the child system as a whole might be more effective in changing health behavior (Thelen and Smith, 2006).

4.1. Strengths and limitations

The quasi-experimental design with matched schools supplemented with an implementation-focused process evaluation is a major strength of this study. We were able to test the effectiveness in terms of children's PA levels of a number of PEIs and SEIs that shared the same scope, but differed in magnitude and design. The objectively assessed PA levels collected in the same season, and the matching of measurements in the same week, were also advantages of this study, as were the number of study sites and children enrolled in the Active Living project.

Using a synergetic physical and social environmental intervention approach was helpful in assessing the magnitude of PA interventions that showed the potential to enhance PA and reduce SB, but simultaneously limited the opportunities to provide concrete suggestions on the effectiveness of specific interventions. In addition, this approach refers only to the number of intervention elements regardless of the quality of their implementation. Furthermore, our study results related to effects of PA and SB during weekdays. It is unclear whether these results are sustained during weekends and in the longer term. According to our protocol, children wore accelerometers for at least 5 consecutive days, including a weekend. Fidelity to the wear protocol during weekends was, however, low. On the other hand, most intervention activities were implemented in the immediate school environment, suggesting that change is more likely to occur during weekdays compared to weekends.

5. Conclusion

Physical and social environmental PA interventions at or around schools hold the potential to activate children on a daily basis. However, the present study showed that multiple physical and social environmental PA stimuli are needed to change the time spent in LPA. The results indicate the need to intensively address multiple types of environmental factors rather than focus on a few specific elements of the children's environment.

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Conflict of interest statement

The authors declare that there are no conflicts of interest.

Authors' contributions

DVK designed the current study, conducted statistical analyses and drafted the manuscript. SK helped interpret the data. MJ initiated the Active Living project. SK, MJ, SdV, and NdV advised on the study protocol and revised the drafted manuscript. All authors critically reviewed and revised the final version of the manuscript. All authors read and approved the final manuscript.

Abbreviations

PA	physical activity
SB	sedentary behavior
LPA	light physical activity
MVPA	moderate-to-vigorous physical activity
PEI	physical environmental intervention
SEI	social environmental intervention
ES	effect size

Transparency document

The Transparency document associated with this article can be found, in online version.

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