THESIS

ROLE OF THE PLAYGROUND ENVIRONMENT ON LEVELS OF PHYSICAL ACTIVITY IN ELEMENTARY SCHOOL CHILDREN

Submitted by

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ABSTRACT

ROLE OF THE PLAYGROUND ENVIRONMENT ON LEVELS OF PHYSICAL ACTIVITY IN ELEMENTARY SCHOOL CHILDREN

The school environment offers opportunities for children to be active, particularly during recess periods. Yet the influence of the playground on levels of physical activity (PA) throughout the day has not been well described.

PURPOSE: The purpose of this study was to determine the role of renovated (Learning Landscapes, LL) vs. non-renovated playgrounds on levels of recess, school day and after school PA in elementary school children. The data collected serve as baseline for the Intervention of PhysicaL Activity in Youth (IPLAY) Study.

METHODS: We measured height, weight and 5-6 days of free-living PA via wrist-mounted Actical accelerometers in 277 elementary school children. These students were enrolled in schools serving low socioeconomic status (SES) families (76.9% receiving free and reduced lunch) in metropolitan Denver, CO. Overweight status was defined as $\geq 85^{th}$ percentile BMI-for-age. We applied age and wrist-specific cutpoints to the data to determine total number of minutes and percent of time spent in moderate-vigorous PA (MVPA). Univariate ANOVA was conducted to determine between-subject effects of weight status, presence of LL and sex on recess, school day and after school PA.

RESULTS: During recess and the school day, but not after school, children in LL accumulated more PA than their non-LL counterparts. Boys were significantly more active than girls at all time points. Normal weight children were more active than overweight children over the course of the whole school day. Children in LL were no more likely than their non-LL counterparts to meet the guideline for daily MVPA.

CONCLUSIONS: These data demonstrate that in LL schools, normal weight girls and all boys participate in greater levels of recess PA compared to their non-LL counterparts. However, overweight girls' levels of PA are not different between playground conditions, signifying the need for additional approaches to encourage them to be more active. Although more active during recess, children in LL are no more likely than non-LL children to meet the guideline for PA, indicating that recess duration may be an important factor in daily PA accumulation.

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CHAPTER I

Introduction

Excess body weight is widely recognized as a major public health concern in the United States. Prevalence rates of overweight/obesity in children are rising at particularly alarming rates, having tripled since the 1980s [1-3]. Currently, 33.6% of US children ages 2-19 are overweight or obese [2]. Physical inactivity is thought to be a large contributor to the childhood obesity epidemic [4]. Because of the link between overweight and disease, even among children, [5] the Centers for Disease Control and Prevention (CDC) has created physical activity (PA) recommendations for children. These include participating in moderate to vigorous PA (MVPA) for a minimum of 60 minutes every day [6]. However, data from the National Health and Nutrition Examination Survey (NHANES) 2003-2004 reveal that only 42% of children ages 6-11 currently meet this guideline [7]. Additionally, studies show that overweight/obese children are even less physically active than their normal weight counterparts [8-10]. Given these statistics, many national organizations, including the Centers for Disease Control (CDC), National Association of Elementary School Principals (NAESP), National Association for Sport and Physical Education (NASPE), US Department of Health and Human Services, and others have publicly recommended increasing PA opportunities during school.

Because children spend approximately half of their waking hours at school, the school environment provides an ideal place for the implementation of effective strategies aimed at increasing PA in children, particularly for those that are overweight [11-13]. Evidence suggests that following the implementation of play-time based interventions in schools, including recess and physical education (PE), PA levels as well as energy expenditure have increased [11, 14]. Examples of interventions include modifications to PE curriculum [15], classroom based fitness breaks [16] and playground renovations [17]. Importantly however, the majority of these studies have measured the PA within the time period of interest, e.g., recess or PE. Very few studies have assessed the effectiveness of school-based PA interventions across the entire school day. This is critical to understand whether these intervention strategies are effective in increasing children's PA over the course of the entire day, or whether children compensate for this increased activity by participating in less activity throughout the remainder of the day. Therefore, there is a need to examine children's PA levels both within the school environment as well as across the whole school day in order to understand how children accumulate the remainder of their activity [18].

The role of the built environment in PA behavior is a critical factor in encouraging health-promoting behaviors [19]. Children who have access to recreational facilities and programs near their homes tend to be more active than those lacking access [20]. In one study conducted by Grow et al., living within a ten minute walk of a recreation site or large public park significantly increased the likelihood of being active at these sites compared to living farther than ten minutes away [21]. Because of this preliminary evidence of the role of the environment on levels of PA, researchers are identifying environmental modifications (e.g., playground renovations) as one approach to increasing PA. However, whether these modifications to the built environment translate into a greater percentage of children actually meeting the PA guideline is not yet elucidated.

One such group aiming to modify the environment through the creation of activity-promoting playgrounds is Learning Landscapes, Inc. (LL). LLs are designed and built through a partnership between the University of Colorado Denver's School of Planning and Architecture and Denver Public Schools. Elements of the LL playgrounds include public and student art, shade structures, blacktop markings, age-appropriate play structures, a large field area and a walking path. Initial studies have been conducted using the System for Observing Play and Leisure Activity in Youth (SOPLAY), a direct observation method. Though SOPLAY is validated for the assessment of recess activity and distinguishes boys from girls, it does not have the capability to differentiate between normal weight and overweight children. We therefore have no understanding whether the playgrounds affect normal weight and overweight children differently. We also have no data on how these playgrounds affect PA levels over the course of the entire school day. Results of the pilot studies would be strengthened by the addition of a more objective and robust measure of physical activity.

Accelerometers have become the most widely used objective measure of physical activity in children, continuing to increase in popularity in all age groups [22]. They have been validated for use in multi-day, field-based research in children [23]. They provide researchers insight into the temporal characteristics of PA over the course of multiple days. Because of their objectivity and high validity, accelerometers are an attractive means by which to assess the effectiveness of these environmental modifications. However, challenges exist in using accelerometers, particularly with regard to compliance in children [24], suggesting that novel methods to encourage compliance, including alternate device placement need to be adopted [25].

The purpose of this investigation was to determine through objective, free-living, multi-day, accelerometry data whether the presence of Learning Landscapes playgrounds translates into greater levels of physical activity (PA) in normal and overweight/obese elementary school children, particularly during recess, the school day and after school periods. We hypothesized the following: 1) that students with LL spend a greater percentage of recess engaged in moderate-vigorous PA (MVPA), 2) because of the presence of the playgrounds, that students in LL schools have higher levels of PA during the school day and after school period compared to their non-LL counterparts and 3) that children in LL are more likely than non-LL children to meet the guideline of 60 minutes of MVPA per day.

CHAPTER II

Literature Review

The prevalence of overweight and obesity in children is increasing at alarming rates [2, 26]. As these rates continue to increase, a concomitant increase in associated disease risks, both physical and mental are observed [27-29]. Because of these health risks, the Centers for Disease Control and Prevention (CDC) has created PA recommendations for children that include participating in moderate to vigorous physical activity (MVPA) for a minimum of 60 minutes every day [6]. However, the percentage of children who actually meet this minimum requirement is low [30]. Therefore, the design, implementation and dissemination of effective programs aimed at increasing PA in children are critical. Because children spend more time in school than any other place away from the home, the school environment provides an ideal place in which to disseminate these programs [31-34]. Recess, for example, provides children with the opportunity for unstructured PA. One strategy for increasing PA during recess involves renovations to playground areas [35]. In order to evaluate the success of these programs in increasing PA, effective, accurate methods for measuring PA must be employed. In recent years, the accelerometer has proven to be an effective and feasible approach for field-based research measuring PA in children [31, 36-41].

Prevalence of Childhood Obesity and Association Disease Risks

Excess body weight in children is a growing health concern in the US. Since the 1980s the prevalence of obesity in children and adolescents ages 6-19 years has tripled [1-3]. Using measured heights and weights in the National Health and Nutrition Examination Survey (NHANES) in 2006, approximately 17.1% of children and adolescents ages 2-19 were considered overweight or obese [2]. Overweight in children was previously defined by the Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services as a BMI-for-age score at or above the 95th percentile [42]. Including the "at risk for overweight" category which encompassed the 85th-94th percentile, the prevalence in 2006 was approximately 33.6% of children ages 2-19 [2]. Noteworthy is the fact that the definition of overweight in children has now changed to include BMI-for-age scores between the 85th and 95th percentile. Greater than or equal to the 95th percentile is now considered obese [43]. Among racial/ethnic minorities and those of lower socioeconomic status (SES) the prevalence of overweight and obesity is significantly greater [2, 3]. NHANES data from 2003-04 show 36.9%, 40.0% and 42.9% of non-Hispanic white, non-Hispanic black and Mexican American children ages 6-11 years have BMI-for-age z-scores ≥ 85% [2].

Numerous health risks, both mental and physical, have been associated with excess body weight in children [44]. Among these are cardiovascular disease [45, 46], type 2 diabetes [47], low self-esteem and depression [28, 48, 49], and risk of adult obesity [50-52]. In obese children, the presence of cardiovascular disease can be seen as early as ten years of age [46]. This excess body weight increases a child's risk for multiple cardiovascular risk factors, including hypertension, hypercholesterolemia, and elevated plasma insulin [27-29, 45]. In a study of over 9,000 children enrolled in the Bogalusa Heart Study conducted by Freedman, et al., overweight children were 2.4 times as likely as normal weight children to have elevated cholesterol [45]. In addition, low self-esteem is a very prevalent and detrimental consequence of childhood overweight and obesity [28, 48]. Stockton, et al. found that girls with higher BMIs had less confidence in their abilities to be active and eat healthy, as well as greater body image discrepancies [49]. Preference tests demonstrated that overweight kids are the least likely group with whom normal weight children chose to be friends [28]. Additionally, children ages 6-11 already associate overweight and obesity with such negative qualities as laziness and sloppiness [28, 53]. Finally, children who are obese are at an increased risk of becoming obese adults [50-52]. Whitaker, et al. found with the presence of parental obesity, as many as 80% of obese adults were overweight as children [52].

Obesity is the result of an imbalance between energy intake and energy expenditure [54-56]. Genetic and environmental factors both contribute to the obesity epidemic [57]. From a genetic standpoint, twin, adoption and family studies demonstrate that 25-40% of inter-individual differences in adiposity is accounted for by inheritance [58]. Others have indicated that 30-60% of childhood obesity cases persist into adulthood [59]. The environment surrounding physical activity also contributes to the obesity epidemic [60]. Our reliance on vehicles for transportation, advances in technology, and decreased occupation-related physical activity are all contributing factors [60]. Specific to children, cutbacks in mandatory physical activity in favor of increased academic time contribute to overall decreases in daily activity [60].

From an energy balance perspective, a major factor affecting energy expenditure is physical activity, and is therefore a contributing factor to excess body weight [57, 61]. Studies demonstrate a negative relationship between physical activity and obesity [57, 62]. In one eight-year longitudinal study, children in the highest tertile of daily physical activity from ages 4 to 11 years had smaller gains in BMI, triceps, and sum of five skinfolds throughout childhood compared to the least active children [63]. Combined data from NHANES 2003-04 and 2005-06 demonstrate that overall, obese youth spent 16 fewer minutes in MVPA than normal weight youth [62].

Physical Activity Guidelines and Prevalence in Children

Several authors have described the link between a lack of PA and childhood obesity [64-66]. Because of this relationship and the risk for disease as described above, it is critical that children maintain a relatively high level of PA. Therefore, the Centers for Disease Control and Prevention have established guidelines for PA in children, currently recommending a minimum of 60 minutes of activity everyday [6]. Others have supported this recommendation as well [11, 34, 67]. However, the number of children who actually meet this recommendation on a regular basis is relatively small [30, 68, 69]. NHANES accelerometry data from 2003-04 report that 42% of children ages 6-11 meet this guideline [7]. When stratified by sex, data reveal that 48% of boys but only 35% of girls meet this guideline [7]. Disparities also exist between normal weight and overweight/obese children when looking at minutes of MVPA. Among children ages 6-17, normal weight, overweight and obese children accumulate 58.9, 48.0 and 43.4 minutes of daily MVPA, respectively [62].

Healthy People 2010 also lists specific PA goals for children, including 20 minutes of vigorous PA at least three days per week [70]. According to the U.S. Department of Health and Human Services (HHS) Physical Activity Guidelines for Americans, vigorous activity includes games involving running and chasing such as tag, bicycle riding, jumping rope, running, and sports such as soccer, ice or field hockey, basketball, swimming and tennis [71]. Again the percentage of children meeting this goal in the United States is low [69]. On average, 6-17 year old children accumulate 7.6 minutes of vigorous activity per day [62]. Boys and girls also differ in their accumulation of vigorous activity, getting 9.3 and 5.8 minutes, respectively [62]. The statistic is even lower when examining overweight and obese children, who accumulate 5.6 and 4.9 minutes of daily vigorous activity, respectively [62].

Opportunities for Physical Activity within the School Environment

Given the statistics on the number of children not meeting current PA guidelines, as well as the relationship between physical inactivity and excess body weight, the need for dissemination of effective programs has been cited by many [72-74]. Schools provide ample opportunities for children to participate in PA, especially when taking into consideration that the majority of children spend more waking time at school than any other place away from the home [75, 76]. Additionally, evidence suggests that following the implementation of play-time based interventions in schools, PA levels as well as energy expenditure have increased [11]. Among the opportunities available during school to increase PA are recess, PE classes, intramural programs, interscholastic sports, PA programs, and access to a variety of facilities including gymnasiums, practice fields and playgrounds during and outside of school hours [74]. It is vital that children take advantage of these opportunities, as evidenced by Dale, et al. who demonstrated that if children did not engage in these activities during the school day; they did not compensate for the missed activity, and in many cases even missed out on other activities later in the day [77].

In many schools the PE classes are the focus of a child's school activity. However, many studies show that PE classes fail to provide the recommended amount of PA [77, 78]. In an observational study by Friedman, et al. conducted on 814 children, students averaged 2.1 PE lessons each week, lasting approximately 33 minutes each [79]. Only 5.9% of children attended daily PE. Children accumulated 4.8 very active (vigorous) minutes and 11.9 minutes of MVPA per PE lesson, accounting for 15% and 37% of lesson time, respectively. Encouragingly, many intervention studies aimed at improving activity during PE demonstrate effectiveness at increasing moderate-vigorous PA (MVPA) [15, 32, 80]. In a study conducted by Sallis et al., PE curriculum delivered by a trained specialist over a two year period showed significantly greater minutes per week of MVPA (40.2) compared to control schools (17.8) [15].

School recess provides an additional opportunity for children to be active during the school day [11, 74]. Recess is distinct from PE in that it allows children to participate in unstructured play. Most studies reveal however, that children spend less than half their allotted recess time engaged in MVPA [81-83]. This may partly be due to the intermittent nature that typically characterizes children's PA [11, 84]. Sarkin et al., compared activity levels of fifth graders during recess and PE, and found that while boys maintained similar levels of PA during recess and PE, girls spent significantly less time in MVPA during recess than PE [85]. This suggests that girls may benefit from more structured active periods. Additionally, as of 2009, only 12% of states require elementary schools to give students regularly scheduled recess [86]. Exacerbating the problem for low socioeconomic status (SES) neighborhoods, results from one study showed that it was less likely for schools in high poverty areas than schools in other areas to have regularly scheduled recess for elementary school students [73]. Much of this evidence supports the opinion that over the years schools have reduced PE and recess time in favor of more academic instruction [87].

Given these statistics, national organizations, including the Centers for Disease Control (CDC), National Association of Elementary School Principals (NAESP), National Association for Sport and Physical Education (NASPE), US Department of Health and Human Services, and many others have publicly recommended increasing PA opportunities in school. Intervention studies repeatedly show promise in increasing PA during school recess to maximize activity during this time [31, 32, 73, 74, 82, 88, 89]. One study conducted by Huberty et al., used accelerometers to assess the effectiveness of an elementary school recess intervention that included staff training, activity zones and playground equipment [89]. Over the course of the school year, moderate PA (MPA) and vigorous PA (VPA) increased 13.1 and 9.6%, respectively [89]. School day MPA and VPA also increased by 17.2 and 4.2 minutes [89]. This evidence demonstrates the need for effective interventions aimed at increasing the amount of PA that children accumulate during the school day, particularly during recess.

Effects of Playground Interventions on Children's Physical Activity Levels

Researchers recognize the importance of the school recess period for accumulating physical activity [90]. Within the recess period, researchers have attempted to increase PA through a variety of means, including the addition of curriculum [91], modifications to the built environment [35], addition of play equipment and increased teacher supervision [92]. To our knowledge, only one study has examined the effects of a curricular intervention on PA during recess, in which they demonstrated that children were significantly more active during the intervention than during unstructured recess [91]. In a study conducted by Willenberg et al., a greater proportion of children engaged in moderate PA where fixed equipment, (i.e., swings, play structures and slides) was present (fixed equipment: 35% MPA vs. no fixed equipment: 20% MPA, $p<.001$). Additionally, the provision of play equipment resulted in a significant increase in vigorous PA (loose equipment: 33% VPA vs. no loose equipment: 20%, $p<.001$) [92]. A cross-sectional study using SOPLAY demonstrated a 5- and 4-fold increase in PA in boys and girls, respectively, with high levels of teacher supervision [93].

Renovating the playground environment is one strategy researchers are using to increase PA during recess. Learning Landscapes (LL) is a non-profit partnership between the University of Colorado Denver's College of Architecture and Planning and a local urban school district, Denver Public Schools. LL is a group aiming to increase activity in children through the construction of innovative playgrounds with diverse elements including student and public art, schoolyard gateways, colorful playground structures and markings, and shade structures [94].

Figure 1. Learning Landscape Playground

Initial research using System for Observing Play and Leisure Activity in Youth (SOPLAY) has been done to evaluate these schoolyards' effects on children's PA [17, 94]. In the first study, the volume of children on the playgrounds was significantly higher in both recently built as well as established LL schools vs. non-LL schools. While boys' activity was higher in LL schools, girls' activity was not [17]. In the second study, overall playground use was quantified before school, during lunch recess, after school and on the weekends. Use was significantly higher in LL schools vs. non-LL schools for most observation periods [94]. Rate of MVPA was also assessed, but no significant differences were found between groups [94]. These mixed results demonstrate a need for more objective methods by which to assess the effects of playground renovations on children's levels of PA.

Methods for Monitoring Physical Activity

Vital to the evaluation of interventions aimed at increasing PA as well as to the internal validity of research assessing PA, are accurate methods for measuring this activity [95]. Criterion measures against which other methods for assessing PA are evaluated, include direct observation (DO), doubly labeled water (DLW), and indirect calorimetry [96]. However, equally important in evaluating the effectiveness of PA interventions in children is the issue of feasibility [97]. Factors which affect instrument selection comprise study size, budget, resources, and staff availability [97]. Therefore, more feasible methods have been created to measure PA in large field-based research. A variety of techniques, both subjective and objective, have been evaluated in the assessment of children's PA. Among these are self-report and diaries [96, 98, 99], interview-administered methods [100-103], pedometry [104-106], heart rate telemetry [107-109], and accelerometry [22, 97, 110]. It is important to recognize the additional challenges that exist when children are the target population. First, children exhibit a very intermittent pattern of PA throughout the day, as well as within a given bout of playtime [11, 111]. Additionally, a variety of cognitive, biomechanical, and physiological changes occur during normal growth and development, also affecting the selection of instrumentation [112, 113]. A short review of the most frequently employed methods for assessing PA in children follows.

Self-report offers an affordable and feasible way to conduct large-scale epidemiological studies [96]. While there are significant challenges with this method, there are many validated self-report questionnaires for use in the pediatric population, including the Previous Day PA Recall (PDPAR) [114], the Self-Administered PA Checklist (SAPAC) [115], and the PA Questionnaire for Older Children (PAQ-C) [116]. The PDPAR Pearson's correlation coefficients using DO as the criterion measure revealed an r=0.19-0.39 [114]. The SAPAC, measured against HR demonstrated a correlation coefficient of r=.02-.32 [115]. Finally, the correlation coefficient using the PAQ-C was found to be r=.39 [116]. Only the PAQ-C was measured for greater than one day of activity, however it is only valid for use in 4^{th}-8^{th} grade children. The greatest limitation in using self-report is individual subjectivity when subjects are asked to describe their behaviors [96]. This challenge is further exaggerated when children are the target population [95]. Additionally, very few studies have been conducted that validate self-reported measures for longer than a single day. Because of the low correlation coefficients, as well as the additional challenges that arise when using these methods with young children, although self-report is an affordable and feasible way to measure PA, it is not the most accurate.

Pedometers offer a relatively low-cost and simple estimate of total volume of PA, reported as number of steps taken [117]. With vertical acceleration of the hip, a spring-suspended lever inside the pedometer moves up and down to detect steps [105]. From a purely measurement perspective, typically pedometers cannot be used to detect patters in PA, but rather simply the total volume of PA (e.g. number of steps) in a given period of time [117]. However, some researchers have used pedometers during a specific period of time (e.g., recess, PE class, etc.). In this way, the pedometer output of total steps taken can be used to obtain steps/min [118]. While not yet validated, some manufacturers have begun to offer features claiming to estimate activity time and time spent in MVPA [117]. However, again due to the intermittent nature of children's PA patterns, determining MVPA from stepping cadence is particularly challenging [119].

For research questions that only require a measure of total PA volume, the pedometer may suffice; however, much research now focuses on more detailed measures of PA including intensity, duration, and frequency [120]. In order to evaluate these more detailed and time sensitive research questions, a variety of commercial and research based accelerometers have become available.

Use of Accelerometry in Physical Activity Monitoring in Children

Accelerometers detect body acceleration units (g; $1g=9.8m/s^2$) on specific body segments, depending on where it is placed (hip, low back, wrist, ankle) [121]. Traditionally, a single sensor had been positioned in line with the vertical axis of the body [121]. However, more recent accelerometers use multiple sensors to measure acceleration in more than one axis of the body [122]. The sensor used in the majority of accelerometers available is a piezoelectric element and a seismic mass [121]. Exposed to an acceleration, the seismic mass causes the piezoelectric element to deform [121]. When the deformation occurs, it creates a detectable positive or negative electric charge on one side of the sensor which then generates an output voltage proportional to the acceleration applied [121]. These voltage outputs are then converted into a unitless numerical value termed “counts” which are a linear reflection of the sum of the voltage output detected [121]. These counts are then summed and stored over a short period of time, typically called an epoch, ranging from approximately one second up to one minute [121].

Accelerometers have become the most widely used objective measure of physical activity in children, continuing to increase in popularity in all age groups [22]. Notable advantages in using accelerometry to objectively measure PA include the avoidance of bias, greater confidence in the amount of activity and sedentary behavior measured, and improved ability to relate variation in PA and sedentary behavior to variation in health outcomes [123]. Disadvantages cited by researchers include high cost, uncertain reliability, and difficulties in the interpretation of data, specifically in large-scale epidemiologic studies [124]. Additional challenges arise in making comparisons between the various studies, due to differing monitors used, protocols followed, and data processing methods employed [44].

Because very few studies have conducted direct comparisons between accelerometer models, there is currently not any one accelerometer that is recommended for use over another [97]. Researchers typically weigh the benefits and drawbacks of each device, including position placement, waterproofing, sampling frequency, storage capacity and battery life. For our purposes, a waterproof device validated on the wrist for children was ideal. Given this, we elected to use the Actical accelerometer (Philips Respironics, Bend, OR) which has been validated for use in children [125]. Many studies have been conducted to calibrate and validate the Actical accelerometer in a variety of populations [125-128].

The placement of the accelerometer on the body has become an important consideration for the researcher [23]. While the hip has traditionally been the preferred location, a variety of studies have experimented with alternative placement specifically with children, including wrist, low back and ankle [40, 129]. Bouten et al. demonstrated that acceleration at the low back was the best predictor of energy expenditure (EE) (r=0.92-0.99), though all sites demonstrated moderate to strong correlations [129]. Although studies conducted on the wrist show slightly decreased correlations [130, 131], for compliance purposes in children, the wrist is a far superior location for the placement of the device.

An additional factor to consider in accelerometry-measured PA is length of epoch [23, 25]. The epoch is defined as the user-specified period of time over which the filtered digitized acceleration signal is integrated [23]. The vast majority of research has been conducted using one minute epochs [40, 132-134]. However, several authors have noted that while this may suffice in adults, the use of one minute epochs with children may be problematic, and may obscure the short bouts of vigorous PA that are characteristic of children's activity patterns [24, 135]. It is therefore recommended that the epoch length be as short as possible, given that data can be reintegrated into a longer time frame but not vice versa [97].

Finally, to ensure adequate data collection, the monitoring period should be considered in the selection of a device. In adults, a period of three to five days is typically suggested [23]. For children, a sampling period of four to nine days has been recommended [23]. While there is characteristically less day to day variability in accelerometer outputs as age decreases, it is still preferable to collect at least one weekend day in addition to multiple weekdays [136].

Conclusions

In conclusion, the increasing rates of overweight and obesity in children are causing a concomitant increase in associated disease risks. Because of this, the CDC recommends all children be physically active for a minimum of 60 minutes every day. However, the number of children actually meeting this recommendation is low. In order to better take advantage of the school environment, feasible and effective programs targeting children's levels of PA should be implemented.

Therefore, the NIH has awarded Colorado State University, the University of Colorado Denver and the University of Hawaii a mulit-institutional R01 to evaluate the effectiveness of a curricular and environmental intervention in Denver Public School Elementary Students. In order to evaluate the effectiveness of this program, objective methods for measuring PA should be employed. The accelerometer proves to be an accurate, feasible means for assessing PA in children.

CHAPTER III

Methods

Study Design

The Intervention of PhysicaL Activity in Youth (IPLAY) study involves 24 Denver public elementary schools in a 2 (environmental intervention vs. no environmental intervention) by 2 (curriculum intervention vs. no curriculum intervention) factorial design with repeated measures (pre-intervention, mid-intervention, immediately post-intervention and one year post-intervention). The environmental intervention comprises the Learning Landscape (LL) initiative, which transforms playgrounds into tailored colorful, multi-use playgrounds. The curriculum involves the combination of SPARK Active Recreation and Balance First, delivered over the two year intervention in the fall and spring for eight weeks each. Data reported here are pre-intervention (baseline) data for four wave 1 schools in the IPLAY study.

Participants

One first, third, and fifth grade classroom from each of four schools (two LL and two non- LL schools, 12 classrooms total) was randomly selected to participate. Classroom size varied across classrooms from 19 to 30 students. The Human Subjects Committee at Colorado State University provided approval for this study. Informed assent and consent were received by each participating child and his/her parent. Detailed procedures on the assenting and consenting process follow.

Instrumentation

We used the Actical (Philips Respironics, Bend, OR) accelerometer in this study. The Acitcal is lightweight (17g), omni-directional, and waterproof and detects low frequency (0.5-2.0 Hz) accelerations common to human movement. It generates an analog voltage signal that is then filtered, amplified and digitized by an A-to-D converter at 32 Hz. These digitized values are summed over the epoch and stored in the device. These stored values are proportional to the duration and magnitude of the movement and therefore correlate to physical activity. This device has been validated for use in children [125]. Devices were calibrated by the manufacturer prior to use. Because of the transient nature of children's activities, we collected data using a 15-second epoch, which is the shortest available for the device.

Data Collection Procedures

At least one week prior to the start of data collection, teachers sent home a parent letter, consent forms and FAQ sheets to parents. Parents were requested to return the consent forms promptly, and were compensated for their participation. On the day data collection began, study staff explained the project to students and answered any questions they had. All participating students signed informed assent forms inside the classroom. Ninety seven percent of the potentially consented students participated. We attached Actical accelerometers on the non-dominant wrist of each student with semi-non-removable bands (see Figure 2).

Figure 2. Actical accelerometer on child's wrist

Next, study staff measured children's height to the nearest 0.001m using a standard tape measure placed against an unobstructed wall, and weight to the nearest .2 kg, using a digital scale (Health o meter professional, Model 349KLX). Finally, children were given their first $10 gift card. During the seven-day data collection period, children were encouraged not to remove the device, and to maintain "typical" activity patterns. Teachers were provided extra bands in the event that a child's band was removed for any reason. At the end of the seven-day period, study staff returned to the schools to collect the accelerometers. At this time, children received an additional $10 gift card, as well as a $30 gift card for their parents.

Data Processing

Study staff downloaded the data using Actical software (Actical v. 2.12). Data recorded on the first day were excluded from analysis due to reactivity effects (i.e. increasing activity due to the novelty of the device). Using a custom Matlab program (Matlab v 12.0, Mathworks, Natick, MA), accelerometry data files were examined for non-wear, defined as 60 or more consecutive minutes of inactivity (i.e., >240 consecutive zero count outputs) [7]. If missing data were found such that <600 total minutes of activity were registered for a day, data for that day was excluded. A minimum of four days of activity for each child was required for analysis, including one weekend day. We used an additional custom Matlab program to read the Actical files for each valid day and to analyze specific periods of time, including school day, after school and recess. Times were determined based on individual school schedules, provided by classroom teachers. Outcomes examined included number of minutes and percent of time spent in sedentary, light, moderate, and vigorous activity, defined by cutpoint thresholds of <21, 22-620, 621-1817, ≥1818, per 15 second epoch, respectively (see calibration below).

Accelerometer Calibration

Initially, Actical Software cutpoints were applied to the data to determine minutes of MVPA. However, upon further investigation, we discovered that compared to a large body of literature on children's accelerometer-measured daily PA ranging from 50-90 minutes per day [7, 62], these cutpoints were grossly overestimating minutes of MVPA per day, upwards of 240 minutes per day. Because only one other group has established intensity cut-points and validated the Actical for wrist placement in older children (8-14 years) [125], we elected to conduct a calibration/validation experiment in our laboratory. Briefly, 22 children ages 6-11 (see Table 1) were fitted with the Oxycon Mobile portable metabolic cart (Care Fusion, Yorba Linda, CA) and an Actical accelerometer on the non-dominant wrist. After a period of 20 minutes of quiet resting, each child performed a variety of tasks for six minutes each, including coloring, quiet standing, light aerobics, slow walking (0.75 m/s), fast walking (1.5 m/s), four-square, jogging (2.0 m/s) and jumping rope. We used the WHO/FAO/UNU equation for estimating resting energy expenditure to determine subject-specific resting metabolic rate [137]. We then divided measured VO_2 values for each activity by the predicted resting value to determine METs. Linear regression was used determine appropriate accelerometry count cutpoints associated with sedentary (<1.5 METs), light (1.5-2.9 METs), moderate (3-5.9 METs) and vigorous (≥6 METs) activity.

Table 1. Subject Characteristics for Actical Calibration Study, n=22

Sex	**55% female**
Age	8.72 years
Height	138.75 cm
Weight	74.15 kg

Statistical Analysis

All data were analyzed using SPSS (IBM SPSS Statistics 19, Somers, NY) and the significance level was set at $p < .05$. Subject characteristics are displayed as means ± (SE) in Table 1. The assumption of normality was evaluated using a graphical histogram and passed. We did not evaluate the assumption of independence. We used a three-way ANOVA to analyze minutes and percent time spent in MVPA with sex, weight status (overweight/ obese, ≥ 85^{th} percentile BMI-for-age z-score vs. normal weight, < 85^{th} percentile BMI-for-age z-score) and playground status (LL vs. non-LL) as fixed factors. Where interactions demonstrated statistical significance, data was plotted to further examine the interaction. In the first model, we used a three-way ANOVA to assess recess differences in percent of time spent in MVPA across sex, weight and playground status. In the second and third model, the same three-way ANOVA was used to examine differences in school day and after school MVPA, respectively. We initially included grade as a fixed factor, but no significant differences were observed. We therefore removed grade from the model. We determined odds ratios (OR) using logistic regression between LL and non-LL children to assess whether children with LL were more likely than non-LL children to achieve the guideline of 60 minutes of MVPA per day.

CHAPTER IV

Results

Subject Characteristics

We collected data on 277 children ages 6-12 between April and May 2010. This represented a 97% consent rate. After cleaning the data for non-wear, defined as ≥ 60 consecutive minutes of zero counts, 269 children's files (50.9% male) remained for analysis. The percentage of students receiving free and reduced lunch was 76.9%. Ethnicity breakdown of our population was 62% Hispanic, 28% non-Hispanic whites, 6% African-American, 3% Asian and 1% American-Indian. Mean (SD) values for subject characteristics and subject population by subgroup (i.e., playground status, weight status and sex) are presented in Table 2.

Table 2. Subject Characteristics, Mean (SD) and subject population (n) LL= Learning Landscapes Overweight/Obese (OW/OB) ≥85th percentile BMI-for-age z-score

		Height (cm)	Weight (kg)	Age (yrs)	LL	Non-LL	TOTAL
Girls	Normal Weight (NW)	135.0 (12.1)	30.5 (8.2)	8.5 (1.7)	47	44	91
	Overweight/ Obese(OW/OB)	139.0 (11.9)	43.6 (12.3)	8.8 (1.7)	17	24	41
	TOTAL	136.2 (12.1)	34.6 (11.4)	8.6 (1.7)	64	68	132
Boys	Normal Weight (NW)	137.2 (10.9)	31.1 (6.9)	8.9 (1.8)	32	51	83
	Overweight/ Obese(OW/OB)	138.8 (12.2)	43.7 (13.1)	8.6 (1.8)	28	26	54
	TOTAL	137.9 (11.4)	36.1 (11.6)	8.8 (1.8)	60	77	137
	TOTAL	137.1 (11.8)	35.4 (11.5)	8.7 (1.8)	124	145	269

Table 3. Mean (SE) percent and minutes of recess, school day, and after school time spent in MVPA. Children < 85th percentile are considered normal weight (NW), while children ≥ 85th percentile are considered overweight/obese (OW/OB).

	Learning Landscapes				Non-Learning Landscapes			
	Girls		Boys		Girls		Boys	
	NW	OW/ OB	NW	OW/ OB	NW	OW/ OB	NW	OW/ OB
Recess (mins)	9.8 (0.5)	6.9 (0.9)	14.6 (0.7)	13.2 (0.7)	4.5 (0.8)	4.0 (0.6)	5.9 (0.5)	5.7 (0.7)
Recess (% time)	26.7 (1.9)	20.2 (3.1)	42.6 (2.3)	37.4 (2.4)	20.6 (1.9)	22.1 (2.6)	29.6 (1.8)	28.6 (2.5)
School Day (mins)	34.7 (1.7)	23.4 (2.8)	41.7 (2.1)	38.1 (2.2)	23.0 (1.8)	23.8 (2.4)	27.9 (1.6)	26.6 (2.3)
School Day (% time)	8.5 (0.4)	5.7 (0.7)	10.1 (0.5)	9.2 (0.5	5.7 (0.4)	5.9 (0.6)	6.9 (0.4)	6.6 (0.6)
After School (mins)	11.4 (1.3)	11.1 (2.2)	14.4 (1.6)	11.9 (1.7)	9.3 (1.4)	10.1 (1.8)	15.5 (1.3)	10.4 (1.8)
After School (% time)	9.5 (1.1)	9.3 (1.9)	12.0 (1.4)	9.9 (1.5)	8.7 (1.2)	10.0 (1.6)	13.7 (1.1)	10.4 (1.5)
Total Min MVPA (6AM-11PM)	74.6 (4.2)	56.2 (7.1)	101.1 (5.1)	81.1 (5.5)	61.9 (4.4)	68.3 (5.9)	78.6 (4.1)	67.9 (5.7)
School day/After school % of daily MVPA	61.8	61.4	55.5	61.6	52.2	49.6	55.2	54.5

Recess Activity

Mean (SE) percent of time spent in MVPA during recess was 28.5% (±0.8). Significant main effects were observed with playground status (LL vs. non-LL, p<.001), demonstrating that children attending schools with LL playgrounds spent a greater percent of recess time engaged in MVPA. A significant effect of sex was also found ($p<.001$), indicating that boys spent a greater percent of recess time engaged in MVPA than girls. An interaction was observed between playground status and sex ($p=0.009$), indicating that girls' and boys' levels of PA differ between LL schools compared to their non-LL counterparts. Figure 3 depicts the interaction between playground status and sex, demonstrating that boys in LL schools spend significantly more time in MVPA while girls in LL schools do not. No significant difference was observed between normal weight and overweight children during recess ($p=0.096$). Additionally, no significant interaction was found between weight status and playground status ($p=.069$) or between sex and weight status ($p=.843$)

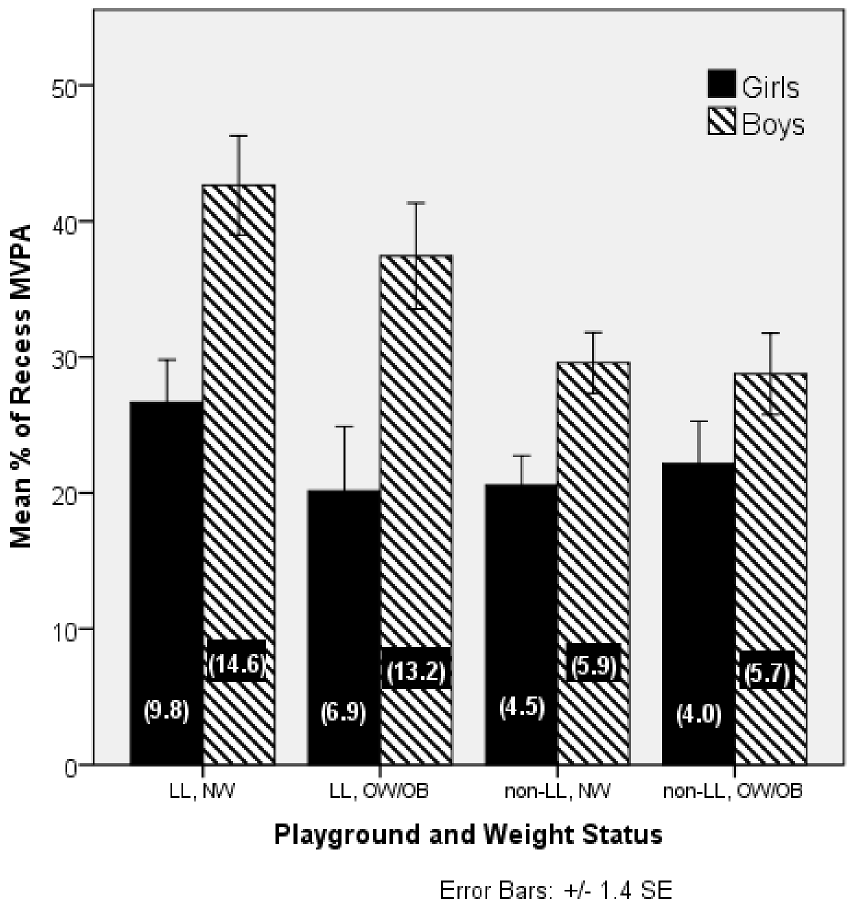

Figure 3. Mean (1.4 SEM) percent of MVPA during recess. Error bars (1.4 SEM) represent the Least Significant Difference. Bars that do not overlap indicate significant differences between groups. Values inside bars represent minutes of MVPA during recess. LL= Learning Landscapes (renovated playgrounds), non-LL= Non-Learning Landscapes, NW= Normal weight, OW/OB= Overweight/Obese.

School Day Activity

School day was defined based on each individual school's schedule and ranged from 405-420 minutes. Results analyzed using percent of school day in MVPA did not differ from results using minutes of MVPA. Table 3 shows minutes and percent time in MVPA. Mean (SE) minutes of the school day spent in MVPA were 30.2 (±0.8). Significant effects were found with sex ($p<.001$), playground status ($p<.001$) and weight status ($p=0.013$, Figure 4). Similar to recess activity, a significant interaction was observed between playground status and sex (p=0.022), indicating that boys in LL were more active than boys in non-LL while girls in LL were not more active than girls in non-LL. We also observed a significant interaction between weight and playground status (p=0.018), indicating that while normal weight children were more active than overweight children in LL schools, no difference in activity was observed between normal weight and overweight children in non-LL schools. No significant interaction was found between sex and weight status (p=.344).

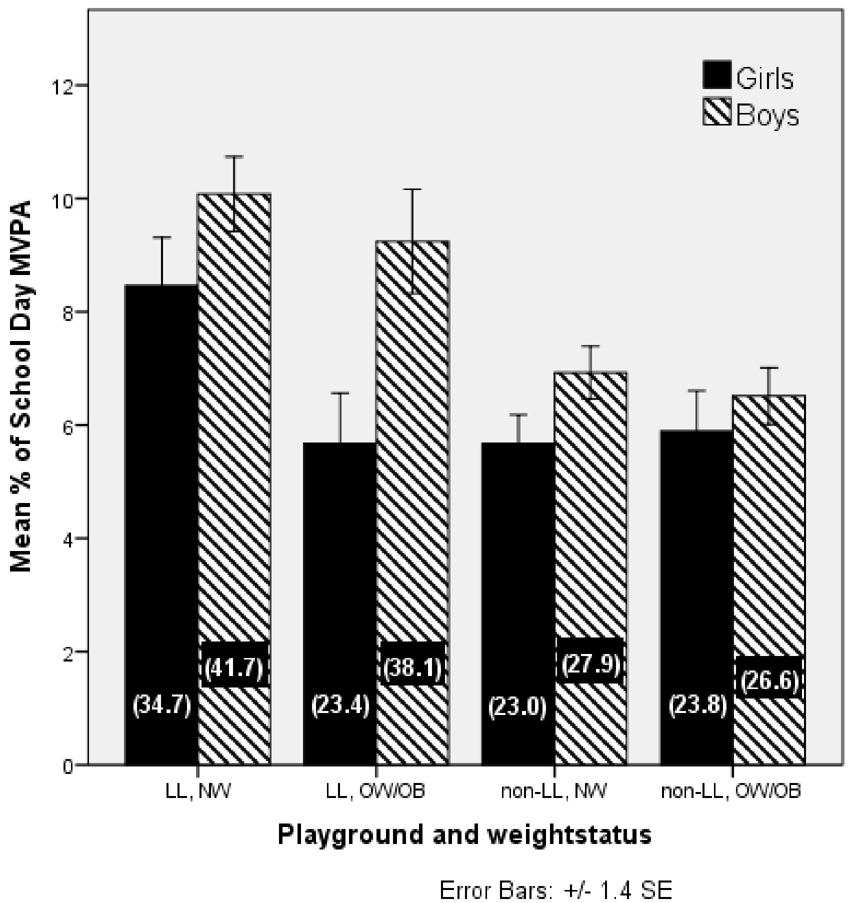

Figure 42. Mean percent of school day in MVPA. Error bars (1.4 SEM) represent the Least Significant Difference. Bars that do not overlap indicate significant differences. Values inside bars represent minutes of MVPA during recess. LL= Learning Landscapes (renovated playgrounds), non-LL= Non-Learning Landscapes, NW= Normal weight, OW/OB= Overweight/Obese.

After School Activity

We defined the after school period from the end of the school day until 5PM. Mean (SE) percent of after school time spent in MVPA was 10.4 (±0.5). We observed a significant effect of sex (p=0.033) indicating that boys are more active than girls during this time. No significant differences were observed with playground status (p=0.593) or weight status (p=0.282). No significant interactions were observed between playground status and weight status (p=.969), playground status and sex (p=.581) or sex and weight status (p=.108). Minutes and percent time spent in MVPA between sex, playground and weight status are displayed in Table 3.

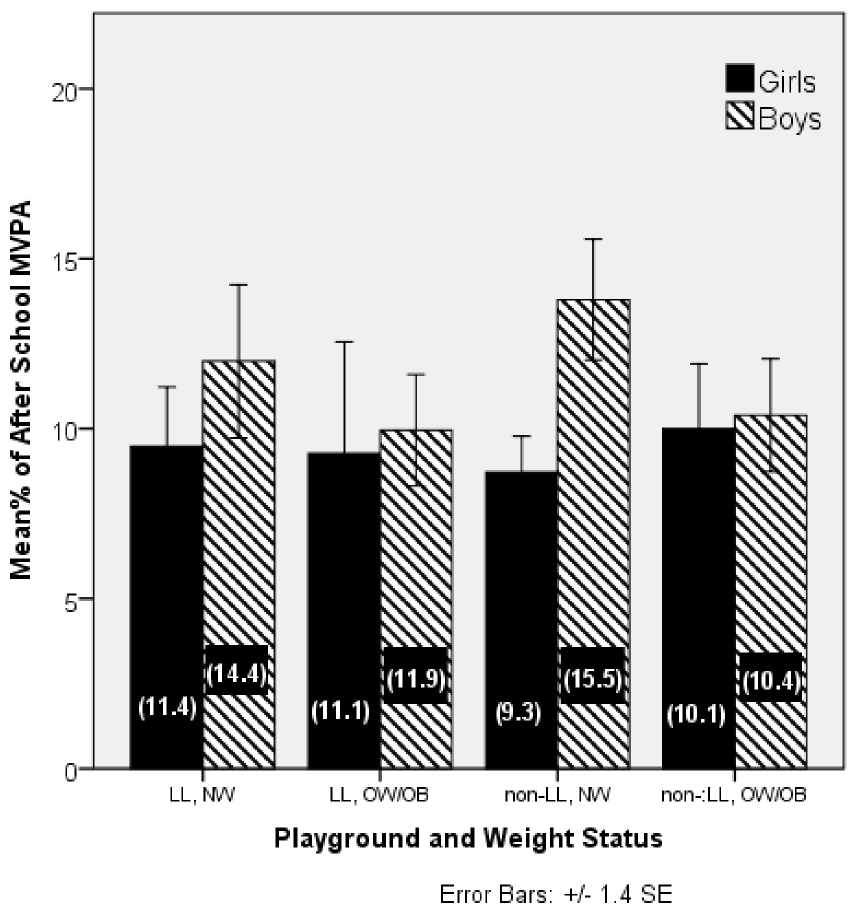

Figure 53. Mean percent of MVPA after school. Error bars (1.4 SEM) represent the Least Significant Difference. Bars that do not overlap indicate significant differences. Values inside bars represent

minutes of MVPA during recess. LL= Learning Landscapes (renovated playgrounds), non-LL= Non-Learning Landscapes, NW= Normal weight, OW/OB= Overweight/Obese.

Meeting Current PA Guidelines

Overall, 63.9% of our population met the current PA guidelines of ≥60 minutes per day of MVPA. We defined the day as 6AM-11PM. Odds Ratios (OR) revealed a significant association between sex and meeting the guideline (OR=2.85, p<.001), indicating that boys are 2.85 times more likely to achieve 60 minutes of MVPA per day than girls. No significant association between LL and non-LL in the occurrence of children meeting the guideline for PA was observed (OR=0.895, p=0.662).

Table 3. Percent (SEM) of subject population meeting current PA guidelines

	Learning Landscapes				**Non-Learning Landscapes**			
	Girls		**Boys**		**Girls**		**Boys**	
	NW	OW/ OB	NW	OW/ OB	NW	OW/ OB	NW	OW/ OB
% ≥60 min MVPA (Weekday)	57.4 (6.8)	35.3 (11.3)	87.5 (8.2)	71.4 (8.8)	45.5 (7.0)	66.7 (9.5)	74.5 (6.5)	65.4 (9.1)

CHAPTER V

Discussion

The aim of this study was to evaluate the effects of renovated (Learning Landscapes, LL) playgrounds on levels of physical activity in elementary school children during recess, the school day, and after school using accelerometry. The results demonstrated that children in LL schools participate in greater amounts of MVPA than their non-LL counterparts during recess and the school day. No differences were observed in the afterschool period. Additionally, children in LL were no more likely than their non-LL counterparts to achieve the recommended 60 minutes of MVPA per day.

In our sample, the average number of recess minutes each day ranged from 15 (recess only) – 45 (combined lunch/recess). Because recess is the primary means by which children accumulate MVPA during the school day, it is vital that these children take advantage of this period to engage in MVPA [89]. Our recess results revealed that children participate in an average of 7.9 minutes of MVPA, representing a range of 20.2-42.6% of recess. On a percentage basis, this is similar to Ridgers et al., who reported a range between 21.9% to 38.1% [138]. An additional study by Ridgers et al. reported boys and girls to be spending 32.9% and 23% of recess in MVPA, respectively [139]. However, when examining minutes of MVPA in their study, a very different story emerges. These percentages represented 28 and 21.5 minutes of MVPA for boys and girls, respectively, indicating that children were allotted approximately 90 minutes of recess daily [139]. These results indicate that children spend a relatively similar percent of recess time engaged in MVPA, rather than an absolute number of minutes. This is likely due, in part, to children's intermittent pattern of activity, whereby spontaneous short bouts of high intensity activity are alternated with longer bouts of standing or resting [140]. If this is the case, increasing recess duration may be a necessary strategy for increasing recess MVPA [13, 138]. Others support this idea, suggesting that increasing recess duration allows children ample time to organize games [141] and habituate to the playground environment [13]. Ridgers et al. assessed recess duration and found a positive interaction between a PA intervention and recess duration, indicating that the intervention effect was stronger with increasing recess time [138]. When stratifying our data by recess duration (minutes), an interesting trend is revealed. As the number of recess minutes increases up to 30 minutes, so does the percent of time spent in MVPA (see Table 4). This provides further evidence for the importance of recess duration. Further investigation into the temporal characteristics of the recess period to understand how MVPA is accumulated within this time period is warranted.

Table 4. Mean percent time spent in MVPA during recess stratified by recess duration. Time (min) represents total recess duration.

Time (min)	Mean % Time in MVPA (SD)	N
15	21.52 (9.81)	43
18	25.24 (12.22)	26
20	27.80 (13.39)	24
23	27.22 (10.14)	30
25	28.48 (12.58)	22
30	38.86 (17.19)	67
45	24.66 (12.66)	57
Total	28.63 (14.60)	269

When stratified by playground status (LL vs. non-LL), our data demonstrate that children with access to LL playgrounds spend a significantly greater percent of recess time in MVPA than children in non-LL, regardless of recess duration. Preliminary studies assessing playground renovations describe mixed results [13, 17, 35, 94]. Two studies using direct observation, the System for Observing Play and Leisure Activity in Youth (SOPLAY), demonstrate that while overall utilization was higher on renovated playgrounds, the intensity of activity was not [35, 94]. Another study using SOPLAY demonstrated that children were more active on renovated vs. non-renovated playgrounds [17]. Only one study using accelerometry showed positive, but non-significant, effects of the playground renovation [13]. These mixed results may be due, in part, to the varying methods of PA assessment and highlights the need for standardization of PA measurement. It is also important to distinguish longitudinal studies on renovated playgrounds from cross-sectional studies. Ridgers et al. has used accelerometry to assess the short-term (6 week) [13] and long-term (6 month) [138] effects of playground renovations, and demonstrated increased activity levels at shorter time points, disappearing after longer follow-ups [138]. Our cross-sectional results indicate significant differences between renovated and non-renovated playgrounds. Because these playgrounds were built between the years of 2004-2005, and data was collected in Spring of 2010, the higher levels of activity are likely not attributed to novelty effects. Although we matched control schools on ethnicity, percent receiving free and reduced lunch, and school size, there may have been baseline differences in activity levels between groups.

Typically, a significant decline in PA is seen as children age [62]. However, it is most pronounced during early adolescence, continuing into adulthood [142]. Consistent with others who have assessed PA in elementary aged children [139, 143], we did not observe any significant differences between the age groups (1st, 3rd, and 5th grade) in recess (p=.556), school day (p=.638) or after school (p=.464) percent of time spent in MVPA. This reflects the idea that the age-related decline in PA may begin later during childhood, typically at the onset of puberty [62].

The significant differences between boys' and girls' activity during recess are consistent with many other groups [85, 139]. Although the reasons behind these differences are not completely understood, it is thought that the social context around playtime may differ between sexes. Blatchford et al. describes that boys engage in more social behavior while girls in more parallel and solitary behavior, and proposes that playgrounds are social settings particularly suited for boys [144]. In one study, Blatchford et al. demonstrated that while boys were more likely to participate in ball games, girls were more likely to participate in conversation, sedentary play, jump skipping and verbal games [144]. Sarkin et al. examined differences between activity levels of fifth graders during recess and PE, and found that while boys were similarly active during these two periods, girls were significantly less active during recess than PE [85]. This suggests that girls may benefit from more structured activity, rather than the free play that recess provides. A promising strategy for increasing PA during recess is to introduce curriculum during the recess period. SPARK is one program aiming to do this through the creation and implementation of school-based physical activity curriculum [145]. Initial research on the effectiveness of SPARK during PE is promising [15], though no studies have assessed its effectiveness during the recess period. Additional strategies to increase MVPA during recess include the provision of game equipment [141], increased teacher supervision [146] and painting of court lines and colored markings [92]. All of these approaches have proven effective in the short-term in increasing time spent in MVPA during recess. Additional long-term studies assessing the combination of playground renovations with these other methods are warranted.

Schools provide many opportunities for children to participate in PA, especially when considering that children spend more waking time at school than any other place away from the home [75, 76]. Because the school day represents such a large percentage of children's waking hours, we elected to assess school day activity. Our results demonstrated significant differences across sex, weight status and playground environment ($p<0.05$). Importantly, because recess is considered a part of the school day, we elected to analyze the school day with the recess period included. Interestingly, while no effect of weight status was seen during recess only (p=.096), a significant difference was observed when assessing the school day, demonstrating that normal weight children were significantly more active throughout the school day than overweight/obese children (p=.014). This may imply that while overweight children are as active as their normal weight counterparts during unstructured playtime (i.e., recess), they may not be participating in other opportunities for PA during the school day, including PE, classroom fitness breaks, transitions between classes and other classroom based PA opportunities. A similar pattern, termed "compensation," is observed in adults, whereby spontaneous physical activity decreases when individuals begin an exercise program [147]. Perhaps overweight children perceive that they are sufficiently active during recess, and therefore do not participate in other opportunities for PA throughout the day. Because few studies have actually reported PA across the entire school day, more detailed analyses of school day activity should be conducted, with particular emphasis on understanding these additional opportunities for PA and where differences between normal weight and overweight children emerge.

Thermal Mapping

One method in which to examine whole day activity patterns is thermal mapping. To graphically represent a high activity and low activity child throughout a day, a cluster heat map was utilized (see figure 6). This technique is described elsewhere [148]. Darker colors represent sedentary time while lighter shades indicate periods of activity. Days 1 and 2 are weekdays, while Day 3 represents a weekend day. This is one way that researchers may begin to investigate PA patterns throughout the course of a day, to understand where differences in the temporal characteristics of activity lie.

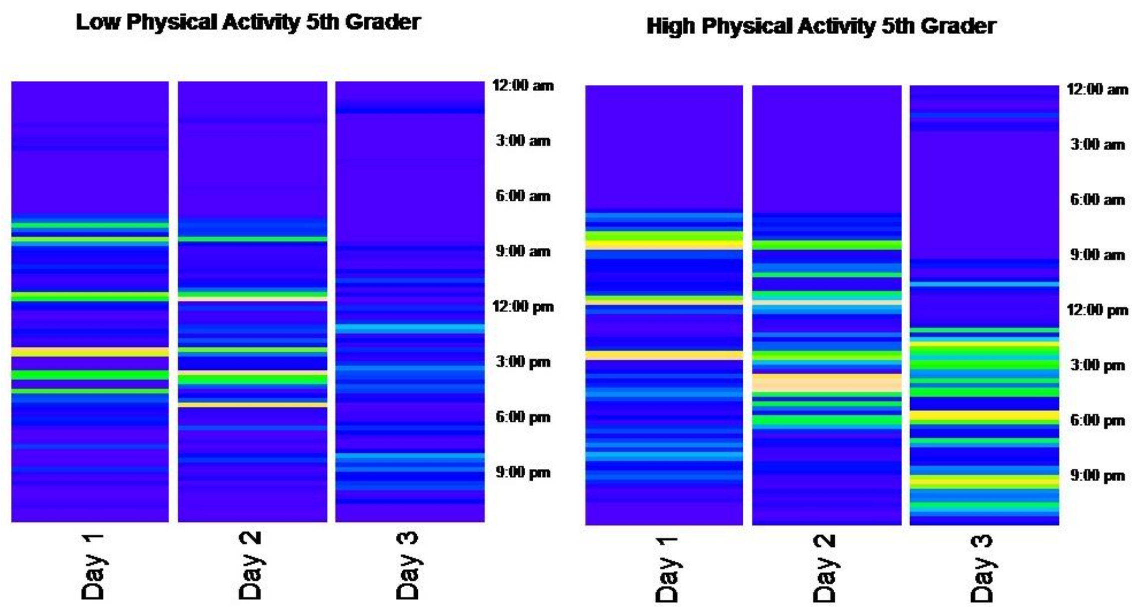

Figure 6. Thermal Mapping Example of Low and High Activity 5th Grader

When examining the interaction between weight and playground status during the school day, we observed that normal weight children were more active than overweight children only in LL, and this is not the case in non-LL. This may suggest that while the presence of renovated playgrounds work well for normal weight children, no such effect is seen among overweight children. It seems counter-intuitive that this interaction would be observed in the school day but not during recess, the primary time period in which the playgrounds are utilized. While detailed records of regularly-scheduled recess times were kept during the week of data collection, it is possible that extra play time on the playgrounds was given spontaneously and not recorded.

The after school period represents an additional opportunity for children to accumulate PA during the day [149]. In order to capture after school activity, we analyzed the period from the end of the school day (school specific) until 5pm.

Consistent with others, mean minutes of MVPA accumulated during this time ranged from 9-15 minutes. To our knowledge, only two other studies have assessed the after school time period in large groups of children using accelerometry [149, 150]. Brockman et al. assessed the after school period (3pm-6pm) in 747 primary school children and found that minutes of MVPA ranged from 7.5-13.3 minutes [150]. Dzewaltowski et al. assessed the effectiveness of an after-school program and found a range from 11.33-20.98 minutes [150]. Similar to these groups, the only significant difference observed during this period in our sample was between boys and girls, where boys accumulated more activity than girls. Because no differences were observed between LL and non-LL playgrounds, this may suggest that children are not taking advantage of the playground environment after the school day. If this is the case, the after school period may represent an important time period in which to intervene. Offering after school programs that encourage the use of the playground environment, with structured activities particularly for girls, may be one strategy to increase PA during this time. Because of the very limited objective data on PA levels during the after school period, additional studies to understand after school activity patterns are warranted.

Current physical activity guidelines recommend that children participate in at least 60 minutes of MVPA per day. Combined NHANES data from 2003-04 and 2005-06 revealed that 41.4% of children ages 6-19 years met the guideline [62]. Our results revealed that approximately 64% of the students met the PA guideline during the weekday. The higher value in our population is likely reflective of the age differences between samples. Brodersen et al. demonstrated a drastic decline in PA between the ages of 11-12 and 14-15 years [151]. Therefore, the lower NHANES values are likely reflective of the low activity levels of children in the older age category (up to 19 years old). Interestingly in our sample, although children in LL were more active during recess, they were no more likely than their non-LL counterparts to achieve the recommended levels of MVPA. This may suggest that the recess period is not enough of a stimulus to have a meaningful impact on PA over the course of a full day. This provides additional support that recess duration is an important factor in accumulating MVPA [77, 138].

It is well accepted that over the course of the full day, boys accumulate more MVPA than girls [7, 62]. Similarly, odds ratios for our sample demonstrated that boys were more likely than girls to meet the PA guideline of 60 minutes of MVPA per day (OR=2.85, $p<0.001$). Interestingly however, girls are not more likely than boys to be overweight [2]. This suggests that from a weight management perspective, girls may not need to achieve the amount of PA that boys accumulate throughout the day. Perhaps the focus should be to increase overweight girls' levels of PA to those of the normal weight girls. Combined NHANES data from 2003-04 and 2005-06 for 6-11 year olds demonstrate that normal weight girls spend significantly more minutes per day in MVPA than overweight girls [62]. Some movement toward sex-specific PA guidelines has been made. Daily step guidelines differ in boys and girls, recommending that boys accumulate 15,000 steps per day while the recommendation for girls is 12,000 [152].

The selection of PA measurement tool is an important factor in interpreting results [153]. Because it is waterproof and calibrated for wrist placement in children, we elected to use the Actical accelerometer. However, the initial device calibration was done on children slightly older (ages 8-14 years) than our population [125]. We therefore elected to conduct a calibration study in our laboratory to establish cutpoints for sedentary, light, moderate and vigorous activity. To determine MET values of each activity, we divided subjects' measured VO_2 values both by resting VO_2 values measured in our laboratory, as well as by estimated resting values based on the Schofield equations [137]. The values for each of these methods vary substantially. Because we did not use stringent criteria for the resting measurement, we elected to use the estimated values from the Schofield equations to establish cutpoints. Inherent in every set of cutpoints are multiple decisions regarding MET cutoffs, the calculation of resting VO_2, and the specific activities chosen for the calibration. It is therefore critical that the research community begin to move toward the collection of raw acceleration data [121, 154]. This standardization will allow researchers to confidently interpret results and make comparisons across studies. It would also provide the precision necessary to accurately capture the short bouts of vigorous activity that are characteristic of children's activity patterns.

Strengths

The strengths of this study include a large sample size and the multi-day data collection. Largely attributable to the placement of the device on the wrist, our compliance was also very high (97%) eliminating any selection bias that may have occurred. We also collected data across the age spectrum, from first to fifth graders. Our sample was socioeconomically and ethnically diverse, with 76.9% receiving free and reduced lunch, 62% Hispanic, 28% White, 6% African-American, 3% Asian and 1% American Indian. Finally, we are confident that our findings were not due to the novelty of the playground environment. These data were collected in the spring of 2010, while the LL playgrounds were constructed in 2004-2005. Therefore, we are confident that any novelty of these environments had likely disappeared by the time data was collected.

Limitations

This study was not without limitations. We elected to use a wrist-mounted accelerometer. Upon analysis of the data using device software, we decided to conduct a calibration study of the device in our laboratory and applied these cutpoints to the data. While we acknowledge the challenges associated with establishing cutpoints, the majority of our comparisons were between-groups, thereby eliminating any error inherent in the cutpoints. Additionally, schools vary greatly with regard to scheduling, particularly the lunch and recess periods. Some schools provide a combined lunch/recess period, whereas others have defined recess-only periods during lunchtime. To account for any differences in recess duration, we analyzed the data on a percentage basis. However, there may be differences based on the type of lunch recess period (separate vs. combined) that our data do not have the precision to detect. Further analysis of the effects of different types of recess periods on MVPA should be conducted. Although schools were matched on size, ethnicity and percent receiving free and reduced lunch, because of the community-based nature of this research, there could have been other potential confounders that were not controlled for in the analysis. Finally, we relied on teachers to provide accurate times for recess, PE, school start and end time, and other active periods. We therefore acknowledge that some inaccuracies regarding times may have been reported. If, for example, additional recess opportunities were provided but not recorded on the teacher log, some overestimation of non-recess school day activity may have been observed. However, because we did not remove recess from our school day analysis, our school day comparisons were reflective of all activity taking place in a given day. The results of this cross-sectional study may not be generalizable to the general population. These data were collected in lower SES schools with a large number of Hispanic children. Therefore, care must be taken in generalizing these results. Finally, our cross-sectional study design does not allow for cause and effect conclusions to be drawn, but rather represents a snapshot of activity taking place between schools with LL playgrounds and schools without.

Conclusion

This study utilized wrist-based accelerometry to examine the role of renovated playgrounds on levels of PA in elementary school children. Our results indicate that children, particularly boys, on renovated playgrounds participate in more MVPA during the recess period and school day than those without access to LL playgrounds. Additionally, children with renovated playgrounds were not more likely to meet the PA guidelines than children without renovated playgrounds, likely due to the limited amount of recess time allotted. Therefore, although renovated playgrounds encourage a greater percentage of time spent in MVPA during recess, in order for children to achieve physical activity guidelines, further opportunities for PA should be provided.

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APPENDIX A

HUMAN SUBJECTS APPROVAL

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011
Fort Collins, CO
TEL:#(970) 491-1553
FAX:#(970) 491-2293

NOTICE OF APPROVAL FOR HUMAN RESEARCH

DATE:	July 29, 2009	
TO:	Browning, Ray, PhD, Health & Exercise Science	
	Israel, Richard, EdD, Health & Exercise Science	
FROM:	Barker, Janell, CSU IRB 1	
PROTOCOL TITLE:	The Impact of an Environmental and Curriculum Change on Children's Obesity Related Behaviors	
FUNDING SOURCE:	National Institute of Health : 082476	
PROTOCOL NUMBER:	09-1142H	
APPROVAL PERIOD:	Approval Date: July 29, 2009	Expiration Date: July 15, 2010

The CSU Institutional Review Board (IRB) for the protection of human subjects has reviewed the protocol entitled: The Impact of an Environmental and Curriculum Change on Children's Obesity Related Behaviors. The project has been approved for the procedures and subjects described in the protocol. This protocol must be reviewed for renewal on a yearly basis for as long as the research remains active. Should the protocol not be renewed before expiration, all activities must cease until the protocol has been re-reviewed.

If approval did not accompany a proposal when it was submitted to a sponsor, it is the PI's responsibility to provide the sponsor with the approval notice.

This approval is issued under Colorado State University's Federal Wide Assurance 00000647 with the Office for Human Research Protections (OHRP). If you have any questions regarding your obligations under CSU's Assurance, please do not hesitate to contact us.

Please direct any questions about the IRB's actions on this project to:

Janell Barker, Senior IRB Coordinator - (970) 491-1655 Janell.Barker@Research.Colostate.edu
Evelyn Swiss, IRB Coordinator - (970) 491-1381 Evelyn.Swiss@Research.Colostate.edu

e-protocol

Janell Barker

Barker, Janell

Includes: Approval is for a maximum of 500 children, grades 1st, 3rd and 5th using the approved assent form and the approved consent form for the parents.**Please submit COMIRB's approval once obtained for our files; the approval will need to be submitted as an amendment.**

Approval Period:	July 29, 2009 through July 15, 2010
Review Type:	EXPEDITED
IRB Number:	00000202

Page: 1

Colorado State University
Knowledge to Go Places

Research Integrity & Compliance Review Office
Office of the Vice President for Research
321 General Services Building - Campus Delivery 2011
Fort Collins, CO
TEL:#(970) 491-1553
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Funding: National Institute of Health : 082476

Notes: Parental consent must be obtained for participants who are minors.

e-protocol

INFORMED CONSENT

Consent to Participate in a Research Study
Colorado State University

TITLE OF STUDY: The Impact of an Environmental and Curriculum Change on Children's Obesity Related Behaviors

PRINCIPAL INVESTIGATOR: Ray Browning, PhD. 970-491-5868

WHY IS YOUR CHILD BEING INVITED TO TAKE PART IN THIS RESEARCH? Your child's elementary school is participating in a research project and your child's class was randomly selected to participate in this research. Our research will explore how school playgrounds, a program to increase physical activity during recess, and classroom instruction on healthy behaviors affect the levels of physical activity of the students.

WHO IS DOING THE STUDY? This research is being performed by Ray Browning, Ph.D., of the Health and Exercise Science Department at Colorado State University. Trained graduate students, undergraduate students, research associates, or research assistants are assisting with the research.

WHAT IS THE PURPOSE OF THIS STUDY? The number of children who are not physically active or overweight continues to increase and we need programs that can increase children's levels of physical activity. The purpose of this study is to determine if changes in school playgrounds, PE classes and recess result in increases in physical activity of the students during the school day as well as before and after school.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? This study will take place at your child's school and home. Your child will be asked to wear a small device that measures movement for 6 consecutive days. During this 6 day period, we anticipate that you will need to spend approximately 30 minutes (total) of your time helping your child.

WHAT WILL WE BE ASKED TO DO? During the 6-day study period, your child will be asked to wear a small, waterproof device (an accelerometer) that measures their body movements. Your child will wear the device on a band attached to his/her wrist. The child will be asked to keep it on at all times, unless otherwise specified. The days that your child wears the device should be typical and your child will not be asked to do anything out of the ordinary. Study personnel will contact you and your child at various times throughout the study period to confirm that your child is wearing the device and to answer any questions. We will also measure and record your child's height and weight at the beginning of the study period.

ARE THERE REASONS WHY YOUR CHILD SHOULD NOT TAKE PART IN THIS STUDY? Because this research does not require you or your child to change your daily activities, there are no known reasons why your child should not participate.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

- Height and Weight measurement: Your child may not be comfortable having their height and weight recorded in public. In this case, we will measure your child's height and weight in private. If your child does not want to see/know his/her height or weight the information will be kept private.
- Instrumentation: the device used to measure your child's movements is non-invasive and poses no known risk.
- It is not possible to identify all potential risks in research procedures, but the researchers have taken all reasonable safeguards to minimize any known and potential, but unknown, risks.

 Participant's initials _______ Date _______

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? There are no direct benefits to you or your child for participating in this study.

DOES MY CHILD HAVE TO TAKE PART IN THE STUDY? Your child's participation in this research is voluntary. If you and your child decide to participate in the study, you may withdraw your consent and your child can stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHAT WILL IT COST US TO PARTICIPATE? There is no cost to you for participating.

WHO WILL SEE THE INFORMATION THAT WE GIVE? We will keep private all research records that identify your child, to the extent allowed by law.

Your child's information will be combined with information from other children taking part in the study. When we write about the study to publish or share it with other researchers, we will write about the combined information we have gathered. Your child will not be identified in these written materials. Your child's name will be kept separate from your child's research records and these two things will be kept private and stored in different places under lock and key.

CAN MY CHILD'S TAKING PART IN THE STUDY END EARLY? Your child's participation in the study could end in the rare event of an injury or illness that prevents them from attending school.

WILL WE RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? Your child will receive a $10 gift card to a local department store at the start of the study, and an additional $10 gift card at the end of the study. When your child returns the accelerometer at the end of the study period, you will receive a $30 gift card to the same local department store.

WHAT HAPPENS IF I AM INJURED BECAUSE OF THE RESEARCH? The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

WHAT IF I HAVE QUESTIONS?
Before you decide whether to accept this invitation for your child to take part in the study, please ask any questions that might come to mind by contacting Chrissy Schaefer at 970-492-4072. If you have any questions about your rights as the parent of a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655. You will keep a copy of this consent form to have on file. This consent form was approved by the CSU IRB for human subjects protection on March 1, 2010.

Study staff will contact you various times throughout the six day study period to answer any questions you may have. Please note your preferred method of contact with an "X" below, as well as the corresponding information.

Phone: ____ Text message: ____ Email: ____

Phone number: ________________
Email address: ____________________________

Participant's initials _______ Date _______

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 3 pages.

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Child's Name

_______________________________________ ____ ________________
Parent Signature Date

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Printed name of parent

_______________________________________ ________________
Name of research staff providing information to participant Date

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Signature of Research Staff

Participant's initials _______ Date _______

INFORMED ASSENT

Hi!

I'm a teacher at Colorado State University. I study physical activity and exercise. This is called research. My research is about how much you move each day. I am asking you if it is OK that I study you for 6 days while you do your normal everyday activities.

If you say it is OK, I'll ask you to wear a very small plastic box that is attached to a band that you will wear around your wrist. You will wear this box every day for 6 days. You will keep the box on all the time, except maybe when you take a bath or go swimming. We will check with you during the week to make sure you are wearing the box and to answer any questions you may have. After 6 days, you will bring the box back to school and return it to us.

Agreeing to be in this project cannot hurt you. It won't help you, either. You and your family will receive a gift card for doing it. You don't have to do it. If you say "yes" now but later change your mind, you can stop being in the research any time by just telling me.

I will ask your parents if it is OK that you do this, too. If you want to be in this research, sign your name and write today's date on the line below.

____________________________ ________________

Child Date

____________________________ ________________

Researcher Date