Changing the School Environment to Increase Physical Activity in Children

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We examined the hypothesis that elementary school–age children will be more physically active while attending school in a novel, activity-permissive school environment compared to their traditional school environment. Twenty-four children were monitored with a single-triaxial accelerometer worn on the thigh. The students attended school in three different environments: traditional school with chairs and desks, an activity-permissive environment, and finally their traditional school with desks which encouraged standing. Data from the school children were compared with another group of age-matched children (n = 16) whose physical activity was monitored during summer vacation. When children attended school in their traditional environment, they moved an average (mean ± s.d.) of 71 ± 0.4 m/s^2. When the children attended school in the activity-permissive environment, they moved an average of 115 ± 3 m/s^2. The children moved 71 ± 0.7 m/s^2 while attending the traditional school with standing desks. Children moved significantly more while attending school in the activity-permissive environment compared to the amount that they moved in either of the traditional school environments (P < 0.0001 for both). Comparing children's activity while they were on summer vacation (113 ± 8 m/s^2) to school-bound children in their traditional environment showed significantly more activity for the children on summer vacation (P < 0.0001). The school children in the activity-permissive environment were as active as children on summer vacation. Children will move more in an activity-permissive environment. Strategies to increase the activity of school children may involve re-designing the school itself.

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INTRODUCTION

Poor diet and physical inactivity are associated with 400,000 deaths per year (1). The situation is projected to get far worse because now there are three times more obese children than there were two decades ago (2,3). It is imperative for both health (4,5) and fiscal (6,7) reasons that effective childhood obesity prevention and intervention programs be developed immediately. Previous approaches to reverse low levels of physical activity in children have generally focused on affecting the behaviors that children and their parents engage in at school and/or at home (8,9). However, these approaches, in general, vary in success. Rather than trying to have an effect on behavior, one wonders whether a redesigned physical infrastructure could affect how children behave.

Collaborators from the local school board, private developers, a large computer company, and ourselves built a new type of school environment we called "The Neighborhood". The Neighborhood was designed specifically to encourage an active learning environment. While children were learning everything that they would in a traditional classroom, they were moving about in a dynamic, fun space that promoted physical activity. One aspect of the redesigned physical infrastructure was to provide the children with more opportunities for standing during the school day. We have previously shown in adults that obese adults stand for significantly fewer minutes per day compared to lean adults (10). In this study we examined the hypothesis that elementary school–age children will be more physically active while attending school in a novel, activity-permissive school environment compared to their traditional school environment. We also examined a more practical approach that could be easily adopted in schools across the country: replacing traditional classroom tables and chairs with vertical work stations. Finally, we compared the level of physical activity of children in the three school environments to the level of physical activity of children who were on summer vacation.

METHODS

Participants

One classroom of grade 4/5 students (14 girls, 10 boys) and their teacher were selected from the Rochester Public School district to participate in the study. Another group of similarly aged children (6 girls, 10 boys) underwent physical activity monitoring during the summer months when school was not in session. Each child's weight and height were measured using a calibrated digital scale (Scale-Tronix 5005 Stand-On

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Scale; White Plains, NY) and attached stadiometer. BMI percentile was determined using Centers for Disease Control growth charts. Using these growth charts, it was found that two children were underweight, 7 children were at risk for overweight, 7 children were overweight, and 24 children were normal weight (**Table 1**). The study was approved by the Mayo Clinic's Pediatric and Adolescent Medicine Research Committee and the Institutional Review Board. Informed written assent was obtained from the child and informed written consent was obtained from the parent(s).

School environments

The focus of the project was to evaluate the effect of novel school environments on physical activity in elementary-school children. The students attended school in three different environments: traditional school with chairs and desks, an activity-permissive environment called "The Neighborhood", which allowed more activities and movement, and finally their traditional school with desks, which encouraged standing called the "Standing Classroom". Learning tools (notebook computers and video iPods) were generously borrowed from Apple Computers for use both in The Neighborhood and in the Standing Classroom.

The traditional school environment was a grade 4/5 classroom at Elton Hills Elementary School in Rochester, MN. The classroom had individual table/chair desks for each student and the seating chart was fixed and assigned by the teacher weekly. Children were allowed to get out of their desks for breaks, lunch, class projects, and physical education, but were encouraged to sit at their assigned seat for the majority of the school day.

The activity-permissive environment was housed at the Rochester Athletic Club, Rochester, MN. The Neighborhood was designed specifically to encourage an active learning environment; it was enclosed, centrally heated and air conditioned. It was 35,000 feet^2 and resembled a village square. The actual "classroom" was a plasticized hockey rink complete with standing desks and vertical, mobile white-boards that allowed for activity-permissive lessons. The Neighborhood also included miniature golf, basketball hoops, indoor soccer, climbing mazes, and activity-promoting games (11). The children used wireless laptop computers and portable video display units to facilitate mobile learning. Children were allowed to move throughout The Neighborhood during lesson plans.

The third environment, the Standing Classroom, combined aspects of the traditional school environment and The Neighborhood. Although The Neighborhood offered many and varied opportunities for physical activity and alternative learning, the study investigators recognized that this environment was likely not a feasible environment for typical US schools to adopt considering such issues as funding, space, and safety concerns. We therefore used the traditional grade 4/5 classroom and replaced the chair/table desks with the same vertical desks from The Neighborhood where children could stand during lessons. We retained four to five of the traditional chairs/tables in this environment as an option for children. Anti-fatigue floor-mats were provided to the students. The desks were arranged daily by the students under the supervision of their teacher.

Table 1 Characteristics of students during school-time and children during summer vacation

	Children in school (n = 24)	Children on vacation (n = 16)
Age (years)	10.2 ± 0.6	9.9 ± 1.4
Height (cm)	142.0 ± 8.7	145.1 ± 11.6
Sex (male:female)	10:14	10:6
Weight (kg)	40.7 ± 15.1	44.8 ± 12.7
BMI (kg/m^2)	19.7 ± 4.9	21.1 ± 4.7
BMI percentile	62.8 ± 29.8	65.1 ± 29.0
BMI z-score	1.84 ± 0.34	1.95 ± 0.35

Data are expressed as mean ± s.d.

The vertical desks were adjustable in height which allowed the students to stand or kneel at their workstations. The students were also given three stability balls which could be shared in the classroom and used for more active sitting time.

Physical activity monitors

Students wore a triaxial accelerometer (Model MMA 7260Q; Spark Fun Electronics, Boulder, CO) on the thigh with a range of ±2gs with the data being sampled at 10 times per second. The zero g point on the sensor occurs at 1.66 V, and 1 g = 0.303 V. For physical activity monitoring during the summer vacation, children wore a biaxial inclinometer (Model CXTA02, Crossbow Technology, San Jose, CA) on the thigh with a reported range of ±1.25gs (12). The inclinometer is an analog sensor and data are sampled two times per second. The zero g point on the sensor occurs at 2.5 V, and 1 g = 2.0 V.

We used different physical activity monitors with the students and children who were on summer vacation. We have performed comparison tests to measure movement in children using both types of accelerometers. Seven children (two boys, five girls, mean ± s.d. age 10.4 ± 1.5 years) wore the Spark Fun and Crossbow monitors simultaneously on the right thigh while they were lying, sitting, standing, and walking at 0.5, 1.0, 1.5, and 2.0 mph. The two physical activity monitors were tested in this validation experiment where the two systems were colocated on participants and the accelerometer results were compared between the systems. The results were not significantly different. The two systems correlated very well (r^2 > 0.95) with the slope of the regression between the two systems of 1.015 and the intercept of the regression of the two systems not significantly different from 0. A residual plot of the regression showed a random distribution of residuals with >99% of the residuals (measured value—fitted value) falling below the acceleration difference between 0.5 mph (0.22 m/s) speed increments on the treadmill. Another important consideration when choosing monitors used for the study was cost. The Spark Fun accelerometer was more affordable (US $25 compared to US $230). Because we needed to produce enough monitors for 24 children at the same time, we elected to use the Spark Fun accelerometer for the students.

Protocol

School-time physical activity monitoring. The duration of the protocol was 12 weeks during the springtime (March–May). The typical school day started at 9:15 AM. The children experienced a play break at 10 AM and lunch time was around the noon hour. During lunch time, the children were also allowed free-play after their meal. The students remained in their classroom for a majority of their school day, but attended weekly music, art, and physical education classes outside of their classroom. A majority of the free-play time at recess and lunch occurred outside where playground equipment, basketball courts, and playing fields were available to all students. The school day ended at 3:35 PM. The usual school-day schedule was adhered to throughout the study period in all school environments. The state curriculum was adhered to at all times.

The Superintendent, School Principal, and teacher attended preliminary planning meetings to help develop the research protocol so that the study investigators took into consideration specific concerns about lesson plans, disruption to the school day, and parent involvement. Parents and students were invited to attend preliminary informational meetings about the study presented by the study investigators, and they were also allowed to visit the activity-permissive environment at the Rochester Athletic Club.

Week 1 of the study occurred in the traditional school environment with no changes in the school classroom design (**Table 2**). For each school environment, the goal was to collect 3–4 days of physical activity data (13–15). This number of days of data collection was chosen in order to obtain a more stable and reliable measure of physical activity. At the start of the school day, study investigators placed the triaxial accelerometer onto the right outer thigh using elastic material (Coban, 3M; St Paul, MN). The accelerometer was connected to a data logger (Ready DAQ

Table 2 Timeline of study activities for students attending school in three different school environments

Week	Environment	Acclimatization	Days of PA monitoring
1	Traditional school	No	4
2	Activity permissive	Yes	1
3	Activity permissive/ standing classroom	No	2/3
4–11	Standing classroom	No	None
12	Standing classroom	No	4

The school environment study duration was 12 weeks. There was an acclimatization period when children moved from the traditional school environment into the activity-permissive environment. Physical activity monitoring occurred for the indicated number of days during the entire school day as described in the text.

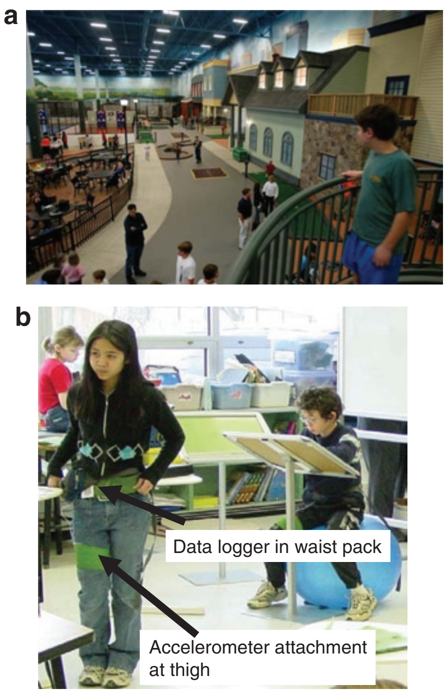

Figure 1 Redesigned school environments. (**a**) Activity-permissive environment, The Neighborhood. Children were allowed to move throughout The Neighborhood during lesson plans. (**b**) Students attending class in the Standing Classroom. Students could stand, kneel, or sit on stability balls at the adjustable vertical desks. During the measurement periods (weeks 3 and 12), students wore an accelerometer which was attached to the thigh using elastic material. The accelerometer was connected to a data logger and worn in a pack at the waist.

AD2000; Valitec, Dayton, OH) that was worn in a waist-pack (**Figure 1**). The study investigators started the data collection for each child. Placement of sensors on all children occurred during the first 10 min or less of class time, to minimize disruption to the school day. Children wore the accelerometers for the entire school day. At the end of the school day, the study investigators returned to stop the data loggers and help the students remove the accelerometers. The removal process occurred in the last 10 min of the school day. The data loggers were downloaded daily at Mayo Clinic and returned each morning for the next day's data collection period. Physical activity was monitored for 4 days during study week 1.

During study week 2 the children attended classes in The Neighborhood. During study week 2, students attended classes without physical activity monitoring for 2 days in order to adjust to the new school environment (**Table 2**). Each morning the children arrived at Elton Hills Elementary and then they were bused 1.5 miles to the Rochester Athletic Club. After the acclimation period, physical activity was monitored in the same manner as described earlier. The accelerometers were placed in the morning by study investigators and removed at the end of the school day. The data loggers were downloaded daily onto a personal computer and returned each morning for the next day's data collection period. Physical activity was monitored for 1 day during week 2 and for 2 days during week 3 while students were in The Neighborhood.

After attending classes in The Neighborhood, children returned to attending classes at Elton Hills Elementary in the Standing Classroom. Physical activity was monitored for the first 3 days after returning to the modified traditional environment using the thigh-worn accelerometers (**Figure 1**). For the next 8 weeks of the study, children attended school in the Standing Classroom. Physical activity was not monitored during this time period. During the last week of the study, physical activity was once again monitored for 4 days using the thigh-worn accelerometers.

Summer vacation physical activity monitoring. Physical activity was monitored in a separate group of similarly aged children using one axis of a biaxial thigh-worn inclinometer and data logger (Ready DAQ AD2000, Valitec) over a 10-day-period. The inclinometer was fixed onto Lycra shorts using Velcro straps (12). Children reported daily to the Mayo Clinic General Clinical Research Center where study investigators placed the inclinometer and performed daily downloads of the previous day's data. Children were allowed to continue all of their normal activities except for swimming because the monitoring equipment was not waterproof. All waking hours were monitored.

Data analysis

Height, weight, age, sex, BMI, and acceleration data were calculated for each child. Data from the accelerometers worn by students were analyzed through standard kinematic equations ($\Sigma\Delta A/\Delta t$ over a 1 min epoch) (16–18). Data from the accelerometers worn by the students were transformed to match inclinometers worn by the children whose physical activity was monitored during summer vacation. To compare the two activity monitors, one axis on the accelerometer that matched one axis on the inclinometer was compared: (i) The axis coincident with the long axis of the femur from the school accelerometer data was sampled two times each second to match the axis and the sampling rate of the summer vacation inclinometer data. All resampled signals (resampled from 10 times each second to two times each second) from each subject were compared to ensure that no aliasing of the signal occurred (data not shown). (ii) Data from the students were "clipped" to a maximum output of ±1.25 V by changing any value outside the ±1.25 V range to exactly 1.25 V or −1.25 V. This mimics the behavior of the sensor used for the summer vacation inclinometer data. (iii) Both sensor outputs were mathematically converted to m/s^2. Acceleration was recorded as the sign-corrected differential of each consecutive data point summated over a 1 min epoch.

To address our hypothesis that the activity-permissive school environment increases student physical activity, we used ANOVA with *post hoc* paired *t*-tests. To evaluate school-time and summer vacation physical activity, we used ANOVA with *post hoc* unpaired *t*-tests. Statistical analyses were conducted using StatView v. 5.0 (SAS Institute, Cary, NC).

RESULTS

All children in the study tolerated the protocol well and enjoyed participating in the study. Characteristics of the children are listed in **Table 1**. For the students, the children (10 ± 1 years, 10 boys, 14 girls) were of varying height (142 ± 9 cm) and weight (41 ± 15 kg); BMI was 20 ± 5 kg/m^2. Seventeen of the students were considered normal weight according to their BMI (15th percentile < BMI < 85th percentile), one student was at risk for overweight (85th percentile < BMI ≤ 94th percentile), four students were overweight (BMI ≥ 95th percentile), and two

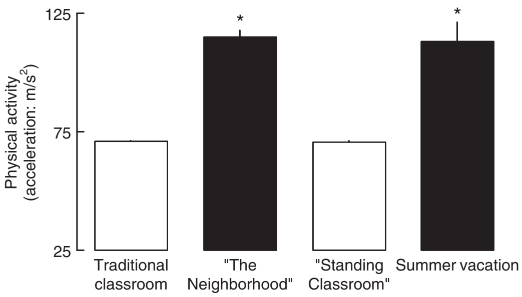

Figure 2 Physical activity levels in children attending school in three different environments: (i) traditional classroom, (ii) an activity-permissive classroom (The Neighborhood), and (iii) traditional classroom with activity-permissive technology (Standing Classroom). For comparison, physical activity levels of same-age children on summer vacation are shown. Values shown are mean ± s.e.m. *Significantly different from either traditional school environment, $P < 0.0001$.

students were underweight (BMI ≤ 15th percentile). The children on summer vacation (10 ± 1 years, 10 boys, 6 girls) were of varying height (145 ± 12 cm) and weight (45 ± 13 kg); BMI was 21 ± 5 kg/m^2. Seven of the children were considered normal weight according to their BMI (15th percentile < BMI < 85th percentile), six students were at risk for overweight (85th percentile < BMI ≤ 94th percentile), and three students were overweight (BMI ≥ 95th percentile). There were no significant differences in age, height, weight, and BMI percentile between the students and the children on summer vacation.

There was no significant difference in activity in the Standing Classroom between weeks 3 and 12 and these days of monitoring were averaged in our analysis. When placed in The Neighborhood, the children moved an average of 115 ± 3 m/s^2 vs. 71 ± 0.4 m/s^2 at traditional school and 71 ± 0.7 m/s^2 at traditional school with standing desks (**Figure 2**). There was a significant difference in activity between The Neighborhood and both traditional school environments ($P < 0.0001$ for both). There was no significant difference in activity between the traditional school environments. Upon comparing free-living (113 ± 32 m/s^2) to school-bound children (71 ± 0.4 m/s^2), we found that there was significantly more activity in the children on summer vacation ($P < 0.0001$, **Figure 2**). The physical activity of school children in The Neighborhood was virtually identical to the physical activity of children who were out of school for summer vacation.

DISCUSSION

Obesity is a complex disease and the mechanisms targeted thus far in childhood obesity prevention/intervention strategies include behavioral, biological processes, genetics, social, and environmental approaches (19–23). Behavioral and environmental approaches are accepted as important frontline therapies for children, primarily due to ethical considerations. However, it is also becoming increasingly apparent that more novel approaches beyond encouraging children to eat less and be more physically active are needed (24). In this study we focused on a novel school-based environmental approach to the obesity epidemic in children.

We first compared physical activity levels, measured using validated technology (12), between a traditional school environment and an activity-permissive school environment, "The Neighborhood". The Neighborhood was associated with a 50% increase in physical activity (**Figure 2**). In general, the increase in physical activity was dispersed throughout the school day, for example children would walk or play games while they reviewed lessons with mobile learning technologies.

To determine whether the increase in physical activity associated with The Neighborhood was because the students were given the opportunity to move or because of the building *per se*, we replaced the chairs and desks in the children's traditional classroom with the same standing desks and educational technology that were used in The Neighborhood. Physical activity levels of students attending class in the traditional school environment and the physical activity levels of students attending class in the Standing Classroom were remarkably similar to each other. It therefore appeared that The Neighborhood building was associated with the increase in physical activity rather than the educational technologies. Interestingly, the increased physical activity associated with The Neighborhood enabled the children to be as active as similarly aged children would be during their summer vacation, where the activity-restricting effects of school are absent.

Presently, there is little information about modifying the school environment to increase physical activity in children (25). There has been an association with physical activity levels and the number of activity-related equipment and structures (such as balls and soccer nets) (26,27). For example, if children have greater access to the soccer balls and goals with nets during recess, they are more likely to be active compared to when the equipment and structures are absent. This observation appears to be more robust when children are under adult supervision.

In a different approach, one group modified the school environment by using colorful, fluorescent playground markings to encourage play in school children (28). Heart rate monitoring was used to compare time spent in moderate vigorous physical activity and vigorous physical activity of children ($n = 99$, 51 boys, 48 girls) attending school in either intervention or control schools. This interesting and low-cost approach to modifying the school environment was associated with increased time spent in moderate vigorous and vigorous physical activity in intervention schools compared with control schools. It has also been reported that larger school space is associated with higher levels of physical activity in middle school students (29). Children attending school in the largest spaces who had their physical activity monitored using accelerometry were walking ~2 extra miles over the course of a school week.

Although our study demonstrates that changing the school environment can affect students' physical activity levels, we recognize that there are limitations to our study. This study focused on a single classroom of students during part of the school year. Future studies with more classrooms and for a longer period of time may address the sustainability of such an intervention. We also only monitored physical activity during the school day. It would be interesting to monitor all daily physical activity in future studies to understand the impact of school environmental changes on children's physical activity levels more thoroughly. With our study design, there was a potential for period effects. It would have been helpful if we had monitored physical activity in another classroom that had been transformed into the Standing Classroom before experiencing the activity-permissive environment in The Neighborhood. We did not evaluate the effect of this intervention on academic performance. However, we included the District Elementary Facilitator with our study team to help ensure that academics were not compromised during the research protocol. The Facilitator's role is to oversee curriculum and Minnesota Academic Standards for elementary grades in the district. Finally, there may be various psychosocial factors (such as enthusiasm of teacher, social acceptance for exercise and movement) that had an effect on our observations of physical activity in the three environments. Future studies in this area will include psychosocial measurements to help us to better understand how these factors affect physical activity levels in children.

One way to address the recent increase in childhood obesity is to develop new approaches to increase daily physical activity levels during school. If our studies are confirmed in larger future studies, these data suggest that we may need to design activity-promoting buildings so that children can move more. Reversing low physical activity and obesity in children may require broad-based collaboration whereby physical infrastructure becomes coupled to health.

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DISCLOSURE
The authors declared no conflict of interest.

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