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ORIGINAL RESEARCH

A Multicomponent Schoolyard Intervention Targeting Children's Recess Physical Activity and Sedentary Behavior: Effects After 1 Year

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Background: The aim of the study was to test the 12-month effects of a multicomponent physical activity (PA) intervention at schoolyards on morning recess PA levels of sixth- and seventh-grade children in primary schools, using accelerometry and additional global positioning system data. **Methods:** A quasi-experimental study design was used with 20 paired intervention and control schools. Global positioning system confirmatory analyses were applied to validate attendance at schoolyards during recess. Accelerometer data from 376 children from 7 pairs of schools were included in the final analyses. Pooled intervention effectiveness was tested by multilevel linear regression analyses, whereas effectiveness of intervention components was tested by multivariate linear regression analyses. **Results:** Children exposed to the multicomponent intervention increased their time spent in light PA (+5.9%) during recess. No pooled effects on moderate to vigorous PA were found. In-depth analyses of intervention components showed that physical schoolyard interventions particularly predicted a decrease in time spent in sedentary behavior during recess at follow-up. Intervention intensity and the school's commitment to the project strengthened this effect. **Conclusions:** The multicomponent schoolyard PA intervention was effective in making children spend a larger proportion of recess time in light PA, which was most likely the result of a shift from sedentary behavior to light PA.

Keywords: accelerometry, GPS, youth, moderation, built environment

Physical activity (PA) is positively associated with a range of health, psychosocial, and academic outcomes in youth.[1–5] Hence, the current decreasing PA levels and increasing levels of sedentary behavior (SB) in children are worrying, especially since activity patterns and sedentary patterns in childhood seem to track into adulthood.[6] Intervening at an early age might therefore be essential and has great potential in terms of beneficial outcomes at population level in later life. The sustained effect of current PA interventions on children's daily PA levels, however, is small,[7,8] which emphasizes the need to better understand how PA interventions should be developed in order to become more effective.

Schools are suitable environments to reach children and create substantial impact with interventions.[9] Schoolyards can influence children's PA and SB, especially during recess periods. In recent years, several reviews have been published about the association between physical and/or social attributes of the schoolyard environment on PA and the effect of physical schoolyard interventions (PSIs) and social schoolyard interventions (SSIs) on PA.[10–14] These reviews provide useful indications as to what attributes potentially contribute to more PA and less SB at schoolyards. Although often studied in cross-sectional research designs or short-term effect studies, the availability of fixed and portable equipment has most consistently and positively been associated with higher PA levels.[15–17] Studies regarding long-term effects (ie, ≥12 mo) of schoolyard interventions on children's PA levels using controlled study designs are scarce.[18] Moreover, studies that implemented schoolyard interventions as a long-term process rather than a "(time)-framed" intervention were not found in the literature. This continuous process of sustainable improvements of the schoolyard environment reflects a real-life situation better than "traditional" interventions conducted in a specific period of time.

Most schoolyard interventions at primary schools were found to be delivered as multicomponent interventions rather than as isolated attributes.[12,14] An example of such a multicomponent intervention is the PLAYgrounds program in which, for instance, playground markings were combined with "activity coaches."[19] These ecological system approaches seem to have greater impact than isolated physical or social environment interventions.[18–22] A core feature of ecological systems theory is the interaction of elements of the environment in shaping human behavior,[23,24] and testing moderators of environmental influences is the most commonly mentioned suggestion for future research.[25]

Although SB and PA have been identified as distinct constructs and independent risk factors for several health risks in children,[26,27] environmental interventions at schoolyards aimed at reducing SB have been scarce.[28,29] Only one experimental schoolyard study has been designed to reduce sedentary time. This study

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showed that increasing the number of square meters of schoolyard per child (by reducing the number of children present at the schoolyard at once) contributed to less SB.[29] Ongoing schoolyard intervention studies,[30] however, tend to focus more on limiting SB in addition to encouraging PA.

The use of global positioning system (GPS) data in addition to accelerometer data has been advocated in health behavior studies in order to enrich data with location-specific information,[31] allowing researchers to more accurately specify the use of physical environments in relation to PA and SB. The combination of GPS data and accelerometry at schoolyards has been used in only a few studies,[32–34] all having a cross-sectional study design.

The primary goal of the project under study was to determine sustained changes in children's PA levels due to environmental changes. The focus of the environmental changes was on enhancing sustainable PA changes in primary school children after 1 year of implementation, rather than on immediate intervention effects on children's PA. Therefore, the aim of the current study was to examine the 12-month effect of multicomponent schoolyard interventions on 8- to 11-year-old primary school children's PA levels during recess, in terms of SB, light PA (LPA), and moderate to vigorous PA (MVPA), using accelerometry and additional GPS data. Moreover, we tested the moderating effect of the intensity of the schoolyard intervention and the commitment of schools to the intervention on the relationship between PSIs and SSIs and children's PA levels to better understand contextual factors that might influence the long-term effect of schoolyard interventions on PA levels.

Methods

Recruitment of Schools and Participants

Data used in this study were derived from the Active Living project (ZonMw, project number: 200130003).[35] The Active Living project started in 2012 and is a 3-year project focusing on increasing PA among children by means of adjustments to the physical and social environment of primary schools situated in deprived areas. The Active Living project used a quasi-experimental study design in which 10 schools served as intervention schools and 10 schools as controls. Control schools were matched to intervention schools on geographical characteristics, including level of neighborhood deprivation and urbanization. In addition, control schools were not located within an 800-m radius of an intervention school. All schools were situated in deprived neighborhoods in the southern Limburg area in The Netherlands. Moreover, included schools executed a "regular" Dutch school system; that is, no schools for children with special needs were included. Children in grades 6 and 7 (between 8- and 11-y old at baseline) were invited to participate in this project. This age range was selected because children at this age become able to travel and move around independently.[36,37] Baseline data for the current study were gathered between April and June 2013, prior to any interventions being conducted at schools. The follow-up measurement took place after physical and social interventions in the schoolyard environment had been implemented between April and June 2014. As part of the Active Living project, children were asked to fill out a questionnaire (N = 1340 at baseline; N = 1322 at follow-up), including demographic information. In addition, they were asked to wear an accelerometer, the ActiGraph GT3X+ (ActiGraph, Pensacola, FL; N = 791, 59% at baseline; N = 740, 56% at follow-up), and a random selection of them (due to limited availability of devices) were asked to wear a GPS device, the QStarz BT1000-XT (QStarz, Taipei, Taiwan). Before they started wearing the device (or both devices), written consent was obtained from their parents and oral consent from the children. Neither the children nor their parents received an incentive for participation in the study. This study was given ethical approval by the ethics committee of the Maastricht University Medical Centre (reference number: METC 12-4-077).

Interventions. Recess periods form an opportunity to support PA and reduce SB in schools.[38] As in many countries, recess periods are recommended in schools in The Netherlands, though not mandated. During morning recess (approximately 15 min), children stay at school, whereas during lunch, schools apply a variety of policies ranging from 30-minute recess at school up to 75-minute recess either in school or at home. Schools were supported in implementing PSIs and SSIs to stimulate children's PA by, for example, providing new fixed equipment (PSI) and/or teachers introducing schoolyard games (SSI). The implementation of the number and content of PSIs (eg, soccer goals, table tennis courts) and SSIs (eg, sports clinics by local sports organizations) differed across schools. Schools took part in working groups, chaired by a municipal health service employee, to identify the schools' needs for environmental changes. Interventions were tailored to the schools' needs, resulting in a variety of implemented interventions. Each school received a small working budget (2000 euros per school) to initiate interventions. If the planned interventions exceeded the budget, this had to be covered by sponsoring or external investment. Nondrastic schoolyard interventions with a limited magnitude and interventions not exceeding the budget were considered to be of low intensity (eg, a playground marking), whereas drastic schoolyard interventions with a large magnitude and interventions substantially exceeding the budget were categorized as interventions of high intensity (eg, providing a large soccer court with a renewed surface). The number of different types of PSIs and SSIs—that is, different environmental stimuli—and the intensity of PSIs were monitored by the municipal health service employees, who kept diaries of activities performed. The municipal health service employees also kept a diary on the schools' project commitment by scoring the level of attention given to the project in a school and external manifestations of the project, such as communications in parent newsletters and the presence of posters in school, on a 4-point scale (1 = low to 4 = high; Table 1).

Measures

Activity Measures. Children were asked to wear an accelerometer (ActiGraph GT3X+; 30 Hz, 10-s epoch) during waking hours for at least 5 consecutive days, including a weekend (ie, 3 weekdays and 2 weekend days). Children's PA data were analyzed using ActiLife version 6.10.4 (ActiGraph), while Evenson et al's cutoff values[39] were used to classify SB, LPA, and MVPA. We used a 480-minute (8-h) daily wear time as a validation check for inclusion in the analyses[40] to prevent the inclusion of children who wore their devices only while in recess, which was considered a proxy for a measurement effect. In other words, children wearing the device only during recess were assumed to be very aware of wearing the device, which probably increased the risk of overestimating PA during recess. Morning recess data were extracted from class timetables for each child. Weekend days were excluded, as was the first day of wearing the devices, because of potential reactivity to the measuring equipment,[41] while the remaining wearing days were checked for validity. Children spending over 90% of the recess epochs in SB were excluded, since it was considered

Table 1 Overview of PSIs and SSIs at Each School, the Intensity of PSIs, and the Schools' Level of Commitment to the Project

	I_1	I_2	I_3	I_4	I_5	I_6	I_7
PSI							
New fixed equipment in schoolyard (eg, soccer goals, table tennis courts)	+	+	+	+	–	+	+
New loose equipment in schoolyard (eg, balls, jumping ropes)	+	–	+	+	+	–	+
Playground markings	+	–	–	+	+	–	–
Dedicated ball games area	+	–	+	+	–	+	–
Sound equipment in schoolyard environment	+	–	–	–	–	–	–
Number of PSIs	5	1	3	4	2	2	2
Intensity (1 = low; 2 = high)	1	1	2	1	1	2	1
SSI							
Additional sports day in schoolyard	+	+	–	+	+	+	–
Sports clinics during recess (clinics by PE teachers; clinics by sports organizations)	+	+	+	+	+	–	+
Use of schoolyard games (teacher instruction cards)	+	–	–	–	+	+	–
Number of SSIs	3	2	1	2	3	2	1
Project commitment (1 = low to 4 = high)	4	3	3	2	2	2	3

Abbreviations: +, implemented; –, not implemented; I, intervention school; PE, physical education; PSI, physical schoolyard intervention; SSI, social schoolyard intervention.

unlikely that these children wore their device appropriately while in recess based on a feasibility check on walking time between the classroom and the schoolyard. Valid recess data (with a minimum of 1 school day) were aggregated per child for the morning recess period. We included only the morning recess period because this was the only recess period in which all children stayed at school (ie, lunch breaks at school were not mandatory at all participating schools). To correct for different recess durations across schools, the proportion of time spent in SB, LPA, and MVPA was the main outcome measure. Change scores between baseline and follow-up were calculated by subtracting the percentage of time spent at a particular activity level at baseline from the percentage of time spent at that activity level at follow-up.

Confirmatory Analyses Based on GPS Data. To examine whether children were actually present at schoolyards during recess, we compared GPS data on schoolyard presence with class timetables. In total, 120 children wore a GPS device at baseline and 537 at follow-up. The Personal Activity and Location Measurement System (PALMS; University of California, San Diego) was used to merge accelerometer and GPS data. A purpose-built PostgreSQL database was used to combine the location-activity matched data with class timetables and GIS data on schoolyards (an example is shown in Figure 1). Schools operated according to an all-indoors or all-outdoors policy during recess. If at least some of the children who wore a GPS were present at the schoolyard during recess, we assumed that all children in that class had the opportunity to use the schoolyard during the recess time listed in the class timetable. Consequently, the criterion of 90% of epochs spent in SB criteria was applied to further increase actual exposure to intervention(s). A flowchart including inclusion and exclusion criteria is presented in Figure 2.

Weather Conditions and Demographics. Weather conditions (temperature, sun exposure, and precipitation) for every hour of a measurement day were obtained from the Royal Netherlands Meteorological Institute. A change score was calculated for temperature, sun exposure, and precipitation between follow-up and baseline for each day of measurement. Weather data were aggregated in line with the aggregation of valid recess PA data. Demographics, such as gender, age, and ethnicity, were collected by a questionnaire that children filled in as part of the Active Living project.

Data Analysis

Data analyses were conducted using SPSS 20.0 (IBM Corp, Armonk, NY), and a *P*-value of .05 was used as the significance level for both main effects and interaction effects.[42] First, we studied the pooled intervention effects of multicomponent interventions by means of multilevel regression analyses, using change scores of PA levels as the dependent variable. Gender, grade, ethnicity of the child, change in temperature, change in precipitation, change in hours of sunshine, intervention (experimental/control condition), and baseline PA levels (SB, LPA, and MVPA, respectively) were entered as independent variables at level 1, whereas school was entered as an independent variable at level 2. Other confounding factors, such as available square meters at the schoolyard and teacher supervision,[14] were not controlled for because they stayed the same over time.

After defining the pooled effectiveness of the multicomponent schoolyard intervention, the effectiveness of the number of PSIs and SSIs, intervention intensity, and school's commitment to the Active Living project on PA change scores in the intervention schools were tested. Within the subsample of intervention schools, 3 multivariate linear regression analyses were performed, with the change in time spent in SB, LPA, and MVPA as the dependent variable and gender, grade, ethnicity of the child, change in weather conditions, number of PSIs, number of SSIs, level of commitment to the project, intervention intensity, and baseline PA levels as the independent variables. Mean PA changes after 12 months in the paired control school were subtracted from individuals' PA

Figure 1 — Example of defining physical activity levels in a schoolyard combining global positioning system and accelerometry [left panel: moderate to vigorous physical activity (MVPA); right panel: sedentary behavior (SB); green area: schoolyard].

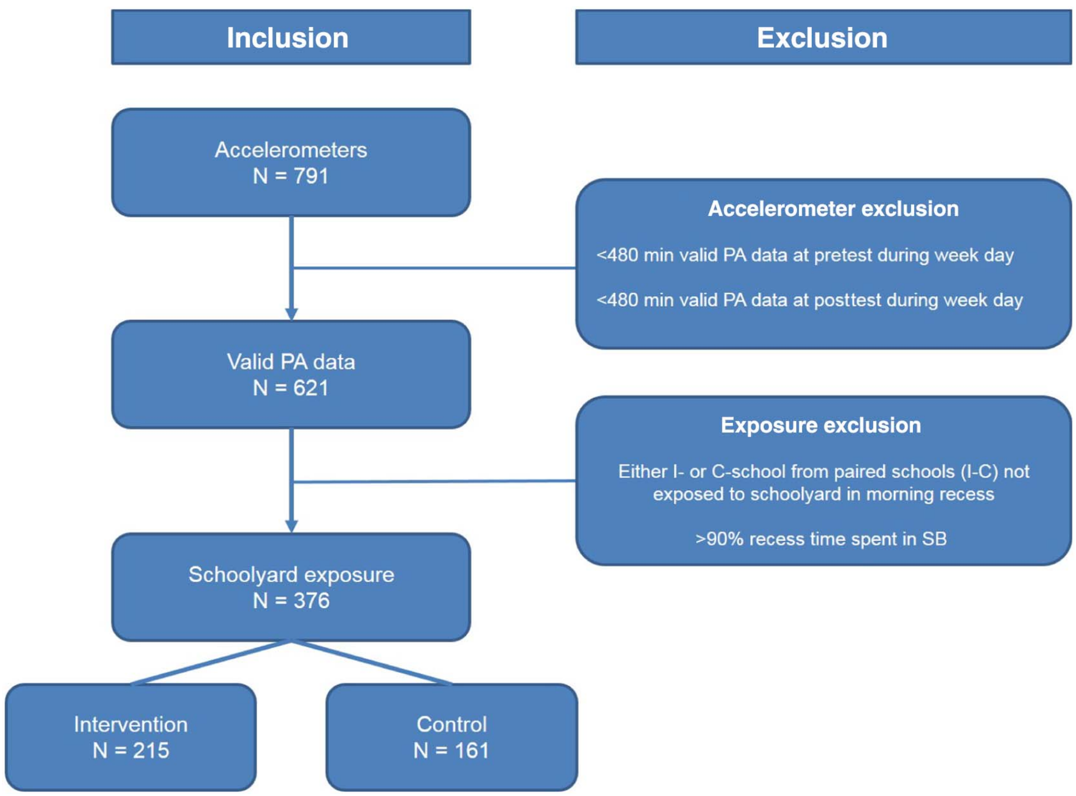

Figure 2 — Flowchart of data reduction in study. PA indicates physical activity; SB, sedentary behavior.

changes in intervention schools. To correct for seasonal effects and varying number of children in intervention and control schools, mean PA change scores for the matched control school were subtracted from individual PA change scores for the intervention school. Potential contextual factors affecting the influence of physical environmental interventions were tested by including interaction terms of the number of PSIs and the intensity and number of PSIs and project commitment in the analyses. In case of significant interaction, stratified analyses were performed.

Results

Description of Population and Time Spent in PA and SB at Baseline and Follow-Up

In total, 740 children were asked to wear an accelerometer at follow-up, of which 621 (84%) provided valid PA data. These 621 children were checked for a valid PA measurement at baseline. Moreover, the confirmatory GPS analyses showed that data from

3 out of 10 pairs of schools (intervention–control) were invalid for the purpose of the current study, as no children used the schoolyard during recess at baseline and/or follow-up. These pairs of schools were removed from the study sample, resulting in the inclusion of 376 children from 7 pairs of schools (mean N per school = 27), providing valid accelerometer data at both baseline and follow-up. Both at baseline and follow-up, the number of children providing 1 valid day of PA data was 125 (33%). The number of children enrolled in the intervention schools (7 schools; 215 children) was slightly higher than that in the control schools (7 schools; 161 children; Figure 2). There was a slight overrepresentation of children in grade 6 (55%) compared with children in grade 7 (45%). A total of 200 girls (53%) and 176 boys (47%) were included. The average size of the included schoolyards was 1984 m^2 (approximately 15 m^2 per child), and all schools provided fixed and loose equipment to their children at baseline.

On average, schools implemented 2.7 PSIs, whereas 2.0 SSIs per school were implemented. Two schools implemented high-intensity PSIs, and 4 out of 7 schools scored (very) high on project commitment (Table 1). Recess time lasted on average 15.3 minutes (SD ± 1.4) and did not significantly change over time. At baseline, children spent an average of 43% (SD ± 20) of recess time in SB, 42% (SD ± 12) in LPA, and 15% (SD ± 11) in MVPA. At follow-up, the average time spent in SB and LPA was 42% (SD ± 21 and SD ± 13, respectively) and time spent in MVPA was 16% (SD ± 15). Children in the intervention condition spent slightly less time in SB at baseline ($P = .06$; $t = 1.88$) and spent more time in MVPA at baseline than children in the control condition ($P < .01$; $t = -3.74$; 45 s; 5%).

Pooled Intervention Effect on Change in SB, LPA, and MVPA After 12 Months

In the intervention schools, a 5.9% decrease in SB and a 5.4% increase in LPA were found after correcting for effects in the matched control schools (Figure 3). The decrease in the time spent in SB was not significant, but the increase in the time spent in LPA was significant. No difference was found between control and intervention schools regarding change in MVPA (Table 2). Female gender was a significant predictor of more SB during the follow-up measurement, as well as a significant predictor of decreased proportion of time spent in LPA and MVPA after 12 months. Children attending grade 7 at baseline spent more time in SB at follow-up. Furthermore, decreased time spent in SB after 12 months was predicted by more sun exposure during the follow-up measurement. Additionally, more sun exposure during the follow-up measurement predicted an increase in LPA after 12 months. Regarding MVPA, children attending grade 7 at baseline were less likely to show increased time spent in MVPA at follow-up.

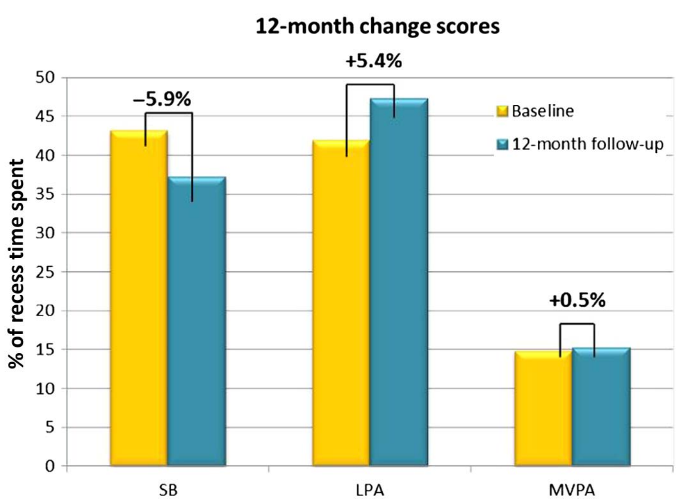

Figure 3 — Twelve-month follow-up change scores for SB, LPA, and MVPA in which the effect in intervention schools is adjusted for that in control schools. SB indicates sedentary behavior; LPA, light physical activity; MVPA, moderate to vigorous physical activity.

What Intervention Components Predict Change in SB, LPA, and MVPA Over Time?

To study the effectiveness of implemented intervention components, additional in-depth linear regression analyses were conducted among intervention schools only. Change in the time spent in SB was affected by the number of PSIs implemented at schoolyards. More PSIs resulted in less SB at schoolyards after 12 months. The number of PSIs also showed a trend toward predicting a higher proportion of recess time spent in LPA and MVPA ($P < .10$). In addition, implementation of interventions with a high intensity led to a larger decrease in the time spent in SB and a larger proportion of time spent in LPA and MVPA at 12-month follow-up. Neither the number of SSIs nor the level of project commitment had a main effect on the changes in SB, LPA, and MVPA (Table 3). We found a significant interaction effect between the number and intensity of PSIs (SB: $P < .01$; LPA: $P = .03$; MVPA: $P < .01$). Stratified analyses showed that the decrease in SB and the increases in LPA and MVPA were largest for children attending schools that implemented more and higher intensity PSIs [eg, facilitating a panna court with corresponding safety tiles (high) vs facilitating simple line markings (low)]. Regarding change in the time spent in LPA and MVPA, an interaction effect was found for PSIs and project commitment (LPA: $P = .03$; MVPA: $P = .05$). PSIs implemented in highly committed schools showed better results. As regards MVPA, stratified analyses [low (≤ 2) vs high (≥ 3) commitment] showed a positive though nonsignificant effect of the number of PSIs and high project commitment on MVPA at follow-up (std. $\beta = 0.241$; $P = .16$), but an increased number of PSIs and low project commitment showed a negative trend in terms of MVPA at follow-up (std. $\beta = -0.250$; $P = .08$).

Discussion

The aim of the current study was to test the 12-month effects of a multicomponent PA intervention at schoolyards on morning recess PA levels of sixth- and seventh-grade children in primary schools, using accelerometry data and additional confirmatory analyses using GPS data. During morning recess, children spent approximately 16% of the time in MVPA, which is lower than that found in other studies that focused on objectively assessed recess MVPA.[28,32,43] Perhaps, this is attributable to the limited focus on a 15-minute morning recess period only rather than on a long-lasting afternoon recess (lunch break) period.[32,43]

The multicomponent schoolyard intervention resulted in an increase in the time spent in LPA over time but not in MVPA. An increase in LPA and the absence of an effect of the schoolyard intervention on MVPA are in contrast to various (multicomponent) schoolyard intervention studies that showed positive (MV)PA

Table 2 Predictors of Change Scores in Percentage of Recess Time Spent in SB, LPA, and MVPA

	SB		LPA		MVPA	
N = 376	β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
Baseline % in PA level	−0.88 (−0.99 to −0.77)	<.01	−0.88 (−0.98 to −0.79)	<.01	−0.76 (−0.87 to −0.65)	<.01
Grade (6)	−3.96 (−7.52 to −0.39)	.03	0.11 (−2.23 to 2.45)	.93	3.20 (0.49 to 5.90)	.02
Gender (male)	−13.17 (−16.72 to −9.61)	<.01	5.02 (2.73 to 7.30)	<.01	6.46 (3.70 to 9.23)	<.01
Ethnicity (Dutch)	1.69 (−7.58 to 10.96)	.72	−3.03 (−9.11 to 3.03)	.33	1.40 (−5.61 to 8.42)	.69
Δ in temperature (°C)	0.21 (0.14 to 0.27)	<.01	−0.12 (−0.15 to −0.09)	<.01	−0.11 (−0.16 to −0.07)	<.01
Δ in sun exposure	−1.35 (−2.11 to −0.59)	<.01	1.10 (0.78 to 1.42)	<.01	0.18 (−0.38 to 0.74)	.53
Δ in precipitation	1.40 (−1.26 to 4.05)	.30	−0.02 (−1.22 to 1.17)	.97	−0.59 (−2.54 to 1.36)	.55
Intervention (exposed)	−2.30 (−10.48 to 5.88)	.54	2.40 (0.09 to 4.71)	.04	0.30 (−5.38 to 5.98)	.91

Note. Multilevel structure applied in analyses to correct for nested structure of data within schools.
Abbreviations: CI, confidence interval; LPA, light physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; SB, sedentary behavior.

Table 3 Intervention Components Predicting Change in Percentage of Recess Time Spent in SB, LPA, and MVPA After 12 Months

	SB		LPA		MVPA	
N = 215	Std. β	P	Std. β	P	Std. β	P
Baseline % in PA level	−0.606	<.01	−0.712	<.01	−0.646	<.01
Grade (6)	0.145	.01	−0.058	.30	−0.142	.02
Gender (male)	0.217	<.01	−0.116	.03	−0.147	.01
Ethnicity (Dutch)	−0.055	.31	−0.075	.15	−0.010	.86
Δ in temperature (°C)	0.256	.01	−0.178	.05	−0.182	.06
Δ in sun exposure	−0.162	.17	0.221	.06	−0.025	.84
Δ in precipitation	0.069	.44	0.019	.82	−0.036	.69
Number of PSIs	**−0.176**	**.01**	0.111	.09	0.135	.06
Number of SSIs	−0.049	.56	0.017	.84	−0.021	.81
Intensity of PSIs	**−0.564**	**<.01**	**0.283**	**<.01**	**0.477**	**<.01**
Project commitment	−0.081	.40	−0.014	.88	0.047	.62
R^2	47.0%		50.1%		42.1%	

Note. Bold values indicate the significant predictor of change caused by intervention component.
Abbreviations: LPA, light physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; PSI, physical schoolyard intervention; SB, sedentary behavior; SSI, social schoolyard intervention.

outcomes.[15,22,28,44] A possible explanation for our null effect on MVPA could be found in the study duration. Most schoolyard intervention studies reported on short-term effectiveness of interventions,[45,46] while we, in line with our study purpose, studied only sustained effects (ie, 12-mo effects). A study by Ridgers et al[18] showed a pattern that effectiveness after 6 months attenuated after 12 months. It might therefore be possible that we missed short-term effects of the current study. Results on short-term outcomes, however, could be attributable to a "novelty effect,"[47] while long-term effects are more likely to indicate sustained behavioral effects of interventions. The study design could also partially explain the lack of effect on MVPA. This study implemented a variety of schoolyard PA interventions of different types and intensities in different contexts. The fragmented, although consecutive process of introducing small changes at schoolyards might explain the increase in LPA; that is, children received stimuli that trigger activity, although (too) little comprehensive or with insufficient magnitude to enhance MVPA. The comprehensiveness of interventions addressing multiple environmental types might be an important element in achieving effective change in MVPA.[19,28,46] For example, providing new loose play equipment in the schoolyard could contribute more to MVPA when accompanied by social environmental interventions, such as activity coaches. By providing the intervention activities in a consecutive order rather than simultaneously, the optimum to reach effectiveness in MVPA might be missed. Further, additional sensitivity analyses were conducted in which MVPA was split into MPA and VPA to test whether using MVPA as an outcome attenuated a potential effect of interventions on higher intensity PA (data not shown). Neither MPA nor VPA was significantly influenced by the schoolyard interventions; however, the influence of interventions was (slightly) positive on MPA and (slightly) negative on VPA (both nonsignificant). For future studies, it might be recommended that the focus be on MPA and VPA separately rather than solely on MVPA.

The analytic approach testing the pooled effect of this multicomponent approach could have suppressed the effects of specific intervention components on MVPA. Therefore, we also introduced in-depth analyses of intervention schools to identify what type of intervention component (PSI vs SSI) most affected the changes in recess SB and PA over time. The main goal of the study was predicting sustainable change in children's PA levels during morning recess while environmental contexts in which intervention were implemented differed. This approach led to studying the effectiveness of the number of implemented stimuli per type of environment rather than evaluating specific intervention elements. PSIs predicted a decreased time spent sedentary and an increased, although nonsignificant ($P = .09$ and $P = .06$, respectively), proportion of time spent in LPA and MVPA at schoolyards at follow-up in these intervention schools. Next, we calculated the number of PSIs and assessed their effect. This approach showed that the more physical environmental stimuli implemented, the larger the change in SB. The current project was originally designed to provide low-budget multicomponent PA schoolyard interventions, yet 2 schools succeeded in either raising more funds to increase investment in the PSIs substantially (up to 70,000 euros) or implementing drastic changes at the schoolyard. These high-intensity PSIs resulted in significantly larger increases in the time spent in LPA and MVPA than PSIs of low intensity. SB decreased more over time after the implementation of high-intensity PSIs. Although PSIs of higher intensity would be beneficial, the positive results for PSIs of low intensity are also promising in terms of cost-effectiveness. It seems possible to successfully intervene on schoolyard SB with limited financial resources and nondrastic environmental adaptations. Because we noticed the use of smartphones at schoolyards during recess in elementary schools, the focus on reducing SB might become even more important in the future.

No main effects were found for SSIs, likely because of what was considered an SSI in this study. PA involvement and support by teachers (eg, teachers playing together with children in recess) were previously shown to have positive associations with children's PA levels, especially among younger children,[22,48,49] but these types of interventions were not included in the current project. The lack of inclusion of these types of interventions was probably caused by the design of the project, in which a substantial amount of autonomy was granted to the schools to implement interventions, which was hypothesized to enhance local support. Teachers showed less enthusiasm for interventions they were actively involved in themselves.

In this study, a prospective effect of the social environment was found in the moderating effect of a school's commitment on the relationship between PSIs and LPA and MVPA change over time. PSIs in highly committed schools showed better results in terms of LPA and MVPA. In contrast, PSIs in less committed schools seemed to have a negative effect on change in MVPA over time. A supportive school PA climate might therefore be essential for effective PSIs.

This was the first study to test the moderating effect of a school's commitment on the effect of schoolyard interventions on SB and PA. Embedding physical interventions in a supportive PA school climate is in line with the concept of ecological models,[23,24] which supports the moderating effect found in this study. Although not directly comparable, the moderating effect of a supportive social environment has also been found in studies focusing on active school transport,[50,51] and a supportive climate has also been reported to be beneficial in family-based childhood PA interventions[52,53] as well as school-based obesity prevention programs[54] and childcare.[55] In addition, recent reviews showed better results for interventions implemented in multiple settings (eg, school and home) and for a focus on multiple components (eg, fixed equipment and green space) and multiple environmental domains (eg, physical environment and policy environment).[14,56,57]

Strengths and Limitations of the Current Study and Recommendations for Future Research

A major strength of the current study is the use of GPS and accelerometry. Without the combination of GPS and accelerometer data, we would have included all 10 pairs of intervention and control schools in the effect analyses, while in reality only 7 pairs were comparable in terms of exposure to the schoolyard during recess. Although we were able to adjust for this, it was striking that so many schools reported using the schoolyard during recess without actually doing so, especially since all schools reported a policy of children going outdoors during recess irrespective of weather conditions. Apart from data acquisition and processing techniques, the longitudinal quasi-experimental design of the study was also an advantage, as it enabled us to detect relationships between the environment (schoolyard) and children's behavior (PA). We also corrected for weather change scores between baseline and follow-up, correcting for potentially strong confounding variables, such as temperature and precipitation.

This study was also subject to some limitations. First, too few children wore a GPS device at baseline to make use of all the benefits of the combined GPS–accelerometry methodology; instead, we used the GPS data to confirm if the schoolyard was used at all during recess. Particularly in longitudinal studies, a well-considered power calculation for both premeasurement and post-measurement would be helpful to enable use of the full opportunities provided by combined accelerometry and GPS data. Although the combined GPS–accelerometry methodology[31] was not applied in this study, the use of GPS enhanced reliability of the results by testing whether or not children were exposed to environmental stimuli at schoolyards. The data included in the final analyses consisted of accelerometer data for the full period of scheduled recess time rather than for time spent at schoolyards only. Because of the lack of GPS data for a substantial part of our sample at baseline, we were unable to check whether children accessed the schoolyard during afternoon/lunch recess (nonobligatory)—that is, whether they were exposed to the intervention areas at both time points. Therefore, the focus of the current study was solely on morning recess, which reflects one of 2 major opportunities for PA at a school day: morning and afternoon/lunch recess. In addition, with respect to the implemented PA schoolyard interventions, it should be addressed that in the primary schools' surroundings, additional PA-stimulating activities were undertaken to support active school transportation and PA during leisure time.[35,58] Although such activities are unlikely to directly influence the relationship between PA schoolyard interventions and children's PA and SB during morning recess at schoolyards, a potential spillover effect of these activities cannot be ruled out completely. Schools' commitment to the project might be considered as a proxy for these additional activities and was corrected for in the analyses. Moreover, the number of included days of valid PA data was limited. Children providing at least 1 valid day of data were included, which lowers the validity of the data. To account for this limitation of the study design, additional inclusion criteria were formulated to enhance validity, such as providing valid daily PA data, defined as 480 minutes per day, instead of checking for valid recess PA data only. Besides, the thresholds for SB, LPA, and MVPA remain arbitrary and could have considerably influenced our findings regarding the proportion of time spent at the various PA levels[59]; hence, they were kept the same during baseline and follow-up, which allowed us to study change in PA levels. Furthermore, we lost some children at follow-up (N = 53; 6.7%) due to illness, moving to another school, or refusal to continue participation. Over time, the number of children providing valid accelerometer data during recess decreased; that is, compliance was highest during the first days of the data collection period at each school. Therefore, when planning future longitudinal studies among children using measuring equipment, especially studies combining accelerometers and GPS devices, it would be best to oversample at baseline. Finally, children in the intervention and control schools differed at baseline in the time spent in SB (significant trend) and MVPA. Since children in the intervention schools were both less sedentary and more moderately to vigorously physically active during recess at baseline, the effect of the interventions may have been underestimated. We tried to limit this confounding effect by correcting for the baseline proportion of time spent at different PA levels in the analyses.

Conclusion

The multicomponent schoolyard PA intervention was effective in making children spend a larger proportion of recess time in LPA, which was most likely the result of a shift from SB to LPA. Implementation of the intervention did not result in 12-month changes in MVPA. With regard to intervention components, implementing more PSIs contributed to less time spent in SB in primary school children during recess. This effect was further enhanced by the intensity of PSIs and by implementation in a PA-supportive school environment.

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