PHYSICAL ACTIVITY BY SCHOOLYARD LOCATION: CURRENT LITERATURE, COMPARISON WITH ACTIVITY TYPE, AND USE OF A GPS-BASED APPROACH

By

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PUBLIC ABSTRACT

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Participation in physical activity is associated with numerous benefits. Promoting this behavior in young children is particularly important due to the potential for life-long benefits and because physically active children often become physically active adolescents and adults. The physical environment allows children to participate in specific behaviors, which in turn impacts participation in physical activity (e.g., grassy areas allow children to participate in running games). Understanding how the school environment affects children's physical activity can help researchers and practitioners develop interventions that promote physical activity attainment and the associated short- and long-term benefits in large numbers of children. Of particular interest is the schoolyard, as outdoor time is one of the main opportunities for free-play during the school or childcare day. Prior research has suggested that certain aspects of the physical environment, such as having an open, grassy field, are important for physical activity in children. The first aim of this dissertation was to review the literature on how youths' physical activity varies by location on the schoolyard. We found 24 studies on this topic, which generally supported that physical activity is not uniform across the schoolyard. There is also evidence to suggest that the locations which promote the highest levels of physical activity vary by age group (e.g., preschool vs. adolescence) and by sex. This information could be used to inform interventions to promote physical activity participation in all youth, including those with the lowest levels of physical activity, such as adolescents and girls. However, this review brought to light a number of gaps in the literature- namely the lack of control of or consideration for other potentially impactful variables, such as the time of year or other provided equipment. To truly understand the role of the physical environment, a method is needed that can be used to

measure physical activity by schoolyard location in a large number of schools. Recent research has supported the use of monitor-based approaches, like Global Positioning Systems (GPS) receiver units, which collect continuous, individual-level data on a child's location, and, when paired with accelerometry, physical activity intensity. However, the majority of studies have relied on direct observation and, in preschoolers, this most often involves recording the child's activity type and their physical activity level, not their location. It is unknown how comparable measuring physical activity by location is to prior research that used a physical activity by activity type-based approach. The second aim of this dissertation was to identify how similar activity type and location are in a preschool sample. We report that children participated in multiple types of activities within each location, but all locations had a primary activity type, in which children were engaged for 52.7-94.5% of their time in that location. Children spent the majority of outdoor time in open spaces (37.6-48.9%), and physical activity was highest during teacher arranged activities or while children were located on the fixed equipment. This finding provides some information about the limitations of using a location-focused methodology, like GPS plus accelerometry. The final aim of this dissertation was to use GPS plus accelerometry to identify where children are being active on the schoolyard and how this changes over the course of the day and over the course of an individual outdoor period. We demonstrate that the location of high and low levels of physical activity changed over the course of the outdoor period and over the course of a day, supporting our hypothesis that consideration of both location and time is important for understanding children's physical activity participation during provided outdoor time. In conclusion, the physical environment influences participation in physical activity. GPS plus accelerometry is a viable method for understanding both where and when children are being active, but there are a number of methodological limitations that still need to be overcome before this methodology can be used on a large scale to inform the design of and to assess the impact of schoolyard interventions.

ABSTRACT

PHYSICAL ACTIVITY BY SCHOOLYARD LOCATION: CURRENT LITERATURE, COMPARISON WITH ACTIVITY TYPE, AND USE OF A GPS-BASED APPROACH

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Participation in physical activity is associated with numerous benefits, including maintenance of healthy weight status, reduced risk of chronic disease, and improved psychosocial outcomes. Promoting this behavior in young children is particularly important due to the potential for life-long benefits and for tracking of this health behavior into adolescence and adulthood. The physical environment affords specific behaviors, which in turn impacts participation in physical activity. Understanding how the environment in venues such as schools affects children's physical activity can inform the development of interventions that promote physical activity attainment and the associated short- and long-term benefits in large numbers of children. Of particular interest is the schoolyard, as outdoor time is one of the main opportunities for free-play during the predominantly sedentary school or childcare day. Prior research has suggested that certain aspects of the schoolyard environment, such as having an open, grassy field, are important for facilitating physical activity in children. The first aim of this dissertation was to systematically review the literature on how youths' physical activity varies by location on the schoolyard. Only 24 studies met our inclusion/exclusion criteria and generally supported that physical activity is not uniform across the schoolyard. There is also evidence to suggest that the locations that elicit the highest levels of physical activity vary by age group (e.g., preschool vs. adolescence) and by sex. This information could be used to inform interventions to promote physical activity participation in all youth, including those with the lowest levels of physical activity, such as adolescents and girls. However, this review brought to light a number of gaps in the literature- namely the lack of control of or consideration for other potentially impactful variables, such as the time of year or provided portable equipment. To understand the role of

the physical environment, in conjunction with and separate from these other variables, a method is needed that can be used to measure physical activity by schoolyard location in a large number of schools, children, settings, and situations. Recent research has supported the use of monitor-based approaches, like Global Positioning Systems (GPS) receiver units, which collect continuous, individual-level data on a child's location, and, when paired with accelerometry, physical activity intensity. However, the majority of studies have relied on direct observation and, in preschoolers, this most often involves recording activity type and physical activity level, not location. It is unknown how comparable measuring physical activity by location is to prior research that used a physical activity by activity type-based approach. The second aim of this dissertation was to identify how similar activity type and location are in a preschool sample. We report that children participated in multiple types of activities within each location, but all locations had a primary activity type, in which children were engaged for 52.7-94.5% of their time in that location. The majority of outdoor time was spent in open spaces (type or location; 37.6-48.9%), but there was a disparity in the setting that promoted the highest activity levels between methods (teacher arranged activity type, but fixed equipment location). This finding provides information about the limitations of using a location-based methodology, like GPS plus accelerometry. A second issue when using GPS plus accelerometry is lack of consensus as to how to analyze these data. The final aim of this dissertation was to explore the use of hot spot analysis with spatiotemporal weights matrices to identify statistically significant clusters of high/low accelerometer vector magnitude counts/15-s. The location of hot/cold spots changes over the course of the outdoor period (intraperiod) and over the course of a day (interperiod), supporting our hypothesis that both location and time are important when aiming to understand children's physical activity participation during provided outdoor time. GPS plus accelerometry is a viable method for understanding both where and when children are being active, but there are methodological limitations that need to be overcome before this methodology can be used on a large scale to inform the design of and to assess the impact of schoolyard interventions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Participation in physical activity is associated with numerous physical and psychosocial short- and long-term benefits (Burdette & Whitaker, 2005; Janssen & LeBlanc, 2010; Reilly & Kelly, 2011; United State Department of Health and Human Services [USDHHS], 2018). As such, it is recommended that preschool-aged children attain 15 min/hour of physical activity, including light, moderate, and vigorous intensities during childcare (McGuire, 2012), and be active throughout the day (USDHHS, 2018), while children and adolescents should participate in at least 60 minutes/day of moderate-to-vigorous physical activity (USDHHS, 2018). Unfortunately, only 24.2% of 6- to 17-year-old youth meet these recommendations (National Physical Activity Plan, 2018). While national data are not yet available, approximately half, but potentially an even smaller proportion, of preschool-aged children meet daily activity recommendations (Cardon, Van Cauwenberghe, Labarque, Haerens, & De Bourdeaudhuij, 2008; Pate et al., 2015; Tucker, 2008). Lack of participation in physical activity during early childhood increases risk for obesity and its comorbidities, throughout childhood and into adolescence and adulthood (Freedman, Khan, Dietz, Srinivasan, & Berenson, 2001; Guo, Wu, Chumlea, & Roche, 2002; Herman, Craig, Gauvin, & Katzmarzyk, 2009; Reilly & Kelly, 2011), while participation in physical activity improves motor skills and leads to further participation in activity throughout the lifespan (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2009; Telama, 2009; Telama et al., 2005).

Participation in physical activity is driven by one's surrounding environment. As posited by Gibson's theory of affordances, our environment offers opportunities for action, called affordances, and this subsequently drives our actions (Gibson, 1977). If the environment affords physically active play, this ultimately leads to participation in physical activity (Cosco, 2006). The childcare or school environment is an ideal place to promote physical activity participation because most children and adolescents regularly attend some form of childcare or schooling (McFarland et al., 2017). The school environment has also been identified as one of, if not the most, salient predictors of children's school day physical activity (Guinhouya et al., 2005; Iruka & Carver, 2006; Mota et al., 2005; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004). In young children, Pate, McIver, Dowda, Brown & Addy (2008) found that the preschool attended accounted for 27.6% of the variability in school day physical activity, while other studies suggest that the preschool attended accounts for over half of the variability between young children in school day physical activity (Gubbels et al., 2011; Tandon, Saelens, Zhou, Kerr, & Christakis, 2013; Vanderloo et al., 2014). This between-school variability supports that aspects of the school environment influence physical activity participation. Understanding how the environment affects children's physical activity can inform the development of school-based interventions that promote physical activity attainment and the associated short- and long-term benefits.

During the school or childcare day, outdoor settings elicit higher levels of physical activity compared to indoor settings (Ramstetter, Murray, & Garner, 2010; Tandon et al., 2013), and outdoor time (e.g., recess) provides the greatest, if not only, opportunity for unstructured free-play during the predominantly sedentary day (Ramstetter et al., 2010; Tandon, Saelens, & Christakis, 2015; Tandon et al., 2013). School outdoor time contributes up to 70% of children's weekday physical activity (Guinhouya et al., 2009; Mota et al., 2005; Ridgers, Stratton, & Fairclough, 2006), but children still spend the majority of outdoor time being sedentary (Brown, Pfeiffer, et al., 2009; Ridgers, Stratton, & Fairclough, 2005; Sugiyama, Okely, Masters, & Moore, 2012). In line with Gibson's theory of affordances, features of the schoolyard environment have been shown to influence physical activity participation during provided outdoor time (Broekhuizen, Scholten, & de Vries, 2014). For example, schoolyard size (Boldemann et al., 2006; Dowda et al., 2009), amount of available equipment (Ridgers, Fairclough, & Stratton, 2010), and presence of a grassy field (Berg, 2015; Brown, Pfeiffer, et al., 2009) have all been associated with physical activity participation. However, some findings have been inconsistent between studies, so no consensus can be made as to which schoolyard features have the greatest impact on physical activity participation and therefore, implications for schoolyard design are unclear.

Findings may be inconsistent due to the types of studies that have predominated to date. Research that has correlated the presence or absence of particular features of the outdoor environment to overall physical activity levels (Berg, 2015; Boldemann et al., 2006; Broekhuizen et al., 2014; Cardon et al., 2008; Dowda et al., 2009; Gubbels, Van Kann, & Jansen, 2012; Gunter, Rice, Ward, & Trost, 2012; Haug, Torsheim, Sallis, & Samdal, 2008; Ridgers et al., 2010) cannot inform us as to where, how long, and how intensely children play on the schoolyard and therefore, we have no understanding of what children are actually doing during outdoor time. It is critical to know where children are spending time and being active during outdoor time if the goal is to design activity-promoting schoolyards that children will actually use.

Studies of preschoolers support that physical activity varies by schoolyard location (Cosco, Moore, & Islam, 2010; Nicaise, Kahan, & Sallis, 2011) and Smith et al. (2014) reported that 23% of the variance between children's physical activity could be explained by features of the setting in which a child was located within the schoolyard (e.g., open area, sand area). There are a small number of studies, so a final conclusion cannot be made, but research suggests that while preschool-aged children may be most active in open areas or on fixed equipment (Cosco et al., 2010; Nicaise et al., 2011), adolescents may be most active on ball courts (Fjørtoft, Löfman, & Thorén, 2010; Sallis et al., 2001). Some studies of older children and adolescents also suggest that there are differences in physical activity within locations by age (Fjørtoft, Kristoffersen, & Sageie, 2009; Pawlowski, Andersen, Troelsen, & Schipperijn, 2016) and sex (Farley, Meriwether, Baker, Rice, & Webber, 2008; Saint-Maurice, Welk, Silva, Siahpush, & Huberty, 2011). While certain schoolyard locations favor physical activity in boys compared to girls, sex differences in physical activity participation are mitigated in other areas of the schoolyard (Farley et al., 2008; Fjørtoft et al., 2009; Saint-Maurice et al., 2011). Differences in physical activity by location overall and by group have important implications for the development of schoolyard designs and interventions that promote physical activity in all children or specifically promote physical activity in groups of children with low physical activity levels, like girls or adolescents.

Research on how schoolyard location affects physical activity participation should be conducted in a large number of schools to better understand the influence of schoolyard size (Boldemann et al., 2006; Dowda et al., 2009), available equipment (Cardon et al., 2008; Gubbels et al., 2011; Gubbels et al., 2012), and quality (Bower et al., 2008; Gubbels et al., 2011), while also controlling for variables like child density (Cardon et al., 2008; Van Cauwenberghe, De Bourdeaudhuij, Maes, & Cardon, 2012), weather (Ridgers et al., 2010; Soini et al., 2014), or supervision (Brown, Googe, McIver, & Rathel, 2009; Cardon et al., 2008) (Broekhuizen et al., 2014). However, this has yet to be done, potentially due to the time-consuming nature of the available methods to assess location and physical activity on the schoolyard. Research on what children do during recess has primarily relied on direct observation, which can be limited by researcher burden and the difficulty collecting continuous data for each child across the entire schoolyard and outdoor recess period (Fulton et al., 2001). Monitor-based approaches, specifically, coupling Global Positioning System (GPS) receiver units with accelerometers, have successfully been used in older children and adolescents and can provide location, duration, and intensity of physical activity while limiting both researcher and participant burden (Andersen, Klinker, Toftager, Pawlowski, & Schipperijn, 2015; Clevenger, Sinha, & Howe, 2018; Fjørtoft et al., 2009; Fjørtoft et al., 2010; Pawlowski et al., 2016). Of note, Clevenger et al. (2018) reported that GPS plus accelerometry was comparable to video direct observation. These studies support that physical activity varies by schoolyard location and illustrate the feasibility of this methodology, which may facilitate the collection of data from a large number of participants on a variety of schoolyards.

While the use of monitor-based approaches is promising, there are some issues with using a monitor-based approach for understanding the context of schoolyard physical activity that we aim to address in this dissertation. First, we should consider how comparable these monitor-based approaches are to more traditional approaches, like direct observation. With direct observation, investigators can assess physical activity and its context, operationalized as the type of activity in which a child is participating (e.g., ball/object play) in the commonly used Observational System for Recording Physical Activity in Children-Preschool Version (OSRAC-P; Brown et al., 2006). However, a monitor-based approach, like GPS plus accelerometry, measures physical activity by schoolyard location. It is unknown how comparable activity type-based and location-based approaches are and if measuring physical activity by location masks important differences in activity type within locations between children or between groups (e.g., boys versus girls). Thus, it is important to identify physical activity types that occur within schoolyard locations to better understand the potential limitations of a monitor-based approach that captures physical activity by schoolyard location.

A second concern when using GPS plus accelerometry is lack of consensus on how to analyze or interpret these data for the purpose of identifying how location impacts children's physical activity (Clevenger et al., 2018). Researchers have used a variety of approaches to analyze this type of data, ranging from purely visualization approaches (e.g., dot or grid maps; Fjørtoft et al., 2009; Fjørtoft et al., 2010) to statistical methods (e.g., hot spot analysis; Pawlowski et al., 2016) (Clevenger et al., 2018). Consistency in methodology is critical to ensure comparability between studies, but methods used to date have one major limitation in that they do not allow for spatial information to vary over time. This is important because data are collected from children moving through both time and space, not stationary objects. This temporal information is also of interest because it has been shown that physical activity declines with recess duration (Holmes, 2012; McKenzie et al., 1997), so it is possible that the location of physical activity may also change over the course of the outdoor period. A spatiotemporal approach could be used to identify which areas of the schoolyard elicit physical activity at various time points during the outdoor period or day. Hot spot analysis using spatiotemporal (instead of spatial-only) weight matrices would allow researchers to identify clusters of points that are both spatial (e.g., within 3 m) and temporal (e.g., within 3 min) neighbors and consist of statistically higher- or lower-than-expected values in regard to a non-spatial attribute (e.g., accelerometer counts/15-s). This could be used to identify in which schoolyard locations children are physically active and how this varies over the course of provided outdoor time.

Summary

The environment influences behavior, and this means that we can promote health behaviors, like physical activity, through the design of activity-promoting environments. One location of interest is the schoolyard due to the ability to reach a large number of children, but more information is needed about what specific schoolyard locations or designs promote physical activity in children overall, and if there are differences by age or sex. Development of a monitor-based approach for assessing spatiotemporal patterns in physical activity participation on the schoolyard would facilitate data collection at a large number of schools that vary in schoolyard design features (e.g., size, amount of equipment). Before a monitor-based approach can be used on a large scale, research must be conducted on the utility and potential limitations of this method, specifically identifying what information may be missed when focusing on physical activity by schoolyard location, with disregard for other types of context, like activity type. Thus, it is the purpose of this dissertation to first, systematically review the literature on physical activity of children and adolescents by schoolyard location. Then, we use data from preschool-aged children to both identify activity types within schoolyard locations and demonstrate the use of a spatiotemporal approach to identify locations on the schoolyard where children are active and how this varies over the course of the outdoor period. This dissertation will inform future large-scale studies on physical activity by schoolyard location with the long-term goal of designing schoolyards that promote physical activity in all children.

Aims and Hypotheses

Aim 1. To systematically review the literature on children and adolescents' physical activity by schoolyard location.

Hypothesis 1a: Available literature will support that physical activity participation varies by schoolyard location.

Hypothesis 1b: Schoolyard locations that elicit the highest levels of physical activity will vary by age group (e.g., preschool versus adolescents).

Hypothesis 1c. Physical activity within schoolyard locations will vary by sex; boys will be more active than girls within some locations, but there will be no, or smaller sex-related differences in physical activity levels between boys and girls in other locations.

Aim 2. To compare an activity-type vs. location-based approach to characterizing children's schoolyard physical activity.

Hypothesis 2a. Preschoolers will participate in multiple activity types within each schoolyard location, but the majority of time in a schoolyard location will be spent in the activity type most relevant to that location (e.g., predominantly sandbox play within the sandbox location)

Hypothesis 2b. Physical activity (as vector magnitude) for a given activity type will vary by the location in which the activity occurred.

Hypothesis 2c. Physical activity (vector magnitude) will vary by both schoolyard location and activity type.

Aim 3. To identify the timing and location of spatiotemporal clusters in preschooler's physical activity on the schoolyard.

Hypothesis 3a. Global clustering will be present on the schoolyard.

Hypothesis 3b. Clusters will demonstrate temporal patterns within an outdoor period (intraperiod), such that some will be present only at the beginning or emerge towards the end of outdoor time, while others may be persistent over the outdoor period.

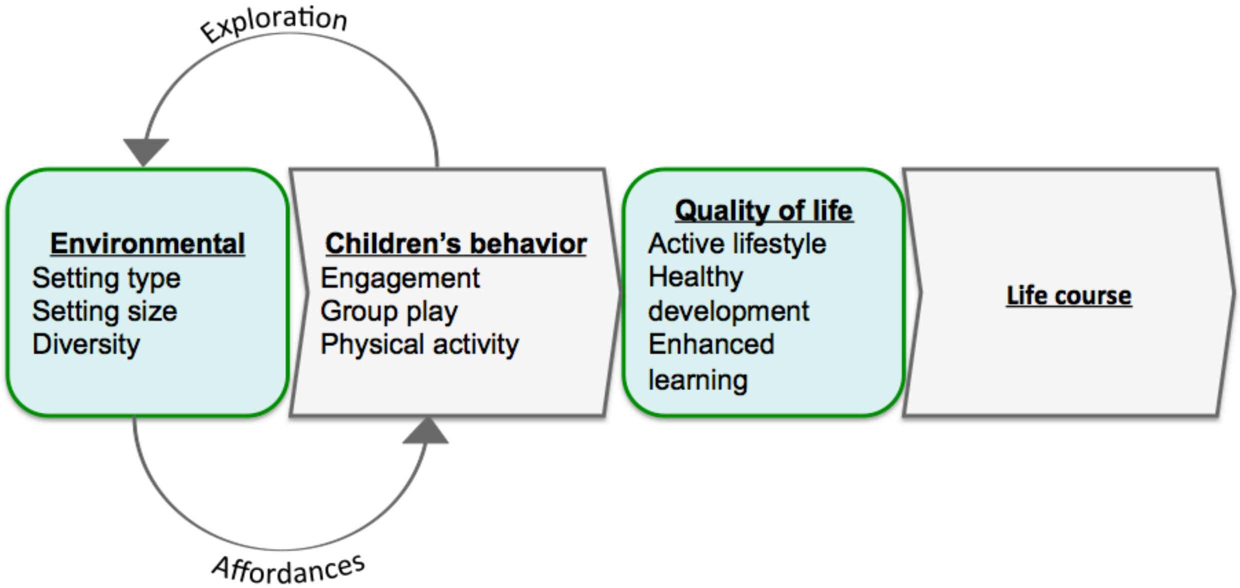
Hypothesis 3c. Timing and locations of clusters will differ between outdoor periods (interperiod).

CHAPTER 2: REVIEW OF LITERATURE
Theoretical Framework

Gibson's theory of affordances provides a theoretical basis for this line of research and posits that we perceive our environment as opportunities for action and this subsequently drives our actions (Gibson, 1977). So, if children perceive that climbing is afforded, they will climb. However, they do not inherently perceive all affordances in the environment but may perceive more affordances after exploration or development. As Gibson (1979) explains, "*The observer may or may not perceive or attend to the affordance according to his needs, but the affordance, being invariant, is always there to be perceived… The object offers what it does because it is what it is*" (Gibson, 1979). Cosco (2006) modeled the relationship between the environment and children's behavior through the theory of affordances, positing that the environment drives children's behavior through the child's perceived affordances for activity and this leads to further exploration of the environment, which can lead to further changes in behavior through additional perceived affordances (Figure 2.1). If the environment affords physical activity, this ultimately leads to an overall healthy lifestyle and development of healthy habits (Cosco, 2006).

While the physical environment impacts behavior, it is important to consider that behaviors, like physical activity, do not occur in isolation. While the structure of the environment affects behavior, human agency and other, often unmeasured factors, also play a role. Children are individuals moving through time and space who choose what to do during school outdoor time, but their choices are limited to what is available on their schoolyard (what the environment affords) and school policies regarding physical activity and outdoor time. Areas of the schoolyard are also occupied by other individuals and have pre-existing subtexts often unknown to researchers. Overall, the structure of the environment will affect physical activity participation, but the individual will also be affected by myriad other factors.

Figure 2.1. Relationship between environmental affordances, children's behavior, and future benefits (adapted from Cosco, 2006)



Physical Activity for Children and Adolescents

Physical activity has numerous benefits for both children and adolescents (collectively referred to as youth) and as such, recommendations have been made for daily physical activity attainment (McGuire, 2012; USDHHS, 2018). We first review these benefits and recommendations, then discuss the prevalence of physical activity and the influence of personal characteristics and the environment on this behavior. Our primary (but not sole) focus is on early childhood because promotion of physical activity and prevention of obesity is particularly important at this age, as physical activity, weight status, and the associated comorbidities track into adolescence and adulthood.

Benefits of Physical Activity

The benefits of physical activity are cardiovascular, metabolic, cognitive, and psychosocial in nature. The advisory committee for the United States Department of Health and Human Services (USDHHS) 2018 Physical Activity Guidelines indicated in their scientific report that there is strong evidence to support a relationship between physical activity and both body composition and bone health in youth of all ages. In youth over 6 years of age, there is also strong evidence for a positive impact of physical activity on cardiovascular and muscular fitness and moderate evidence to support a relationship between physical activity and cardiometabolic health biomarkers. Additionally, in the 2008 Physical Activity Guidelines for Americans, it was noted that there was moderate evidence to support a positive effect of physical activity on reduced depression symptoms in youth (USDHHS, 2008) and in the 2014 United States Report Card on Physical Activity for Children and Youth, additional health benefits associated with daily physical activity included improvements in motor control and academic performance, and decreases in risk of cardiovascular disease and type 2 diabetes in both childhood and adulthood (Dentro, 2014). In adulthood, the health benefits identified by the USDHHS advisory committee expands to include a variety of benefits of physical activity, including lower risk of early death, improved executive function, reduced anxiety and depression, and improved sleep quality and quality of life, to name just a few (USDHHS, 2008; Physical Activity Guidelines Advisory Committee, 2018).

One of the most important benefits of physical activity in youth is that it helps negate the positive energy balance associated with childhood obesity. While the detriments associated with obesity are outside the scope of the present review, it is widely accepted that obese youth suffer from myriad physical (e.g., increased risk for musculoskeletal injury), psychological (e.g., reduced quality of life), and cardiometabolic (e.g., dyslipidemia) ailments (Reilly et al., 2003). Data from the 2015-2016 cycle of the National Health and Nutrition Examination Survey (NHANES) demonstrate that 18.5% of youth, 2-19 years of age, are obese (Skinner, Ravanbakht, Skelton, Perrin, & Armstrong, 2018), defined as Body Mass Index (BMI, kg/m^2) greater than or equal to the 95^{th} percentile according to the Centers for Disease Control and Prevention’s age- and sex-specific growth charts (Kuczmarski et al., 2002). Prevalence of obesity also increases with age, from 15.7% in children aged 2-5 years to 34.5% in those who were 16-19 years of age. As the prevalence of obesity has increased over time (e.g., from 14.6% for 2- to 19-year-olds in the 1999-2000 NHANES cycle; Skinner et al., 2018), it is regarded as a substantial public health epidemic.

Preventing the development of obesity should occur in early childhood for a few reasons. First, the positive energy balance associated with the development of obesity is small in 2- to 7-year-old children, about 14 kcal/day, but this surplus grows with age (Butte, Christianson, & Sorensen, 2007; Wang, Gortmaker, Sobol, & Kuntz, 2006). Thus, even small changes in physical activity level can be of great benefit or detriment to a young child's weight status (Ridley & Olds, 2008). Second, while there are well-known short-term ramifications of obesity that should be avoided, being an obese child also increases one's risk of being an obese adolescent or adult (i.e., weight status tracking) and the majority of obese youth become obese before 6 years of age (Quattrin, Liu, Shaw, Shine, & Chiang, 2005). A review by Singh, Mulder, Twisk, Van Mechelen, & Chinapaw (2008) outlines the overwhelming evidence on this topic, but additional support for the importance of early childhood is provided by Freedman et al. (2001), who reported that 83.0% of overweight 2- to 5-year-old children were obese in adulthood after, on average, 19 years of follow-up. Similarly, Whitaker, Wright, Pepe, Seidel, & Dietz (1997) found that the odds of overweight (BMI 85^{th}-95^{th} percentile) 3- to 5-year-olds being obese in adulthood (21-29 years of age) were 4.7 times greater than non-obese children. Finally, independent of adult weight status, being an obese child negatively impacts adult health, increasing risk for cardiovascular and metabolic comorbidities and premature death (Guo et al., 2002; Reilly & Kelly, 2011). Thus, preventing obesity in early childhood has both short- and long-term impacts on the individual, and as a result, overall population health.

While physical activity can help prevent obesity, it is also related to numerous other benefits in both healthy weight and overweight or obese youth. Sääkslahti et al. (2004) found that in children, 4-7 years of age, physical activity was inversely related to blood pressure, total cholesterol, and triglycerides, and positively related to high-density lipoprotein cholesterol. Vale, Trost, Rêgo, Abreu, & Mota (2015) found that overweight preschoolers who were insufficiently active had 3.8 times greater odds of elevated systolic blood pressure compared to sufficiently active, healthy weight preschoolers (reference group). Interestingly, there was no difference between overweight children who were sufficiently active or healthy weight, insufficiently active children and the reference group. This indicates that physical activity may mitigate some of the cardiovascular risk associated with adverse weight status.

In young children, physical activity also plays a vital role in normal muscular and skeletal growth, the improved economy of movement, and development of overall strength and endurance (Butte et al., 2016; Timmons, Naylor, & Pfeiffer, 2007). For example, a 50-week intervention (30 min/day, 5 days/week) of gross motor play improved tibial bone diameter in 4-year-old children compared to a group receiving the same volume of fine motor activities (Specker & Binkley, 2003). Janz et al. (2001) estimated that for every additional 10 min/day of vigorous physical activity preschool children attained, bone mineral content at the hip and spine would increase by 3.0% and 2.0% of mean bone mineral content, respectively. Again, this has long-term implications for the development of greater peak bone mass, which serves to slow age-related bone loss, prevent osteoporosis, and decrease the risk of fractures (Bonjour, Chevalley, Ferrari, & Rizzoli, 2009). Finally, psychosocial benefits of physical activity may be particularly important in young children since it comes mostly in the form of play and exploration. Play allows children to practice language, motor, and social skills, like negotiation and problem solving, which can have lifelong benefits (Burdette & Whitaker, 2005; Eaton, McKeen, & Campbell, 2001; Ginsburg, 2007).

Being active at a young age also correlates moderately with being active later in childhood (Pate, Baranowski, Dowda, & Trost, 1996), and it has been suggested that physical activity in early childhood drives the development of fundamental motor skills and that possessing those fundamental motor skills drives physical activity participation later in life (Cliff, Okely, Smith, & McKeen, 2009; Fisher et al., 2005; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Stodden, Langendorfer, & Roberton, 2009). Studies on the relationship between fundamental motor skills and physical activity were reviewed by Lubans et al. (2010), with compelling evidence from longitudinal studies. For example, Barnett (2009) reported that fundamental motor skills in childhood were related to physical activity levels six-to-seven years later in adolescence. Overall, being physically active in early childhood is related to overall health and weight status in early childhood as well as physical activity, health, and weight status later in life.

Recommendations for Physical Activity

Due to the aforementioned benefits of physical activity, recommendations for physical activity attainment have been put forth for preschool-aged children (3-5 years of age), as well as children and adolescents (≥6 years of age). The USDHHS Physical Activity Guidelines for Americans (2018) suggest that children and adolescents participate in a variety of age-appropriate activities to attain at least 60 minutes of moderate-to-vigorous physical activity each day, with at least 3 days each of vigorous intensity, muscle-, and bone-strengthening activities. While this recommendation has not changed since the 2008 Physical Activity Guidelines, the new 2018 Physical Activity Guidelines include, for the first time, a recommendation for children between 3 and 6 years of age, which is to participate in physical activity throughout the day, and it is noted that 3 hours of total physical activity (light-to-vigorous) each day may be an appropriate target.

While this is the first time a physical activity recommendation has been made for 3- to 6-year-old children by the United States government, a number of similar guidelines from other agencies and governments exist for preschool-aged children. The United Kingdom, the

Australian Department of Health and Aging, and the Canadian 24-hour Movement Guidelines all recommend preschoolers accumulate at least 180 minutes per day of total physical activity with a goal to develop motor skills (Commonwealth of Australia, 2010; United Kingdom Chief Medical Officers, 2011; Tremblay et al., 2017). The Society of Health and Physical Educators (SHAPE) and the National Association for Sport and Physical Education (NASPE) recommend that preschoolers accumulate 60 minutes of structured and 60 minutes, but up to several hours, of unstructured physical activity a day (Clark et al., 2002). Specific to the childcare day, the Institute of Medicine (IOM) recommends that children participate in at least 15 min/hour of total physical activity while in childcare, including light, moderate, and vigorous intensities (McGuire, 2012). All recommendations also state that sedentary time should be minimized.

The IOM, SHAPE, and NASPE also include statements on aspects of the preschool environment that could promote activity (Clark et al., 2002; McGuire, 2012). The IOM recommendations state that the outdoor and indoor environments should include portable play equipment and adequate space for each child and overall, activities should be developmentally appropriate and include structured and unstructured opportunities (McGuire, 2012). The outdoor context should include an open grassy area, a variety of terrains, and a secure perimeter. The SHAPE and NASPE recommendations also include that indoor and outdoor environments should meet safety standards (Clark et al., 2002). The Canadian guidelines recommend that activities span a variety of environments and suggest trading indoor time for outdoor time (Tremblay et al., 2017). Overall, common themes present in these recommendations include minimizing sedentary time and promoting total physical activity by providing activity-promoting environments during childcare.

Prevalence of Physical Activity

As noted in the 2018 United States Physical Activity Report Card (National Physical Activity Plan, 2018), only 24.2% of youth, 6 to 17 years of age, participate in 60 minutes of moderate-to-vigorous activity every day, a decline from 29.9% in 2007 (based on National Survey of Children's Health self-report data). The percentage of youth meeting physical activity recommendations also declines with age, as evidenced by NHANES accelerometer-measured physical activity data from the 2005-2006 cycle, wherein 42.5% of 6- to 11-year-old children met physical activity guidelines, in contrast to 7.5% of 12- to 15-year-olds (National Physical Activity Plan, 2018).

While researchers have investigated the physical activity levels of preschool-aged children, no national data exist, as data sources like NHANES only use a monitor-based approach to physical activity measurement in children over 6 years of age. Cardon et al. (2008) measured habitual (weekday and weekend) physical activity levels of 4- and 5-year old children with accelerometry and found that they spent, on average, 85.0% of the day in sedentary pursuits with only 26.0% of the sample meeting the guideline of 120 min/day of total physical activity. Pate et al. (2015) studied two samples of preschoolers and found that mean total physical activity per hour was 14.5 and 15.2 min/hour. However, only 41.6 and 50.2% of children met the recommendations of 15 min/hour of total physical activity. Importantly, this activity data was for 5 weekdays, including childcare and non-childcare hours, so interpreting these in light of the IOM guidelines, which are focused on childcare hours, is not completely appropriate.

Children are generally more active during childcare than at home (Hesketh, Griffin, & van Sluijs, 2015). A study focused on 9 preschools (n=22 to 31 each) found that total physical activity during childcare hours ranged from 11.1 to 23.6 min/hour, highlighting the high degree of inter-school variability in meeting the IOM guidelines (Pate et al., 2004). Pate et al. (2008) found that the preschool attended accounted for 27.6% of the variability in school day physical activity, while other researchers have shown that the preschool attended accounted for over half of the variability in physical activity (Gubbels et al., 2011; Tandon et al., 2013; Vanderloo et al., 2014).

Because preschool curriculum is less focused on core academic curriculum and requires less sedentary, seated time, there should be ample opportunity for physical activity both inside and outside during the school day. Unfortunately, Tandon et al. (2015) found that 88.0% of preschool time was not an opportunity for active play, which explained why children were sedentary for the majority (73.0%) of the school day. Thus, preschool-aged children do not meet physical activity recommendations, overall or during the childcare day, specifically.

Influence of Personal Characteristics on Physical Activity

With the overarching goal of understanding, and subsequently promoting physical activity participation, it is important to consider how personal characteristics, like age, motor skill, race, weight status, or sex, affect physical activity levels. A review by Hinkley, Crawford, Salmon, Okely, & Hesketh (2008) of correlates of preschooler's physical activity participation stated that there was no association between physical activity attainment and age, although as always, there are opposing findings (Gubbels et al., 2012; Henderson, Grode, O'Connell, & Schwartz, 2015; Jackson et al., 2003; Reunamo et al., 2014; Schmutz et al., 2017). It is important to note that the review by Hinkley et al. (2008) included a variety of physical activity measures, including parent-reported, and did not require that the measure be of daily or habitual physical activity (e.g., some studies measured physical activity for 1 hour and compared between groups). In contrast, a longitudinal study following 3- to 4-year-old children for one year found that accelerometer-measured physical activity (in counts/min) over 3 days increased from, on average, 669 accelerometer counts/min at baseline to 849 counts/min at the one year follow-up (Jackson et al., 2003). This is important because the same 60 children were assessed over time and due to the large inter-subject variability in physical activity levels, this may be a more accurate representation of age-related changes in physical activity levels. Conversely, another longitudinal study measuring physical activity at 3, 4, and 5 years of age with accelerometers found that 4- and 5-year-old children had lower physical activity levels than 3-year-olds (Taylor et al., 2009). While research across childhood and adolescence demonstrates that activity decreases with age (National Physical Activity Plan, 2018), one reason this may not be observed in preschoolers is due to the small age window (3-5 years) that is typically studied (Sallis, Prochaska, & Taylor, 2000).

Other variables may obscure the relationship between age and physical activity. Pate et al. (2004) found that 4- and 5-year-old children were more sedentary and participated in less light physical activity compared to 3-year-olds, with no differences in moderate-to-vigorous physical activity. Thus, it may be important for researchers to consider different intensities of activity. There may also be an interaction between age and weight status, as Rice & Trost (2014) found that healthy weight 4- and 5-year-olds elicited higher levels of total physical activity than 2- and 3-year-olds, with no differences in overweight children. Or, there may be some confounding effects of motor skill development such that as children improve their motor skills, they participate in more physical activity, but these improvements in motor skills can occur at different ages for different children (Williams et al., 2008). Research has shown that children with better motor skills attain more moderate-to-vigorous and vigorous physical activity than those with poorer motor skills, which has been supported by Fisher et al. (2005). No consensus has been made about how physical activity participation changes with age in preschool-aged children, so more research is needed, preferably longitudinal studies using monitor-based measurements of physical activity.

While Pate et al. (2004) supported that age was not related to physical activity, he did find that black children attained more vigorous physical activity than white children. McKenzie (1997) found that Mexican-American preschoolers participated in less moderate-to-vigorous physical activity than European-American children at baseline (4.4 years of age) and 2.2 years later (6.6 years of age). However, Baranowski, Thompson, Durant, Baranowski, & Puhl (1993) found no differences in directly observed physical activity among Anglo-American, African-

American, and Mexican-American children who were observed up to four times over the course of a year. These conflicting results may be due to differences in methodological approach or because racial differences in physical activity may be confounded by socioeconomic status. While some researchers have reported no difference in physical activity by socioeconomic status, few studies have been conducted in preschool children; they may suffer from small sample sizes, or take place in other countries, which limits generalizability to the United States (Jackson et al., 2003; Kelly et al., 2007).

The systematic review by Hinkley et al. (2008) also concluded there was no difference in physical activity level of preschoolers by weight status, but the research is again divergent (Henderson et al., 2015; Pate et al., 2015; Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003). Pate et al. (2015) found that overweight children are more likely than healthy weight children to meet the IOM guidelines of 15 min/hour of total physical activity (58.3 vs. 37.9%). Importantly, there was no difference in average activity when expressed as min/hour, highlighting the importance of reporting both mean total physical activity per hour and the percentage of children meeting hourly guidelines. Similarly, Henderson et al. (2015) found that overweight preschoolers participated in more moderate-to-vigorous physical activity during the childcare day than healthy weight children. Metallinos-Katsaras, Freedson, Fulton, & Sherry (2007) found that overweight preschoolers participated in less vigorous and very vigorous physical activity, specifically, again highlighting the importance of studying different activity intensities. There may also be an interaction between weight status and sex as Trost et al. (2003) found that overweight boys were less active than healthy weight boys, but there was no difference for girls. Similarly, there may be an interaction between weight status and age as Rice & Trost (2014) found that overweight and obese 4- and 5-year-olds exhibited lower levels of total physical activity than their healthy weight counterparts, but activity levels were similar for 2- and 3-year-old children. Overall, results are inconclusive in preschool-aged children.

Research has shown overwhelmingly that males are more active than females at all ages and this has been reported in reviews focused on preschoolers by Hinkley et al. (2008) and by Tucker (2008). Hinkley et al. (2008) found that 16 of the 18 included studies reported this sex difference. Pate et al. (2015) found that more boys met the recommendation of 15 min/hour of total physical activity than girls in two samples of preschoolers (53.5% vs. 33.5% and 57.6% vs. 45.9%). Some research has related this disparity to differences in motor skills and how different sexes use the same space. For example, Robinson (2011) found that preschool-aged boys had significantly greater motor skills and perceived motor competence than girls. Harper & Sanders (1975) found that boys used 1.2 to 1.6 times more outdoor space than girls and utilized more target areas on the schoolyard than girls. Overall, there is a difference in preschoolers' activity levels by sex, but age, weight status, and race likely play a lesser role or could be affected by motor skills or environmental factors that warrant further study.

Physical Activity during Outdoor Time

In addition to personal characteristics, physical activity participation is influenced by context or setting, with outdoor settings eliciting higher levels of physical activity compared to indoor settings (Brown, Pfeiffer, et al., 2009; Raustorp et al., 2012; Tandon et al., 2013; Vanderloo, Tucker, Johnson, & Holmes, 2013). Outdoor time during the school day, specifically, is of interest because it provides youth the opportunity for unstructured, free-play physical activity during the otherwise predominantly sedentary school day. School (or childcare) is a relevant setting to promote participation in physical activity in early childhood and to promote maintenance of physical activity during the transition into adolescence, as school is a consistent point of access for those aiming to promote health behaviors, like physical activity, in youth. Unfortunately, the percent of schools offering regularly scheduled outdoor time falls from 95.0% in 1^{st} grade to 34.9% in 6^{th} grade (Centers for Disease Control, 2015), which parallels the sharp decline in physical activity participation with age. This demonstrates the importance of maximizing opportunities for physical activity during the outdoor time that is provided, particularly for youth with routinely low physical activity levels, like girls and adolescents.

In the childcare setting, children are still largely sedentary during outdoor time, despite being more active outdoors compared to indoors (Brown, Pfeiffer, et al., 2009; Raustorp et al., 2012; Tandon et al., 2013; Vanderloo et al., 2013). Vanderloo et al. (2013) measured daily outdoor activity of children during childcare via accelerometry and found that preschoolers spent from 55 to 180 min outdoors, highlighting the high degree of inter-center variability. While outdoors, children accumulated 25.3 min/hour of sedentary behavior and while they attained 31.7 min/hour of total physical activity outdoors, only 5.0 min/hour were of moderate-to-vigorous intensity. Similarly, Sugiyama et al. (2012) used accelerometry and found that children spent 114.3 min/day outdoors (range 42-198 min/day), accumulating 13.5 min/day of moderate-to-vigorous physical activity (12.0% of outdoor time) and 75.2 min/day of sedentary behavior (66.0% of outdoor time). Children in a study by Gubbels et al. (2011) attained slightly more physical activity, with 21.3% of outdoor time classified as moderate-to-vigorous physical activity and 31.2% classified as sedentary behavior. In stark contrast to the previously described studies, Trost, Fees, & Dzewaltowski (2008) found that children participated in moderate-to-vigorous physical activity for 71.7% of outdoor free play.

There are two main explanations for the diverse findings- 1) the influence of preschool attended or 2) differences in methodology. Gubbels et al. (2011) and Trost et al. (2008) used direct observation to determine activity level and found lower levels of sedentary behavior than Vanderloo et al. (2013) and Sugiyama et al. (2012), who used accelerometry. Due to accelerometer placement on the hip, it is possible to miss some activities that involve a stationary trunk, but moving limbs (e.g., throwing). One would expect accelerometer-based studies to report greater levels of sedentary behavior. However, the large amount of variability between childcare programs should not be ignored and this variability supports the importance of considering center-specific environmental variables, like equipment availability and quality.

Influence of Environmental and Contextual Variables on Physical Activity

While outdoor time is offered in most preschool and elementary schools (and some middle schools), there is variation in physical activity levels during provided outdoor time between programs. Some of this variability is due to differences in the schoolyard environment, including overall area (size), number of children, provided equipment, and quality or other contextual factors, like the duration of outdoor time or weather.

Regarding the overall schoolyard environment, preschoolers are more physically active on schoolyards rated as higher quality (Bower et al., 2008; Gubbels et al., 2011). A review by Broekhuizen (2014) supports this finding and additionally concluded that in preschoolers, adequate schoolyard size may be an important factor in promoting activity (Boldemann et al., 2006; Clark et al., 2002; Dowda et al., 2009). However the strength of the relationship between schoolyard size and physical activity has also been reported as weak (r=0.13;Gubbels et al., 2012), and a study by Smith et al. (2014) found that overall schoolyard size was inversely related to preschooler's physical activity. However, Smith et al. (2014) did report that the area of individual behavior settings was positively related to physical activity attainment.

The number of children in relation to the schoolyard size may be even more important, as higher child density (children per area) would indicate crowding or lack of access to provided equipment. Both experimental and observational studies of preschool-aged children support that lower child density is associated with higher physical activity levels and larger play groups are associated with decreased activity intensity (Cardon et al., 2008; Gubbels et al., 2011; Van Cauwenberghe et al., 2012). However, studies of older children sometimes agreed, but sometimes revealed that higher concentrations of children and larger social groups were associated with higher activity (Fairclough, Beighle, Erwin, & Ridgers, 2012; Harten, Olds, &

Dollman, 2008; Ridgers et al., 2010; Van Cauwenberghe et al., 2012). This disparity may reflect differences in the types of activities in which older children participate (e.g., more group games or sports). If the relationship between child density or group size and physical activity varies by activity type, it may also vary by schoolyard location (Farley et al., 2008), so this warrants further investigation.

Some studies have focused on the relationship between the availability of equipment or a particular schoolyard area and physical activity. Research in preschool populations has reported that the presence of a large, grassy area was related to activity level (Berg, 2015; Brown, Pfeiffer, et al., 2009). The availability of portable equipment has been related to moderate-to-vigorous physical activity (Berg, 2015; Dowda et al., 2009; Gunter et al., 2012), but other studies report no association (Cardon et al., 2008). Intervention studies providing additional portable equipment have been both successful (Hannon & Brown, 2008) and unsuccessful (Cardon, Labarque, Smits, & De Bourdeaudhuij, 2009) in promoting physical activity in preschool-aged children.

Some researchers have reported that fixed play equipment is conducive to more outdoor moderate-to-vigorous physical activity and less outdoor sedentary behavior in multiple types of childcare programs (Gunter et al., 2012; Sugiyama et al., 2012), but others have demonstrated no effect of fixed equipment or a negative effect wherein more fixed equipment was associated with less moderate-to-vigorous physical activity (Cardon et al., 2008; Dowda et al., 2009). In contrast, the presence of fixed equipment has been associated with greater physical activity intensity numerous times in elementary school samples (Nielsen, Taylor, Williams, & Mann, 2010; Ridgers et al., 2010; Taylor et al., 2011; Willenberg et al., 2010). Thus, there are some inconsistent findings as to the relationship between available equipment or locations and physical activity in preschoolers, which may be because relating the general availability of equipment or a type of area (not actual use) to physical activity levels may mask important information about the specific types of equipment children are (or are not) using and their physical activity levels while using that equipment.

Other studies have focused on what surface types promote physical activity participation. Available vegetation (e.g., trees, shrubs) has been correlated to preschooler's physical activity attainment during outdoor time (Boldemann et al., 2006), while some others have reported no relationship (Cardon et al., 2008; Sugiyama et al., 2012). Work by Fjørtoft (2001 and 2004) suggests that natural play environments afford more activity due to a more diverse landscape and that this leads to greater motor skill development. Other research has found that natural play spaces promote longer play episodes and more complex play (Luchs & Fikus, 2013) and that greater diversity in the play environment promotes physical activity (Cosco, 2006). However, Cosco (2007) reported that childcare centers reported, on average, only 3 natural elements (most frequently varied ground surfaces) but 7 manufactured elements (most frequently play equipment). Intervention studies in which a traditional schoolyard was converted to a nature-based schoolyard showed that children increased their levels of moderate-to-vigorous physical activity (Coe, Flynn, Wolff, Scott, & Durham, 2014; Herrington & Brussoni, 2015), so, the addition of natural play environments or elements may be of interest in future studies.

In addition to natural areas, other surface types have been studied, and a study by Cardon et al. (2008) suggested that there may be sex differences in the relationship between surface type and activity, as the presence of a hard surface was only related to the activity levels of boys, not girls. This may be because boys spend more time in or participate in different activities in areas with hard surfaces, like an asphalt court, but simply correlating the presence of hard surfaces on the schoolyard and children's overall activity levels cannot answer that research question. However, a study by Cosco et al. (2010) used behavior mapping to assess physical activity in specific schoolyard locations and found that on one schoolyard, moderate-to-vigorous physical activity levels were highest when children were located on asphalt, but on a second schoolyard, physical activity levels were highest when children played on woodchips. The results from the two schoolyards were likely different because the ground surface composition did not matter, but rather the activities afforded in those areas impacted activity levels.

Additionally, the timing and duration of provided outdoor time may impact physical activity. In regard to timing, play deprivation theory posits that longer bouts of indoor time preceding the outdoor period will result in a ‘rebound effect’ and subsequently higher physical activity levels during the outdoor period (Pellegrini, Huberty, & Jones, 1995; Smith & Hagan, 1980). Additionally, research has shown that children are most active at the beginning of recess, so it has been suggested that more frequent trips outside, instead of longer durations, may be more beneficial for promoting physical activity (Alhassan, Sirard, & Robinson, 2007; Cardon et al., 2008; Holmes, 2012; McKenzie et al., 1997). For example, Cardon et al. (2008) found that shorter recess times were associated with higher step rates (steps/min) and Mckenzie et al. (1997) and Smith & Hagan (1980) demonstrated that children were most active during the first 10 min of recess. If children’s physical activity level is impacted by the timing of the outdoor period (e.g., long deprivation vs. short deprivation) and time during the outdoor period (e.g., beginning vs. end), then it is plausible that other aspects of their behavior would be impacted as well, such as where children play. As such, it is of interest to identify what children actually do throughout provided outdoor time. For example, children may use portable equipment at the onset of outdoor time and therefore, this type of equipment would promote physical activity participation during shorter durations of outdoor time, but this is not captured when simply relating a variable, like the number of pieces of portable equipment, to overall outdoor physical activity levels. There may also be aspects of the outdoor environment that can encourage sustained activity during prolonged outdoor time and if these could be identified, this would have implications for activity-promoting interventions.

The lack of appreciation for what children are actually doing during outdoor time is the most important limitation of research aiming to understand the impact of the schoolyard environment on children's physical activity. It is clear from the available research that there is variability between schools in physical activity participation during provided outdoor time. Results as to what contextual variables influence physical activity are inconsistent and this is due to the fact that studies that simply correlate the presence or absence of a setting or piece of equipment (e.g., portable or fixed equipment) with overall physical activity levels do not determine the duration or intensity of play with a particular piece of equipment or in a specific setting overall or how this changes over the course of the outdoor period. Before spending money on interventions, like provision of additional equipment or schoolyard redesigns, that may or may not work, more research needs to be done to discern what preschoolers actually do and play with during existing outdoor time and how this might vary by setting, school, and individual characteristics, like sex.

Physical Activity by Schoolyard Location

Schoolyards are typically divided into various settings, centers, or areas (Sanoff, 1995), defined as spaces with a variety of materials that are often identified by physical boundaries (Sanoff, 1995). Alternatively, the concept of behavior setting is defined as an ecological unit where physical environment and behavior are linked with behavior settings acting as a set of nested structures (Cosco, 2006). While the outdoor context varies between schools, common outdoor play areas include fixed equipment, open or grassy areas, sandboxes, or asphalt areas that may afford the use of wheeled toys in young children or that may include areas for specific ball games in older children and adolescents.

As evidenced by observational studies examining the physical activity of preschool-aged children in different schoolyard locations, it is clear that physical activity participation varies by location (Cosco et al., 2010; Nicaise, Kahan, Reuben, & Sallis, 2012; Nicaise et al., 2011). For example, Cosco et al. (2010) reported that on one schoolyard, children spent 2% of sandbox time, but 40% of open area time, engaging in moderate-to-vigorous activity. Similarly, Nicaise et al. (2011) reported that children spent 2% of sandbox time, but 31% of grass time in moderate-to-vigorous activity. However, results as to which schoolyard area elicits the most and/or least physical activity are inconclusive and vary both between and within studies. For example, studies have indicated grassy or open areas as promoting the most moderate-to-vigorous activity (Cosco et al., 2010; Nicaise et al., 2012; Nicaise et al., 2011) or total physical activity (Cosco et al., 2010). In those same studies, but on other schoolyards, asphalt/concrete paths have been shown to promote the most moderate-to-vigorous activity (Cosco et al., 2010; Nicaise et al., 2012; Nicaise et al., 2011). This disparity is likely because characteristics of the specific location influence physical activity in that setting.

For example, pathways (tracks) may be looping or linear and this impacts physical activity within that location. Physical activity has been shown to be promoted when children were on looping pathways where the use of riding toys was afforded, while children located on linear asphalt paths engaged in lower activity levels even when similar equipment was available (Cosco et al., 2010; Nicaise et al., 2012; Nicaise et al., 2011). Similarly, the size of the open space/field, the type and amount of provided portable equipment, and the number of children likely impact physical activity in the open space setting due to differences in affordances, but this has not been thoroughly explored due to methodological limitations we will discuss later. Understanding children’s behavior on the schoolyard is a complex problem and therefore, studies of physical activity by location need to be conducted on a large number of schoolyards, to facilitate our understanding of how form and function impact the relationship between location and behavior.

In regard to sedentary behavior, sandboxes and gathering places (i.e., benches) have been reported as the most sedentary locations (Cosco et al., 2010; Nicaise et al., 2011; Smith et al., 2014). On two schoolyards, the fixed play equipment was implicated as the most sedentary (Cosco et al., 2010; Nicaise et al., 2012). Interestingly, a schoolyard redesign intervention by Nicaise et al. (2012) removed some, but not all, of the fixed equipment from a schoolyard and found that physical activity participation increased in that specific area of the schoolyard. Thus, even though the type of fixed equipment was the same, the number of pieces of fixed equipment impacted physical activity participation. These findings suggest that more research is needed to account for both activity location and characteristics of the setting, such as type, number, or size of fixed play equipment.

Finally, researchers have reported that there are differences in the areas that children visit most frequently. Cosco et al. (2010) found that most observations at one childcare occurred in the open areas, while at another schoolyard and in one schoolyard studied by Nicaise et al. (2011), the fixed equipment was the most popular area to play. This may be impacted by characteristics of the environment, like size or number of children. Overall, work in preschool-aged samples has demonstrated that some schoolyard locations promote more physical activity (potentially pathways or open areas), while others promote sedentary behavior (e.g., sandboxes). However, more work is needed to elucidate which areas children actually use and how these differences vary by characteristics of the child (e.g., sex), schoolyard (e.g., duration of outdoor time, weather), or of that specific setting (e.g., size, amount of equipment).

Older children and adolescents may have different play patterns than preschoolers, but studies of these populations also support that activity varies by schoolyard location. In elementary school studies, fields or open spaces have been reported as the most active

(Dyment et al., 2009; Wood, Gladwell, & Barton, 2014), while other studies reported fixed equipment as the most active (Black, Menzel, & Bungum, 2015; Farley et al., 2008). In middle school samples, sport courts elicited the most activity (Fjørtoft et al., 2010; Sallis et al., 2001). These findings are congruent with the idea that, with age, children focus on more group, team, and rule-based, sport games (Roberton & Halverson, 1984; Wortham & Frost, 1990). Some locations have also been shown to nullify sex differences in activity level (Fjørtoft et al., 2009; Saint-Maurice et al., 2011). For example, Farley et al. (2008) found that girls (53.0% very active) were actually more active on fixed equipment than boys (48.0% very active). While more information from preschool samples is needed, identifying which schoolyard locations promote physical activity can be used to design activity-promoting schoolyards and interventions with the end result of increasing physical activity for all children. Further, information about age- and sex-related differences by schoolyard location can be used to ensure that these interventions promote activity in groups with traditionally low physical activity participation, like girls and adolescents. For this to be accomplished, there has to be a feasible and valid method capable of measuring both physical activity and its context during outdoor time.

Summary of Physical Activity and its Correlates in Preschoolers

Most children attend childcare or school for several hours per day and being physically active during this time allows for the development of motor and social skills, in addition to other, well-known immediate and long-term benefits of being physically activity. Outdoor time, in particular, provides youth the opportunity to participate in active free-play, but children spend less than half of provided outdoor time being physically active. Aspects of the schoolyard environment have been related, either positively or negatively, to physical activity in preschoolers, including overall size of the schoolyard, child density (Cardon et al., 2008), the presence of various types of settings or equipment (e.g., grassy field, fixed equipment, portable equipment) (Cardon et al., 2008; Gubbels et al., 2012).

Correlating the presence or absence of these contextual factors with physical activity is insufficient to tell us what children are actually *doing* during provided outdoor time, including both where children play and how active they are in specific areas of the schoolyard. This concept needs to be studied on a variety of schoolyards to gain a true understanding of how various environmental factors impact physical activity in children overall and in specific groups of children. This information may then be used to inform the design of activity promoting schoolyards.

Measurement of Physical Activity

There are many ways to measure youths' participation in physical activity. While one gold standard is direct observation, high researcher burden (i.e., time) has led many to rely more on monitor-based approaches, like accelerometry. However, both methods have strengths and weaknesses. The ideal measure of physical activity must be able to capture the unique nature of young children's play, which is characterized by short bursts of high-intensity activity followed by longer periods of low-intensity activity (Bailey et al., 1995). Further, it should provide additional contextual information beyond activity intensity, such as location or activity type (Fulton et al., 2001).

Direct observation

One gold standard measure of physical activity is direct observation, in which researchers record the activity level of either a group of or individual youth, often in real-time. Additionally, environmental variables, like location, activity type, social interaction, or supervision, can be recorded to provide important context to the behavior. Some direct observation systems, like the System for Observing Play and Leisure Activity in Youth (SOPLAY) and the Child Activity Scanning Tool (CAST), involve systematic scans of target areas. For example, in SOPLAY, researchers scan a target area, record the number of girls (or boys) being sedentary, walking or very active, and then classify the leading activity type for the entire group (i.e., soccer) (McKenzie, 2002). The researcher also codes “yes” or “no” if the area was accessible, usable, supervised, equipped, or organized. The primary limitation of this method is that when conducting a scan for one group of children (e.g., girls), or in one target area, and while recording information, details about what other children are doing is missed.

The CAST system is a modification of the System for Observing Fitness Instruction Time (SOFIT), but after scanning for the number of children participating in different intensity activities, researchers scan for the number of balls in a target area, number of teachers in the area, teacher encouragement of activity, or the number of children playing with balls, other free-moving equipment, or fixed equipment (Zask, 2009). The CAST system entails a high degree of researcher burden, as it requires the presence of 5 observers, with each conducting a scan every 75 seconds for 1 activity intensity and then 1 equipment or teacher characteristic. Thus, only one data point is recorded per 75 seconds, which may be an issue due to the brevity of children’s physical activity behaviors (Oliver, Schofield, & Kolt, 2007). However, both CAST and SOPLAY have the clear benefit of providing rich contextual information in addition to physical activity intensity.

Behavior mapping also relies on scans of target areas, but the sex, setting type, and physical activity intensity of individual observed children are recorded on a handheld device (Cosco et al., 2010). Activity intensity is classified according to the Child Activity Rating Scale (CARS), a scale ranging from 1 (resting) to 5 (strenuous, very high). Additionally, the approximate location of the observed child is recorded on a paper map and researchers can use Geographic Information Systems (GIS) to visually represent the data collected. Strengths of this method include coding individual children’s physical activity instead of overall group activity (as in SOPLAY) and recording schoolyard location more specifically (as opposed to only knowing that a child is in a target area in general). Further, the maps could be tailored to different areas, behavior settings, or layouts of different schools. The downside for all of the scan-based systems is that researchers are unable to monitor the entire schoolyard throughout the entire play period because you cannot visibly see the whole schoolyard at all times. Another limitation is the inability to follow each child over time. For example, after scanning a target area and moving on to the next target area, there is no record of where/if each child moved, if the same children were in the same area, or if the same children were highly active or inactive.

Other direct observation systems, like the Observational System for Recording Physical Activity in Children, which has both a preschool (OSRAC-P) and elementary school (OSRAC-E) version, do not infer location through target scan areas, but instead follow one focal child (discreetly) wherever they travel on the schoolyard (Brown et al., 2006; McIver, Brown, Pfeiffer, Dowda, & Pate, 2016). The OSRAC-P uses 8 observational categories, including activity level (e.g., stationary), activity type (e.g., crawl), location (e.g., outside), indoor context (e.g., art center), and outdoor context (e.g., sandbox). The outdoor context category includes 12 codes for ball and object, fixed equipment, game, open space, pool or water play, portable equipment, sandbox, snacks, sociodramatic props, teacher arranged gross motor, time out, and wheeled object. Researchers observe one child for 5 s and record for 25 s, completing two observations/min for 30 min. So, while this allows for the collection of individual-level data, all children cannot be observed continuously. For example, Brown, Pfeiffer, et al. (2009) used the OSRAC-P and observed 372 children for 34.0 ± 24.5 min each outdoors. While this appears to be a large amount of observation time, in actuality, only one data point was recorded for every 30-s interval because of the nature of the observe-record cycle.

Overall, direct observation can provide valuable context to physical activity measurement, but there is substantial observer burden (i.e., time, focus) and data are missed when researchers are recording data or not observing a particular child or area. Researchers are not able to capture continuous data for each child throughout the entire recess period and accuracy depends on researcher stamina and reliability. For these reasons, unobtrusive, monitor-based approaches have risen in popularity with researchers.

Accelerometry

Fulton et al. (2001) stated that while direct observation has moderate cost, high researcher burden, and low participant burden, monitor-based approaches have moderate cost and participant burden and low-to-moderate researcher burden. Many monitor-based studies have used accelerometry, namely the ActiGraph brand of accelerometers (Migueles et al., 2017) to assess the duration and intensity of behavior. The ActiGraph wGT3X-BT is a triaxial accelerometer that measures raw acceleration (g) ranging from ±8 g's in three planes (vertical, anteroposterior, and mediolateral). While the "raw" acceleration data are available for this device, the more processed count data have historically been used to characterize activity intensity. To obtain count data, acceleration data are rectified and passed through a band-pass filter from 0 to 2.5 g to attenuate non-human movements and then summed (counts) over a specified period of time (epoch) (Chen & Basset, 2005; John & Freedson, 2012). Counts may then be compared to various established cut-points (e.g., in counts/15-s) to determine activity intensity (Cliff, Reilly, & Okely, 2009).

There are several measurement issues that must be considered when using accelerometry, including choice of cut-points, number of axes, epoch length, and wear location (Migueles et al., 2017). Application of different cut-points to the same data set results in significantly different physical activity estimates Van Cauwenberghe, Labarque, Trost, De Bourdeaudhuij, & Cardon, 2011). A review by Migueles et al. (2017) revealed that the majority of studies of preschool-aged children have used either the Evenson, Catellier, Gill, Ondrak, and McMurray (2008) or the Pate, Almeida, McIver, Pfeiffer, and Dowda (2006) vertical axis cut-points. The Evenson et al. (2008) cut-points were developed for children from five to eight years of age and as such, are likely inappropriate for preschool-aged children. However, the Evenson et al. (2008) cut-points are the most frequently used for children and adolescents (Migueles et al., 2017) and as outlined by Trost et al. (2011), they outperformed four other cut-points for 5- to 15-year-old youth. The Pate et al. (2006) cut-points were developed on a sample (n=30) of preschoolers using indirect calorimetry and are defined as sedentary (0-799 counts/min), light (800-1679 counts/min), moderate (1680-3367 counts/min), and vigorous (>=3368 counts/min) physical activity (Pate et al., 2006), although the sedentary and light cut-points were not included in the original validation study.

While not the most commonly used at the time of their review, Migueles et al. (2017) recommended the use of cut-points published by Costa, Barber, Cameron, and Clemes (2014), Jimmy, Seiler, and Maeder (2013), or Butte et al. (2014) in preschool-aged samples. All three of these cut-points include both vertical axis and vector magnitude versions, the latter of which combines information from 3 axes. The Butte et al. (2014) cut-points [sedentary (0-819 counts/min), light (820-3907 counts/min), moderate (3908-6111 counts/min), and vigorous (>=6112 counts/min)] are of particular interest as they were developed using room calorimetry (n=50), but also validated in a relatively large sample of children (n=105) in a free-living setting using doubly labeled water, which is rarely done in research on accelerometer cut-points. While it conceptually makes sense to use more axes to capture more accurate activity data, research in this area is lacking. However, one benefit of vector magnitude is lessened dependence on monitor orientation (as data from all axes are combined) (Aadland & Ylvisåker, 2015; Ozemek, Kirschner, Wilkerson, Byun, & Kaminsky, 2014), which can be helpful when participants (e.g., young children) have difficulty keeping the monitor belt positioned directly over the right hip.

Despite the fact that most studies use the Pate et al. (2006) and Evenson et al. (2008) cut-points, there are at minimum 8 hip-based cut-points developed specifically for ActiGraph data collected from preschoolers and 18 developed for children and adolescents (Migueles et al., 2017). There are also approaches to classifying activity intensity that do not rely on cut-points. In recent years, researchers have started using novel analytical approaches for classifying intensity or activity type using count or raw acceleration data, like machine learning algorithms, but these approaches are outside the scope of this review until more research in preschoolers is conducted (Hagenbuchner, Cliff, Trost, Van Tuc, & Peoples, 2015). Because of the lack of consensus on how to derive activity intensity from accelerometer data, it may be of interest to just use a measure of acceleration or counts (e.g., vector magnitude), to promote comparability with future and past studies.

It is also important to consider the epoch length used due to the transient nature of children's activity. The previously described Evenson et al. (2008) and Pate et al. (2006) cut-points were established using a 15-s epoch, which is the most commonly-used epoch in the preschool age group. Vale, Santos, Silva, Miranda, & Mota (2009) demonstrated that use of a 60-s epoch significantly underestimated activity level for both moderate and vigorous intensities in a preschool-aged sample. Research has shown that children's vigorous intensity physical activity is typically 3-s or less in duration, so averaging over a longer epoch will likely minimize the measurement of this type of activity (Woods et al., 2012). Other researchers state that since vigorous intensity activity is likely to be misclassified as moderate intensity when using a longer epoch, simply calculating moderate-to-vigorous, instead of moderate and vigorous separately, helps to negate this issue (Reilly et al., 2008). However, comparison of the same data from 5- and 6-year-olds using 15-s, 30-s, 45-s, and 60-s epochs still demonstrated significant differences in daily moderate-to-vigorous physical activity (median difference 17-28 min/day). In the review by Migueles et al. (2017), it was shown that the majority of studies use a 15-s epoch in both children and adolescents, but future research should continue to explore the use of shorter epochs (1- or 5-s).

While the hip is the most common wear location for determining activity level, there is some concern that this "misses" some of the unique movement patterns of children. For example, the monitor detects no movement if just the arms are moving, but the trunk is stationary. Recent research has suggested that a combination of hip and wrist data may be more accurate than the hip alone (Trost & Hagenbuchner, 2016). However, research is needed on how to analyze wrist-worn data (e.g., which metric or cut-points to use) before this becomes widely used (Johansson, Ekelund, Nero, Marcus, & Hagströmer, 2015; Johansson, Larisch, Marcus, & Hagströmer, 2016).

Because the data are collected and analyzed later, issues of researcher fatigue, training, reliability, and time commitment may be lessened when using a monitor-based approach compared to direct observation (Cliff, Reilly, et al., 2009). Further, it is difficult to record age, sex, and weight status when using a scan-based direct observation system, but researchers can investigate the effects of these or other personal characteristics on physical activity more easily when using a monitor-based approach. For these reasons, monitors, like accelerometers, have risen in popularity, but have historically not provided important context, like activity location.

Global Positioning Systems Receiver Units

Addition of a second monitor, like a global positioning system (GPS) receiver unit, may provide some context to physical activity measured by accelerometry (Kerr, Duncan, & Schipperjin, 2011). GPS refers to a network coordinated by the United States Department of Defense that has three primary segments: 1) space segment, 2) control segment, and 3) user segment (US Government, 2019). The space segment refers to a network of 31 operational satellites orbiting the Earth, while the control segment monitors the network to ensure the time and orbit of each satellite is correct (US Government, 2019). In physical activity research, we are referring to the user segment, or GPS ground receiver units, which record spatial location, time, and velocity data that is obtained by communicating with at least three (preferably more) satellites (US Government, 2019). Since the receiver knows the satellites locations, signal speed, and how long it took to receive the signal, it can calculate a distance from the satellite and use these distances to triangulate location (US Government, 2019).

Before reviewing how GPS can be used in combination with accelerometry, it is important to consider the limitation of GPS units. The United States Department of Defense published a report on the accuracy of civilian GPS and noted that typically, the horizontal error is ~1 m (Hughes, 2014). However, the error will depend on the monitor used and has been shown to fluctuate from day-to-day or even fix-to-fix. Reliability depends on the accuracy of the GPS's recorded time, number of available satellites, and signal strength, which can be affected by weather or the presence of trees or buildings (Kerr et al., 2011). Schipperijn et al. (2014) conducted a study on the accuracy of GPS when in different locations and reported that 71.9% of GPS data points fell within 2.5 m of the expected location when in an open area (median error of 0.7 m), 74.2% fell within 2.5 m in a tree-covered location (median error of 1.0 m), but only 49.1% fell within 2.5 m when in a half-open location (building within 25 m on one side of route), where the median error was 2.6 m (Schipperijn et al., 2014). Similarly, Beekhuizen, Kromhout, Huss, and Vermeulen (2013) studied several different GPS monitors and found a median error of 2.2 m for a relatively open residential area to a median error of 7.1 m for a commercial high-rise area (Beekhuizen et al., 2013). This error would have implications for the usability of GPS for characterizing activity locations, particularly in small areas surrounded by trees and/or buildings.

A review by Krenn, Titze, Oja, Jones, & Ogilvie (2011) found that of 24 studies reviewed, only 11 reported the positional accuracy of their GPS receiver units and data loss (e.g., due to no signal acquisition) has been reported to be as low as 2.5% in schoolyard studies (Krenn et al., 2011). To assess possible error in reported data, researchers should provide an indication of conditions in which the GPS was used, for example, the positional dilution of precision (PDOP), which expresses the expected horizontal uncertainty based on the alignment and geometry of available satellites at a location (2 is ideal and 10 indicates unfavorable satellite geometry; Langley, 1999). However, satellite geometry is not the only source of error, so other sources could also be explored and reported, for example, range errors caused by signal strength, ionospheric effects, multipath, etc. (Dessler & Fejer, 1963). The Kp index (from 1 to 9) and corresponding Ap index (0 to 400) represent electrical activity in the ionosphere that may disrupt GPS signals (Dessler & Fejer, 1963). This can be obtained for each testing date from the National Oceanic and Atmospheric Administration or the International Association of Geomagnetism and Aeronomy. There may be differences between monitors even of the same model, so researchers should verify that each monitor works appropriately. One way to do this is to take the monitors to a geodetic point, a point of known location to test how accurately the monitors locate this point or compare the interunit reliability when detecting the same location.

Accuracy also depends on aspects of the monitor itself, like time to signal acquisition, number of channels, or sampling rate. For example, the GPS chipset MTK2 operates on 66 channels, with a sensitivity of -165 dBm (Kerr et al., 2011). The number of channels corresponds to how many satellites the device can connect to and will also affect how quickly the device can connect to these satellites; so more is better (Duncan et al., 2013). Sensitivity is the lowest power needed to record location accurately and a more negative number is preferable (Kerr et al., 2011). Finally, sampling rate depends on the device in question (typically 1 to 10 Hz), with an important trade-off between battery life and sampling rate (Kerr et al., 2011). It is also important to know how long it takes the device to acquire a signal from a cold start, warm start, and hot start (Duncan et al., 2013). Before explaining these start times, it is important to define the terms almanac and ephemeris data. The almanac is information on the entire satellite constellation, which tells the receiver which satellites should be overhead, and can either be obtained by the GPS during a cold start or downloaded ahead of time (this decreases start time). Ephemeris data are more precise, including the satellite's current and predicted location, and are downloaded from each satellite in view of the receiver. While almanac data is valid for several months, ephemeris data is updated by the device more regularly and can even be used to plan data collection around times when adequate satellites are present. Cold start occurs when the device attains a signal after being off for some time with no prior information on its location, which satellites to connect to (no almanac), or the position of those satellites (ephemeris). Warm start is when the device knows its last position and which satellites are likely in view (almanac) but still must download ephemeris data from satellites in view. Hot start occurs when the device is near its last known location, knows which satellites are in view (almanac), and has ephemeris data. Thus, shorter cold, warm, and hot start times are preferable and overall, start times can be shortened by turning devices on in the location of interest prior to data collection to allow for the download of relevant ephemeris and almanac data.

Researchers should consider the aforementioned errors, but none are insurmountable and these errors are likely to be reduced in coming years due to on-going government efforts. In the end, Duncan et al. (2013) found that the data collection site (whether shady, in a city, open area, etc.) explained 44.8% of the variability in GPS error, while the GPS model explained 8.5%. Thus, researchers should use the best possible monitor, but it is also important to collect data in locations that are feasible for GPS monitoring and to consider the inherent error of GPS units. Despite potential issues, GPS may still be a viable method of providing context to physical activity.

Several studies have used GPS units to characterize youth's school time physical activity, suggesting that despite potential sources of error, this monitor-based approach is feasible and capable of identifying the variation in physical activity across locations (Andersen et al., 2015; Clevenger et al., 2018; Dessing et al., 2013; Duncan, Badland, & Schofield, 2009; Fjørtoft et al., 2009; Fjørtoft et al., 2010; Pawlowski et al., 2016). Methods used to analyze these data micro-spatially vary, ranging from purely visualization approaches (Fjørtoft et al., 2009; Fjørtoft et al., 2010) to statistical methods (Clevenger et al., 2018; Pawlowski et al., 2016). For example, Fjørtoft et al. (2009) combined GPS and heart rate monitoring using dot maps, wherein each dot represented one data point and the size of the dot represented intensity. The same group of researchers conducted a study in adolescents and used a gridded approach, wherein each grid cell contained an average heart rate for that portion of the playground (Fjørtoft et al., 2010). A study in children and adolescents by Andersen et al. (2015) divided the schoolyard into five different zones (e.g., grassy area) and subsequently determined time and intensity in each zone using accelerometry and GPS data. Group differences (e.g., age and sex) were then statistically compared. A study by the same research group used hot spot analysis, with the Getis-Ord G* statistic to identify statistically significant clusters of high activity, where high accelerometer count values were surrounded by other high accelerometer count values (Pawlowski et al., 2016). Finally, a study was conducted to compare all approaches to each other and to video observation to assess the comparability of results between methods (Clevenger et al., 2018). While these methods were shown to be comparable overall, it is important to be consistent to ensure comparability between studies.

Potential method for combining GPS and accelerometer data

There are a few limitations of the methods previously used to analyze GPS and activity data. Overall, all of the approaches used are purely spatial approaches and do not account for the temporal relationship between features. This is important because the data are from individuals moving through both time and space, thus data points are not being collected simultaneously, but rather are occurring in sequence and in tandem with each other. Disregard for a temporal component is also an issue because previous research has shown that physical activity participation changes over the course of an outdoor period, with children participating in the most physical activity during the first 10 min of outdoor time, for example (McKenzie et al., 1997).

Hot spot analysis has previously been identified as the most promising of the approaches that have been used to characterize physical activity by schoolyard location because this is a statistical test that allows for the identification of significant clusters of high activity counts (hot spots) or clusters of low activity counts (cold spots) using the Getis Ord Gi* statistic (Getis & Ord, 1992). Instead of using spatial-only models of the relationships between variables (e.g., inverse distance weighting), one can use spatiotemporal weight matrices. Spatiotemporal weight matrices allow the researcher to define which points are considered neighbors using both spatial (distance) and temporal (time) parameters. Thus, for points to be allocated to the same cluster, they would have to occur proximally based on both distance and time. One benefit of this method is that hot spot analysis, in general, has been used in previous research on this topic, so the general concept is understood by physical activity researchers.

There is one additional limitation of note in regard to the use of GPS and accelerometry to characterize youths' outdoor physical activity. Coupling these two approaches together merely informs the researcher as to *where* a child is spending time and *where* s/he is being physically active on the schoolyard. Many direct observation approaches do not consider the *location* of physical activity, but rather the *context* or activity type (e.g., ball/object play). Thus, the importance of physical activity by schoolyard location may be called in to question as the comparability with more context-driven approaches is unknown.

As an illustration of the difference between activity type and location, one can compare the data collected by Nicaise et al. (2011) at two schoolyards using a modified version of the OSRAC-P, in which they coded children's location and their activity type. At the first schoolyard, time spent in the sandbox area (221 30-s intervals) and time spent engaging in sand play (212 30-s intervals) was similar, indicating that children were spending the majority of sandbox time playing in the sand. However, on the second schoolyard, children spent disproportionally more time in the sandbox area (791 30-s intervals), but only 214 of those 30-s intervals were spent engaging in sand play. Thus, children were doing something else while located in the sandbox. The descriptions and sizes of the two sandboxes are identical, and their research design did not allow for identification of what other activities children were engaged in while located in the sandbox. Overall, this indicates that some caution should be exercised when measuring physical activity by location without accompanying activity type.

To gain an understanding of the difference between schoolyard location and activity type, researchers could explore what activity types occur within various schoolyard locations. For example, if the majority of time spent in the fixed equipment location is spent playing with fixed equipment, this may be an example of where activity type can be inferred by a child's presence at that location. Alternatively, if it is found that children participate in a variety of activities within a grassy field, it may be more difficult to infer activity type from a child's presence in this location. However, if it is consistently found that presence on the grassy field promotes physical activity, this is important regardless of the activity type or context in which children are engaged. Lastly, there may also be differences in the activity type within a location by individual characteristics, like sex, based on research in older children (Black et al., 2015; Crum & Eckert, 1985; Dyment et al., 2009; Farley et al., 2008; Howe, Clevenger, Plow, Porter, & Sinha, 2018; Springer, Tanguturi, Ranjit, Skala, & Kelder, 2013). For example, a location like an open, grassy field, affords both ball games and lying or sitting, but boys may be more apt to participate in ball games in this location (Kılıçgün, 2014) compared to girls. Some of this context is missed when we only measure physical activity by location (as with GPS and accelerometry). Information is also missed when only assessing activity type as activities can occur in multiple locations (e.g., use of a ball on the grass vs. on an asphalt court). Research on the similarities and differences between location and activity type would improve our understanding of the potential limitations of a monitor-based approach that assesses physical activity by schoolyard location.

Future Directions

Previous research has demonstrated the importance of the childcare or school setting for promoting adequate physical activity participation in youth. While aspects of the environment have been related to physical activity levels (Broekhuizen et al., 2014), more research is needed on specific locations in which children are physically active on the schoolyard. But, since each schoolyard is unique, it would be useful to develop a method for measuring physical activity and its locational context that is less time and resource intensive than methods like direct observation, so that measures can be conducted on many schoolyards with varying characteristics.

Monitor-based approaches, like the combination of GPS with accelerometers, may provide a useful assessment of individual children's physical activity and its context while on the schoolyard, but previously used approaches for analyzing these data are inadequate to identify temporally and spatially relevant clusters of physical activity participation. Once this method is developed, it can be used on a large number of schoolyards to characterize schoolyard activity. As noted by Cosco (2007), there is a particular need to elucidate the play setting preferences of overweight children, minorities, and girls and then, to decipher what attractive features might promote or sustain activity in these groups. This information can then be used to design activity-promoting schoolyards and interventions.

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CHAPTER 3: A SYSTEMATIC REVIEW OF CHILD AND ADOLESCENT PHYSICAL ACTIVITY BY SCHOOLYARD LOCATION

Abstract

We conducted a systematic review of children and adolescents' physical activity by schoolyard location. PubMed and Web of Science were searched and articles were selected that included 3- to 17-year-olds and specifically examined and reported physical activity by schoolyard location. Our primary outcomes of interest were the percent of total time or observation intervals spent in each location and percent of time or observation intervals within each location being sedentary or participating in moderate-to-vigorous physical activity. Included studies (N=24) focused on preschoolers (n=6), children (n=11), adolescents (n=2), or children and adolescents (n=5) and primarily used direct observation (n=17). Fields, fixed equipment, and blacktop were all important locations for physical activity participation, but there were differences by age group and sex. More research is needed that uses a consistent methodology and accounts for other factors, such as time of year, provided equipment, and differences in schoolyard designs.

Introduction

The importance of physical activity for children and adolescents is well known, as there are physical and psychosocial short- and long-term benefits (Berenson & Srnivasan, 2005; Janssen & LeBlanc, 2010; Katzmarzyk et al., 2016; Strong et al., 2005). School is an opportune time to promote participation in physical activity because most young people attend school from 3-5 years of age until 16-18 years of age (McFarland et al., 2017). However, children and adolescents spend the majority of the school day indoors, where they participate in predominantly sedentary behavior (Bailey et al., 2012; Tandon, Saelens, & Christakis, 2015). Outdoor time (i.e., recess) may be the only opportunity for free-play physical activity during the school day (Ramstetter, Murray, & Garner, 2010), and it contributes up to 70% of weekday physical activity (Guinhouya et al., 2009; Mota et al., 2005; Ridgers, Stratton, Clark, Fairclough, & Richardson, 2006). Despite making an important contribution to daily physical activity, many studies report that youth spent less than half of recess being active (defined as participating in light-to-vigorous physical activity for preschoolers or moderate-to-vigorous physical activity for children and adolescents), and activity levels are consistently lower in girls and adolescents compared to boys and younger children, respectively (Brown et al., 2009; McKenzie et al., 1997; Pate et al., 2015; Ridgers, Salmon, Parrish, Stanley, & Okely, 2012; Ridgers, Stratton, & Fairclough, 2005; Sugiyama, Okely, Masters, & Moore, 2012; Tandon et al., 2015). Due to reductions in the frequency and duration of recess time in many schools (Lee, Burgeson, Fulton, & Spain, 2007; McMurrer, 2007), facilitating physical activity participation during provided time is important. However, there is substantial variation in outdoor physical activity levels between schools, partially due to differences in the physical environment.

The schoolyard physical environment affects participation in physical activity, as evidenced by correlations between environmental variables (e.g., schoolyard size, presence/absence of a specific piece of equipment; Boldemann et al., 2006) and physical activity levels and by the activity-promoting effects of interventions that modify the schoolyard environment (e.g., provision of additional equipment; Verstraete, Cardon, Clercq, & Bourdeaudhuij, 2006). In 2014, Broekhuizen, Scholten, and de Vries published a systematic review on playground characteristics as correlates of physical activity. In one of the studies, Gubbels, Van Kann, & Jansen (2012) reported a negative association between having swinging equipment or a sandbox (two types of fixed equipment) and schoolyard physical activity participation and in another study, Ridgers, Fairclough, Stratton (2010) reported a positive association between the number of pieces of fixed equipment and physical activity participation. These disparate results highlight one limitation of using correlation analysis, which does not provide information about actual physical activity levels while playing on or with specific pieces of fixed equipment, for example. Therefore, it is unknown if children and adolescents are using these schoolyard areas for their intended purpose, or if, in avoiding these areas, they are being more or less physically active elsewhere.

Research that has explored physical activity in different schoolyard settings supports that participation in physical activity is not uniform across the schoolyard (see references from the present review). This is because different locations afford different behaviors (e.g., a sandbox affords seated play, while an open field affords more running). However, due to substantial variability not just in schoolyard design, but also in sample characteristics, study design, and recess timing/duration, results have been inconsistent. Comparing results from many studies with a variety of schoolyards and settings would be beneficial to identify the most salient findings to date, as well as to identify future research directions. Research in this area could inform activity-promoting interventions that involve the addition of activity-promoting areas to the schoolyard. Perhaps more importantly, the commonly seen group differences in physical activity participation are ameliorated in some schoolyard locations (Clevenger, Sinha, & Howe, 2018; Dyment, Bell, & Lucas, 2009; Howe, Clevenger, Plow, Porter, & Sinha, 2018; Saint-

Maurice, Welk, Silva, Siahpush, & Huberty, 2011) and this information could be used to develop interventions that specifically aim to promote physical activity participation in groups with low levels of physical activity, like girls or adolescents.

There is some preliminary evidence from intervention studies demonstrating that modification of schoolyard locations can promote increases in physical activity within those specific schoolyard locations (Anthamatten et al., 2011; Nicaise, Kahan, Reuben, & Sallis, 2012). This is critical, as schoolyard redesign interventions can promote long-term increases in physical activity participation, without undue burden to school staff. Assessing physical activity by location in these studies provides evidence for and identifies which intervention components specifically worked to promote physical activity, as opposed to only assessing changes in overall physical activity levels. This was supported by Ridgers, Stratton, Fairclough, & Twisk (2007), who suggested that future research should aim to collect information on what specifically children were doing before and after redesign interventions. For example, addition of a new curved track may lead to an increase in overall physical activity participation, but upon further investigation, it may be demonstrated that children are being more active in other locations and not spending time on the new track and therefore, it may not be the most viable intervention strategy. Thus, both observational and experimental (intervention) evidence regarding the locational context of schoolyard physical activity may inform future intervention design to ultimately promote physical activity in all children and adolescents during provided outdoor time.

Our purpose was to conduct a systematic review of children and adolescents' physical activity by schoolyard location. In line with our purpose, our primary research question was- How does sedentary behavior and/or moderate-to-vigorous physical activity participation of children and adolescents, aged 3–17 years of age, vary by location within a schoolyard? Second, in what schoolyard locations do children and adolescents spend most of their free-play time? Are there group differences (e.g., by age, sex) in overall time spent or physical activity participation by schoolyard location?

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guided this systematic review (Moher, Liberati, Tetzlaff, & Altman, 2009).

Search strategy and data sources

This review was registered in the international prospective register of systematic reviews (PROSPERO) (CRD42018087547) on February 8, 2018. PubMed and Web of Science (core database) were searched on January 30, 2018, by one person (KC) using combinations of the following terms: (physical activity OR activity OR play) AND (environment OR schoolyard OR recess OR playground OR location) AND (preschool* OR child* OR adolescen*). When possible, we filtered for human studies, but no date restriction was included, meaning that results were all-encompassing until January 2018. To identify if there was a large quantity of unpublished literature related to our topic, ProQuest was searched for dissertations and theses (grey literature) using the same search terms, but results were restricted by language (English) and to the 1000 most relevant studies (as determined by ProQuest). The search was restricted to the 1000 most relevant studies because there was no indication that dissertations/theses were available that were not later published as peer-reviewed manuscripts.

Selection of studies

In Excel, duplicates were removed from the exported search results, and remaining studies were screened by title, then abstract, then by full text, by two reviewers (KC and MW). Percent agreement was calculated at each step, with a minimum agreement of 80%, and all discrepancies were resolved between the two reviewers prior to continuing the screening and selection process. Finally, the search was replicated by one person (KC) on October 10, 2018, to include any articles published since the initial search. Numbers of articles reported in subsequent sections of this manuscript refer to the full search (including the October 2018 search). The references of the included full-text articles were screened to identify additional articles that met our inclusion criteria.

Studies were not limited by research design and were selected based on the following inclusion and exclusion criteria. Inclusion criteria were 1) include human subjects aged 3–17 years, 2) specifically examine physical activity by schoolyard location, and 3) be published by October 2018. Exclusion criteria included 1) did not report physical activity by location within the schoolyard or use physical activity by schoolyard location in their analysis, 2) article not available in English, or 3) no full-text article available (e.g., only a conference abstract).

Data extraction

Once full-text articles were selected for inclusion in this review, data were extracted from each article by the two reviewers (KC and MW) using a standardized data extraction form. Study characteristics (e.g., design, setting, number of days and duration of data collection, measures of location and physical activity) were recorded. Setting was a description of the situation in which data were collected (e.g., 24 public schools in San Diego County, California, USA). When location was not reported within the methods, the location of the senior author was recorded, under the assumption that data collection was conducted near their institution. Sample size and characteristics (e.g., number of males, proportion of overweight/obese youth, age range, school grade range) were extracted and when appropriate, were based on the final included sample within the study (i.e., after removing participants with insufficient data). When true sample size (i.e., unique number of individuals observed) was not available in direct observation studies, the study sample was recorded as the number of observed children, although this number may include duplicates (i.e., a child who was observed twice would count as two children). The number of days and duration of data collection were recorded as reported (i.e., could be an approximation by the study's authors, or a specific amount of recorded data).

We extracted the descriptions and measures of area (size in m^2) for each schoolyard location. For the majority of studies, we recorded the percentage of total time or observation intervals spent in each location and percent of time or observation intervals within each location being sedentary or participating in moderate-to-vigorous physical activity. For studies using the System for Observing Play and Leisure Activity in Youth (SOPLAY), we extracted the percent of children observed within that location and the percent of participants observed in that location classified as being sedentary or moderate-to-vigorously active. When necessary, these values were calculated from provided information (e.g., time in a location and overall time were used to estimate the percent of time spent in that location). Due to vast differences in the locations reported in each study and schoolyard, we did not pool estimates for any outcome measures. Finally, group differences that were considered (e.g., by sex) were recorded.

Methodological quality

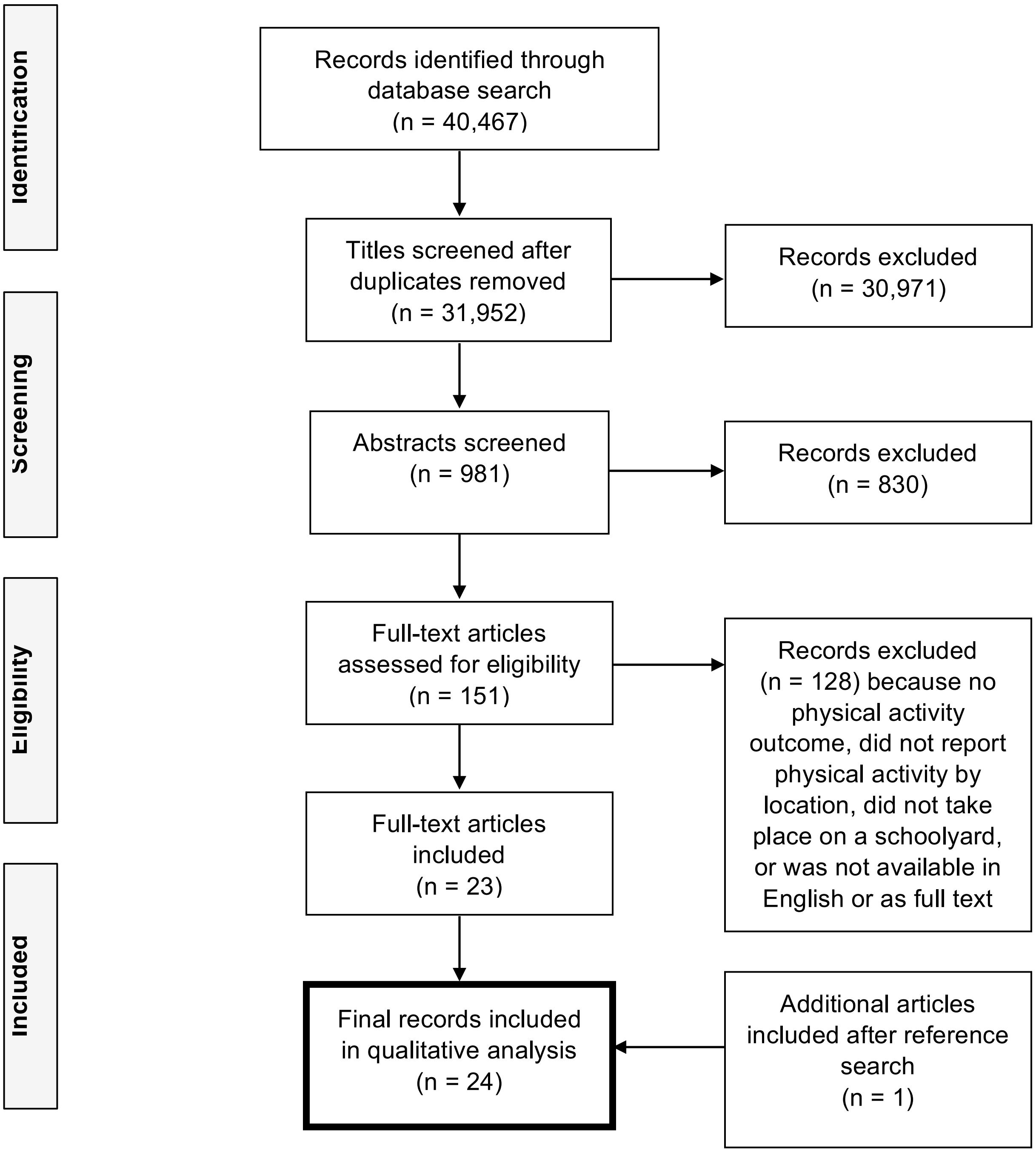
The quality of included studies was assessed using a standardized score sheet adapted from the review by Broekhuizen et al. (2014), in which 12 (cross-sectional/observational studies) to 13 (interventions) items were scored as not present (0), partially present (0.5), or present (1), and then averaged. Examples of quality items include whether the authors stated the representativeness of the sample, described data loss or drop out, reported the area (size) of the schoolyard, specified the age and sex of the sample, and provided support for the measures of location and physical activity (e.g., validity, reliability).

Results

Selection of Studies

As outlined in the PRISMA flow chart (Figure 3.1), the search resulted in 40,467 articles, 23 of which were included in the final selection (Andersen, Klinker, Toftager, Pawlowski, & Schipperijn, 2015; Anthamatten et al., 2011; Barnas, Wunder, & Ball, 2018; Black, Menzel, & Bungum, 2015; Brink et al., 2010; Clevenger et al., 2018; Cosco, Moore, & Islam, 2010; Dyment & Bell, 2007; Dyment et al., 2009; Farley, Meriwether, Baker, Rice, & Webber, 2008; Fjørtoft, Kristoffersen, & Sageie, 2009; Fjørtoft, Löfman, & Thorén, 2010; Howe et al., 2018; Hustyi, Normand, Larson, & Morley; Larson, Normand, Morley, & Hustyi, 2014; Nicaise, Kahan, & Sallis, 2011; Nicaise et al., 2012; Pawlowski, Andersen, Troelsen, & Schipperijn, 2016; Saint-Maurice et al., 2011; Sallis et al., 2001; Smith et al., 2014; Springer et al., 2013; Wood, Gladwell, & Barton, 2014). The remaining articles were removed as duplicates (n=8,515), after screening by title (n=30,791), screening by abstract (n=830), or after reading the full text (n=128). After screening the references of the 23 included articles, one additional article was added (Willenberg et al., 2010), making the final number of articles for this review 24.

Figure 3.1. Flow diagram of the search for studies on physical activity by schoolyard location



Study Designs and Settings

An overview of the age group and measures used in included studies is provided in Table 3.1. Detailed descriptions of the 24 studies, including study design and setting, sample description, and the measures used for location and physical activity participation are outlined in Table 3.2. Studies focused on preschoolers (3-5 years; n=6, 25.0% of studies), children (6-12 years; n=11, 45.8%), adolescents (12-17 years; n=2, 8.3%), or both children and adolescents (n=5, 20.8%) (see Table 3.1 for references). The majority (n=16, 66.7%) of studies were conducted in the United States (Anthamatten et al., 2014; Barnas et al., 2018; Black et al., 2015; Brink et al., 2010; Clevenger et al., 2018; Cosco et al., 2010; Farley et al., 2008; Howe et al., 2018; Hustyi et al., 2012; Larson et al., 2014; Nicaise et al., 2012; Nicaise et al., 2011; Saint-Maurice et al., 2011; Sallis et al., 2001; Smith et al., 2014; Springer et al., 2013), five (20.8%) were conducted in Europe (Andersen et al., 2015; Fjørtoft et al., 2009; Fjørtoft et al., 2010; Pawlowski et al., 2016; Wood et al., 2014), one (4.2%) in Australia (Willenberg et al., 2010), one (4.2%) in Canada (Dyment & Bell, 2007), and one (4.2%) was conducted in both Canada and Australia (Dyment et al., 2009). From one to 59 schoolyards were included in the selected studies, with the majority of studies focusing on one (n=9, 37.5%) or two (n=7, 29.2%) schools.

Five studies were experimental (20.8%; 3 in preschoolers, 2 in children), while 19 were observational (79.2%). Three experimental studies (2 in preschoolers) had groups of children play in different locations and measured their activity levels (Hustyi et al., 2012; Larson et al., 2014; Wood et al., 2014). One experimental study in preschoolers measured activity level by location before and after a playground renovation (Nicaise et al., 2012) and the final experimental study in children measured activity before and after the restructuring of a schoolyard into activity-specific zones (Barnas et al., 2018). There were no experimental studies conducted with adolescent samples. Additionally, one observational study in children was self-identified as “quasi-experimental” as the purpose was to match schools that had undergone a schoolyard redesign within the last year to schools that had the intervention at least two years prior, and to schools that did not undergo intervention (Brink et al., 2010). There was also a second observational study (Anthamatten et al., 2014) in the same setting, using the same intervention, and the same study design, so these two observational studies could both be considered "quasi-experimental." Importantly, 21 studies generated the 24 manuscripts included in this review as three pairs of studies- Brink et al. (2010) and Anthamatten et al. (2014), Clevenger et al. (2018) and Howe et al. (2018), and Hustyi et al. (2012) and Larson et al. (2014) reported on at least partially overlapping samples.

Measures of Location and Physical Activity

A variety of methods for measuring physical activity by schoolyard location were used, including direct observation (n=17, 70.8%), activity monitors (n=6, 25.0%), and one questionnaire (n=1, 4.2%) (references in Table 3.1). Studies of preschoolers predominantly (n=4) used the Observational System for Recording Physical Activity in Children–Preschool Version (OSRAC-P); three of these studies were experimental (Hustyi et al., 2012; Larson et al., 2014; Nicaise et al., 2012) and two used a modified version of the OSRAC-P that included additional codes for schoolyard location (Nicaise et al., 2012; Nicaise et al., 2011a). The remaining two studies on preschoolers, both observational, used the Child Activity Rating Scale (CARS) in conjunction with behavior mapping (Cosco et al., 2010; Smith et al., 2014).

Most studies (n=8) in children and/or adolescents used SOPLAY (Anthamatten et al., 2014; Barnas et al., 2018; Brink et al., 2010; Dyment et al., 2009; Farley et al., 2008; Saint-Maurice et al., 2011; Sallis et al., 2001; Willenberg et al., 2010) and one study used a version of SOPLAY modified to include some aspects of the System for Observing Play and Recreation in Communities (SOPARC) (Black et al., 2015). Five studies of children and/or adolescents used Global Positioning System receiver units (GPS) in conjunction with heart rate monitoring (n=2) (Fjørtoft et al., 2009; Fjørtoft et al., 2010) or accelerometry (n=3) (Andersen et al., 2015; Clevenger et al., 2018; Pawlowski et al., 2016), and one experimental study in children used accelerometry alone (Wood et al., 2014). Of the four studies that used accelerometry, three used the Evenson, Catellier, Gill, Ondrak, and McMurray (2008) cut-points (Andersen et al., 2015; Clevenger et al., 2018; Pawlowski et al., 2016), and one (the experimental study) used Treuth et al. (2004) cut-points (Wood et al., 2014). One study of children used a modified version of the System for Observing Fitness Instruction Time (SOFIT) called 'SOFIT-Recess' (Springer et al., 2013) and one study used video direct observation, in which the activity type of individual children was coded and categorized using the compendium of energy expenditures for youth (Howe et al., 2018). Finally, one study had teachers, parents, and principals complete a questionnaire of where children were physically active on the schoolyard (Dyment & Bell, 2007).

Table 3.1. Overview of study samples and methodological approaches used

	Sample			**Methodological Approach**						
Study	P	C	A	Mon.	SOPLAY	Behav. Map.	Video	OSRAC	SOFIT	Q
Andersen, 2015		X	X	X						
Anthamatten, 2011		X			X					
Barnas, 2018*		X			X					
Black, 2015		X			X					
Brink, 2010		X			X					
Clevenger, 2018		X		X						
Cosco, 2010	X					X				
Dyment, 2007		X	X							X
Dyment, 2009		X	X		X					
Farley, 2008		X	X		X					
Fjørtoft, 2009		X		X						
Fjørtoft, 2010			X	X						
Howe, 2018		X					X			
Hustyi, 2012*	X							X		
Larson, 2014*	X							X		
Nicaise, 2011	X							X		
Nicaise, 2012*	X							X		
Pawlowski, 2016		X	X	X						
Saint-Maurice, 2011		X			X					
Sallis, 2001			X		X					
Smith, 2014	X					X				
Springer, 2013		X							X	
Willenberg, 2010		X			X					
Wood, 2014*		X		X						
Number of Studies	6	16	7	6	9	2	1	4	1	1

*=experimental study; Sample: *P*=preschool, *C*=child, *A*=adolescent; Methodological Approach: *Mon*=monitor-based, *SOPLAY*= System for Observing Play and Leisure Activity in Youth, *Behav. Map.*=behavior mapping, *Video*=video direct observation, *OSRAC*= Observation System for Recording Activity in Children- Preschool Version, *SOFIT*= System for Observing Fitness Instruction Time, *Q*=questionnaire

Study Results

A variety of schoolyard locations were included and descriptions of these locations, as provided by the individual studies, are outlined in Table 3.3. Some locations were common, including grassy areas or open spaces, fixed equipment or play structures, and hard-surface areas, including asphalt (also called blacktop or bitumen), basketball courts, tetherball, etc. Four studies reported the area (size) of each location (Andersen et al., 2015; Farley et al., 2008; Howe et al., 2018; Nicaise et al., 2011), three reported overall or average areas (Cosco et al., 2010; Fjørtoft et al., 2009; Smith et al., 2014), and 17 did not report area.

The mean percent of time spent in moderate-to-vigorous physical activity across studies was approximately 40%, with a minimum of 0% (adolescent girls; Sallis et al., 2001) and maximum of 87% (a school with a jogging and walking incentive program; Black et al., 2015). Study outcomes, including percent of time/observation intervals spent in each location and percent of time/observation intervals within a location spent in sedentary and moderate-to-vigorous physical activity, are outlined in Table 3.4. Outcomes for studies using SOPLAY are found in Table 3.5, including percent of children observed in each location and percent of children in each location engaged in sedentary behavior and moderate-to-vigorous activity. Studies that reported results for multiple schoolyards were included with results from each school reported separately when possible.

Percent of time/observation intervals in specific locations showed a minimum of 0% (tetherball in Black et al., 2015 and porch in Cosco et al., 2010) and maximum of 90.1% (girls on asphalt; Fjørtoft et al., 2009). Preschoolers tended to spend time in open areas (Cosco et al., 2010), on fixed equipment (Cosco et al., 2010; Nicaise et al., 2011), or in an asphalt area with fixed equipment (Nicaise et al., 2011), while children most often played on fixed equipment (Springer et al., 2013), specifically swings (Anthamatten et al., 2014), and hard-surface or blacktop areas (Anthamatten et al., 2014; Black et al., 2015; Clevenger et al., 2018; Howe et al., 2018). Finally, studies on both children and adolescents indicated that asphalt areas (Andersen et al., 2015; Dyment et al., 2009) or grassy areas (Dyment et al., 2009) were commonly-visited locations.

In the observational studies of preschoolers, there was support for grass or open spaces (Cosco et al., 2010; Nicaise et al., 2012; Nicaise et al., 2011), pathways (Cosco et al., 2010;

Nicaise et al., 2012), and fixed equipment (Cosco et al., 2010; Smith et al., 2014) as areas with the highest levels of moderate-to-vigorous physical activity. The two experimental studies also indicated that fixed equipment was the most activity-promoting location, when compared to an unequipped open area, or an area with portable equipment (Hustyi et al., 2012; Larson et al., 2014). In regard to minimizing sedentary behavior (and therefore promoting light-to-vigorous physical activity), open spaces or fields (Cosco et al., 2010; Nicaise et al., 2011), a dramatic play area (Cosco et al., 2010), and paths (Nicaise et al., 2012) were salient locations. In observational studies of children, moderate-to-vigorous physical activity was highest in fields (Brink et al., 2010; Springer et al., 2013), fixed equipment (Anthamatten et al., 2014; Brink et al., 2010; Howe et al., 2018b), and blacktop or asphalt courts (Black et al., 2015), while one experimental study indicated that the field was most activity-promoting when compared to a fixed equipment condition (Wood et al., 2014). Studies of adolescents indicated physical activity occurred on sports-related blacktop/courts (Fjørtoft et al., 2010; Sallis et al., 2001).

One study explored differences by age group and reported that children were more active than adolescents overall (64 vs. 23% of time spent in moderate-to-vigorous physical activity), but physical activity levels were not significantly different when youth were located in grassy areas (29 vs. 25% of time spent in moderate-to-vigorous physical activity) (Andersen et al., 2015). Sixteen studies alluded to sex differences in their results (Andersen et al., 2015; Anthamatten et al., 2014; Barnas et al., 2018; Black et al., 2015; Brink et al., 2010; Clevenger et al., 2018; Dyment et al., 2009; Farley et al., 2008; Fjørtoft et al., 2009; Howe et al., 2018; Pawlowski et al., 2016; Saint-Maurice et al., 2011; Sallis et al., 2001; Springer et al., 2013; Willenberg et al., 2010; Wood et al., 2014). Compared to boys, girls spent more time (Anthamatten et al., 2014; Clevenger et al., 2018; Farley et al., 2008; Howe et al., 2018; Pawlowski et al., 2016; Springer et al., 2013) and were more active (Black et al., 2015; Clevenger et al., 2018; Howe et al., 2018; Willenberg et al., 2010) when located on fixed equipment, or differences in physical activity participation were smaller between boys and girls within this location compared to other locations (Saint-Maurice et al., 2011). Findings for asphalt or court areas were mixed, but studies found that boys spent more time on basketball, blacktop, or court areas (Anthamatten et al., 2014; Clevenger et al., 2018; Dyment et al., 2009; Farley et al., 2008; Howe et al., 2018; Springer et al., 2013) and boys were more active on hard surface, blacktop, court, or basketball areas (Anthamatten et al., 2014; Black et al., 2015; Clevenger et al., 2018; Howe et al., 2018; Sallis et al., 2001), but others suggested girls were more active in a tetherball area (Black et al., 2015) and that differences in physical activity participation between boys and girls were reduced on unstructured hard surface areas (Brink et al., 2010) and basketball courts (Saint-Maurice et al., 2011).

Methodological quality

Average study quality was 0.63 out of a maximum possible score of 1, from a minimum of 0.25 (Hustyi et al., 2012) to a maximum of 0.92 (Andersen et al., 2015; Smith et al., 2014). Quality was lowest for preschool studies (mean of 0.49), but similar for studies of children (0.68), adolescents (0.67), or children and adolescents (0.67). Only three of the eight studies with quality ≤0.5 reported overall physical activity levels (approximately 21% of time in moderate-to-vigorous physical activity). Almost all the studies with quality >0.5 reported overall physical activity (approximately 44% of time in moderate-to-vigorous physical activity).

Table 3.2. Description of studies, design, sample, and measure of location and physical activity

Study	Study design	Study setting	Sample description	Study duration/timing	Measure of location	Measure of PA
Andersen, 2015	Observational	4 city schools in the Haraldsgade district of Copenhagen, Denmark	N=316 46.8% male OW/OB not reported 5-8th grade, 10-15 y	2-4 school days, 2 recesses/day, which were, on average, 55 min total/day	QStarz BT-Q1000x GPS tracker, 15-s epoch	Actigraph GT3X, 2-s epoch, Evenson (2008) cut-points
Anthamatten, 2014	Observational, quasi-experimental	9 schools in low-to-mid socioeconomic status neighborhoods in Denver, Colorado, USA	N=106 observation zones (not children) Male not reported OW/OB not reported Elementary, 5-11 y	4 days, no duration reported, but included before, during and after school and weekends	SOPLAY	SOPLAY
Barnas, 2018	Experimental	One private and one public school, Missouri, USA[c]	N=364 53.8%[c] male OW/OB not reported 3-5th, age not reported	10 school days pre-and post-intervention (5 days of each used for analysis)	SOPLAY	SOPLAY (also used pedometry, but not for microspatial analysis)
Black, 2015	Observational	2 schools in Henderson, Nevada, USA[c]	N~771[c] Male not reported OW/OB not reported K-5[c], age not reported	10 days/school, 15 min/day at morning recess	SOPLAY and SOPARC	SOPLAY and SOPARC
Brink, 2010	Observational, quasi-experimental	9 schools in low-income neighborhoods, in northeastern, southwestern, and western Denver, Colorado, USA	N=3688 (total at schools) 53%[c] male OW/OB not reported Elementary, age not reported	4 days, no duration reported, but included before, during and after school	SOPLAY	SOPLAY

Table 3.2. (cont'd)

Study	Study design	Study setting	Sample description	Study duration/timing	Measure of location	Measure of PA
Clevenger, 2018	Observational	One elementary school in a small city in rural Appalachia, Southeast Ohio, USA	N=23 47.8% male 26.1% OW/OB 3-5th, 8-12 y	2 days, one 20 min recess period/day	LandAirSea Tracking Key Pro GPS receiver unit, 1-s epoch	Actigraph GT3X+, 1-s epoch, Evenson cut-points
Cosco, 2010	Observational	2 childcare centers in North Carolina, USA	N=53 Male not reported OW/OB not reported Preschool, 3-5 y	1 morning recess session, 46-55 min/school	Behavior mapping	CARS
Dyment, 2008	Observational	59 urban, suburban, and rural schools across six provinces in Canada	N=105 parents, teachers, and principals 79% male OW/OB not reported No grade, between 20 and 65 y	Asked about a "typical day"	Questionnaire	Questionnaire
Dyment, 2009	Observational	One school in a middle-upper class neighborhood in Launceston, Tasmania, Australia and one school in an upper socioeconomic status community in Toronto, Ontario, Canada	N=not reported Male not reported OW/OB not reported K-8th grade, age not reported	7-11 days/school, 3 times/day	SOPLAY	SOPLAY

Table 3.2. (cont'd)

Study	Study design	Study setting	Sample description	Study duration/timing	Measure of location	Measure of PA
Farley, 2008	Observational	One large fenced schoolyard in an inner-city neighborhood in New Orleans, USA	N=approximately 71/weekday and 26/weekend day Male not reported OW/OB not reported K-8th, age not reported	1 scan/area/day, 46 weekdays and 16 weekend days over 2 years	SOPLAY	SOPLAY
Fjørtoft, 2009	Observational	One typical old city primary school, one more modern primary school located in a rural area, southern Norway	N=61 46% male OW/OB not reported 1st grade, 6 y	40 min/child, measured once over a 4 week period	Garmin Forerunner GPS 201 tracker, 5-s epoch	Polar 521 heart rate chest strap and watch, 5-s epoch
Fjørtoft, 2010	Observational	Two schools in southern Norway, one in a suburban area, one in a semi-rural area	N=81 56% male 14.3%[c] OW/OB 9th graders, 14 y	25-45 min/school, 1 day/child	Garmin Forerunner GPS 305, ~ 7-s epoch	Garmin Forerunner GPS 305 (heart rate chest strap), ~ 7-s epoch
Howe, 2018	Observational	One elementary, rural Appalachia, southeast, Ohio, USA	N=23 47.8% male 27.3% OW/OB 3-5th grade, 8-12 y	Two 20-min recess periods	Video direct observation	Video direct observation
Hustyi, 2012	Experimental	One day-care center, California, USA[c]	N=4 50% male OW/OB not reported Preschool, 4 y	Sessions of 5 min each, 3-5 sessions/day over a 5 day period	Prescribed as part of experimental design, or observed via video	OSRAC-P

Table 3.2. (cont'd)

Study	Study design	Study setting	Sample description	Study duration/timing	Measure of location	Measure of PA
Larson, 2014	Experimental	One local day care, California, USA[c]	N=8 50% Male 25% OW/OB Preschool, 3-4 y	Sessions of 5 min each, 3-9 sessions/day over a 3-5 day period	Prescribed as part of experimental design, or observed via video	OSRAC-P of video
Nicaise, 2011	Observational	One university preschool (with two playgrounds) in a large city in the southwest USA	N=51 44% male ~11% OW/OB[c] Preschool, 4-5 y	2 recess periods, one at each of the school's two playgrounds, 15-30 min/child	OSRAC-P, modified to include codes for location	OSRAC-P
Nicaise, 2012	Experimental	One university campus children's center in a large coastal city in California, USA	2 independent samples Pre-intervention: N=50 42% male 15.9% OW/OB Preschool, 4-5 y Post-intervention: N=57 60% male 13.8% OW/OB Preschool, 4-5 y	15-30 min/child, 2 observations/child	OSRAC-P, modified to include codes for location	OSRAC-P
Pawlowski, 2016	Observational	One public school in a rural lower middle class area in western Denmark	N=81 42.0% male OW/OB not reported 4th-6th grade, 10-13 y	Three days, three breaks/day for a total of 70 min/day	QStarz BT-Q1000xt GPS tracker, 15-s epoch	Actigraph GT3X, 15-s epoch, Evenson cut-points

Table 3.2. (cont'd)

Study	Study design	Study setting	Sample description	Study duration/timing	Measure of location	Measure of PA
Saint Maurice, 2011	Observational	Two elementary schools, in Nebraska, USA[c], but only one used for microspatial analysis	N=100[c] 52% male ~21.7% OW/OB[c] 3rd-5th grade, 8-12 y	3 scans/area, 3 days, twice (fall and spring)	SOPLAY	SOPLAY (also used accelerometry, but not for their microspatial analysis)
Sallis, 2001	Observational	24 public schools in San Diego County, California, USA	N= ~1081 youth attended each school Male not reported OW/OB not reported 6th-8th grade, age not reported	Before, during, after school (3 observations/day), 3 days/school	SOPLAY	SOPLAY
Smith, 2014	Observational	30 licensed centers in Piedmont/ research triangle region of North Carolina, USA, including urban, suburban, and rural	N=6083 observations 54% male OW/OB not reported Preschool, 3-5 y	Total of 5-9 observation cycles/site (at 7-min intervals) during morning and afternoon recess periods	Behavior mapping	CARS
Springer, 2013	Observational	8 low-income, public elementary schools in a large, urban school district in central Texas, USA	N=616 50% male OW/OB not reported 3rd grade, age not reported	Total of 77 observations, with approximately 4/school each month for 3 months	SOFIT-Recess	SOFIT-Recess

Table 3.2. (cont'd)

Study	Study design	Study setting	Sample description	Study duration/timing	Measure of location	Measure of PA
Willenberg, 2010	Observational	23 primary schools in a low-socioeconomic status part of Melbourne, Australia (Moreland area)	N=3,006 observations 49.6% male OW/OB not reported 4-5th grade, 8-11 y	Lunchtime scan	SOPLAY	SOPLAY
Wood, 2014	Experimental	One urban primary school, Colchester, United Kingdom[c]	N=25 48% male OW/OB not reported Primary, 8-9 y	Morning (15 min) and lunch (30 min-1 hr) playtimes, one day/condition, one week apart	Prescribed as part of experimental design	Actigraph GT1M, 1-s epoch, Treuth cut-points

[c] indicates that the location, sample characteristics, or observation period were estimated for this review based on available information (i.e., not directly reported in the original article); **y**=years of age; **OW/OB,** overweight or obese; **GPS,** Global Positioning Systems; **SOPLAY,** System for Observing Play and Leisure Activity in Youth; **SOPARC,** System for Observing Play and Recreation in Communities; **CARS,** Child Activity Rating Scale; **OSRAC-P,** Observational System for Recording Physical Activity in Children–Preschool Version; **SOFIT,** System for Observing Fitness Instruction Time

Table 3.3. Summary of locations reported on by studies and corresponding results

Study	Locations Reported	Area	Description of Location
Andersen, 2015	Grass	207-5106 m^2	Various play fields and lawn areas, often used for soccer but without any markings or goals.
	Multi-court	253-1177 m^2	Framed play areas on surfaces like artificial grass, rubber, concrete pavers or asphalt designed for different ballgames like basketball and soccer.
	Solid surface	2259-6337 m^2	Solid surface represents all paved areas with surfaces like asphalt or concrete pavers. This area type is characterized by level (flat) open areas, often with various painted markings for games and benches placed in different places.
	Natural	426-1325 m^2	Areas with shrubs, trees, natural stones, etc.
	Playground	363-1138 m^2	Playground represents areas with playground equipment such as swings, slides and climbing frames, typically grouped and placed on surfaces like sand or gravel.
Anthamatten, 2014	Basketball	Not reported	No further description
	Play equipment		Jungle gyms and slides
	Tetherball		No further description
	Swings		No further description
	Hard-surface		Paved surfaces
	Play field		Grassy areas specifically designed for activities
	Unprogrammed		Grassy areas without any programming or play equipment

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Barnas, 2018 School A.	Functional movement obstacle course	Not reported	Students use movable obstacles to create a course between the existing jungle gym and playground structure.
	Basketball		A research volunteer facilitates the initial team creation and the students govern the game and keep track of the score.
	Walking track and balance corner		Chalk was used to add stretching or calisthenic exercise checkpoints to the existing walking track. The balance corner was attached to the track, and students balance on two dome cones in a large circle while attempting to bound a rubber ball between opponents' legs.
	Soccer		A research volunteer facilitates the initial team creation and the students govern the game and keep track of the score.
	Kickball		A research volunteer facilitates the initial team creation and the students govern the game and keep track of the score.
	Castle ball		A research volunteer facilitates the initial team creation and the students govern the game and keep track of the score. Teams defend their Hula-Hoop castle against the opponents' attack, without crossing the territory line.

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Barnas, 2018 School B	Basketball	Not reported	A research volunteer facilitates the initial team creation and the students govern the game and keep track of the score.
	Knock-out/Hopscotch-in		Students line up at the free throw line. The first two student shoot the ball at the basket. If the second shooter makes the shot before the first shooter, the first shooter is knocked out and must hopscotch while dribbling to get back in line. When a shot is made or a player is knocked out, the ball is passed to the next person in line and they can begin shooting.
	Balance corner and 4-square corner switch		The balance corner was attached to the track, and students balance on two dome cones in a large circle while attempting to bounce a rubber ball between opponents' legs. In 4-corner switch, students line up at the corner of a square chalked out on the ground. Four students go to the corners of the square and another goes to the middle. The middle student yells "switch" and all five students must find a new corner to stand in. The student who does not get to a new corner quickly enough goes to the end of the line and the new student goes to the middle. Any disputes, use 1 game of rock, paper, scissors to decide a victor.
	Imagination/free-play		Students create their own games using their imaginations.
	Functional movement obstacle course		Students use movable obstacles to create a course between the existing jungle gym and playground structure.
	Drop that cookie!		"Cookies" are left on the ground in this zone and the first students to pick them up begin the game. Students with a "cookie" are chased by those who did not. If tagged, the student with the "cookie" must drop it and another student can then pick it up. After a 5-second grace period, the new chase begins.

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Black, 2015 School A	Blacktop Grass Painted markings Tetherball Basketball courts Manufactured equipment	Not reported	No further description
Black, 2015 School B	Blacktop Grass Painted markings Tetherball Basketball courts Manufactured equipment Dirt Jog/Walk track Volleyball courts	Not reported	No further description
Brink, 2010 Non-Learning Landscapes	Hard surface structured	Not reported	Basketball and tetherball asphalt areas
	Hard surface unstructured		Unprogrammed creative play or educational marking areas, sitting or social gathering areas, and overhead structure or shade areas
	Soft surface structured		Play equipment requiring fall zones and play fields with or without grass

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Brink, 2010 Learning Landscapes	Hard surface structured	Not reported	Basketball and tetherball asphalt areas
	Hard surface unstructured		Unprogrammed creative play or educational marking areas, sitting or social gathering areas, and overhead structure or shade areas
	Soft surface structured		Play equipment requiring fall zones and play fields with or without grass
	Soft surface unstructured		Planted areas with or without sitting areas and trails, cultivated or habitat garden areas, and grassed or planted unprogrammed areas
Clevenger, 2018	Court	Not reported	Covered in concrete and had basketball hoops and colorful markings for playing games like four square
	Fixed equipment		Covered in mulch and included swings, climbing structures, stairs, bridges, and monkey bars
	Field		Open, grassy area without fixed equipment
Cosco, 2010 Center 1	Dramatic play	Overall 7497 ft^2	Two play houses
	Open area		Five open areas, noted as main location for facilitated activity, group games, or teacher-child interaction
	Pathway		Looped and linear paths
	Play equipment		One composite structure
	Sand play		One small sandbox
	Porch/transition		No further description
Cosco, 2010 Center 2	Dramatic play	Overall 6785 ft^2	One play house
	Open area		Two open areas, less facilitated activity than center 1 (above)
	Pathway		Linear paths
	Play equipment		Two composite structures, one swing set, one merry-go-round, one individual play equipment
	Sand play		One large sandbox
	Gathering area		Two benches

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Dyment, 2008	Turf Asphalt Play structures Greened areas	Not reported	No further description
Dyment, 2009 Australia	Green area Play equipment Paved Court Thoroughfare Courtyard Oval	Not reported	Grass area with trees, rocks, tree stumps and sandpits Slides, metal forts, monkey bars and swings Asphalt area designed for basketball and tennis All concrete walkways between Target Areas Large asphalt area outside school canteen Small, flat, dirt-surfaced recreational space
Dyment, 2009 Canada	Concrete steps Play equipment Green area Open field Treed hill Open asphalt Paved court	Not reported	Shady concrete step area with seating Fixed play equipment area, with six separate pieces of equipment Grass area with rock amphitheater, food garden, native trees and shrubs Open grassy field with a baseball diamond Treed grassy berm, with picnic tables Paved area, with four-square markings, a soccer net Asphalt area designed for basketball, soccer
Farley, 2008	Installed play structure	214 m^2	Primarily a connected network of horizontal bars for hanging, climbing, and balances with impact-absorbing surfacing beneath it (no platform, slide, tunnel, or swings)
	Basketball	290 m^2	One basketball hoop, a picnic table, and benches
	Equipped concrete	955 m^2	Two unshaded basketball hoops, two painted four-square games, two painted hopscotch areas, and a painted US map
	Grass and concrete	1030 m^2	Open concrete area with picnic tables, a covered concrete area with additional picnic tables and benches, and some open grassy patches, but no fixed play equipment
	Field	2252 m^2	Open, unequipped grass field

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Fjørtoft, 2009 School A	Soccer field Asphalt	Overall 3200 m^2	Area for kicking soccer balls in to goal Hopscotch, swings, sandpit, basketball net
Fjørtoft, 2009 School B	Forest Asphalt	Overall 13,000 m^2	Wooded area Afforded soccer and other ball games, had play equipment, sand
Fjørtoft, 2010 Gudeberg School	Asphalt Playground Climbing equipment Ballgame area Basketball field Handball field Green areas	Not reported	No further description
Fjørtoft, 2010 Begby School	Forest Soccer field Sports fields	Not reported	No further description
Howe, 2018	Court	631 m^2	Paved/concrete area with game-specific markings for four square, basketball, and tetherball, and an open, unmarked area.
	Fixed equipment	1280 m^2	Wood-chip turf containing commercial (large manufactured playset with slides, bridges, and climbing structures, obstacle course, and agility steps) and traditional (teeter-totters, monkey bars, and swings) equipment
	Field	3419 m^2	Large grassy field with a baseball diamond and backstop in one corner and soccer goal on one side of the perimeter

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Hustyi, 2012	Outdoor toys	Not reported	Objects used in gross motor play (i.e., two Frisbees, two soft baseballs, one large bouncy ball, one medium bouncy ball, a jump rope, a bucket and shovel, several throwing toys, several orange cones, and a hula hoop)
	Fixed equipment		A jungle gym, including two slides, monkey bars, stairs, and several climbing areas.
	Open space		No specific activity materials were present (grass)
	Control		A table and activities not anticipated to evoke high levels of physical activity (e.g., army guys, coloring books, crayons).
Larson, 2014	Fixed equipment	Not reported	Jungle gym with two slides, monkey bars, stairs, and climbing areas
	Outdoor toys		Objects used for gross motor activities, like balls, jump ropes, and hula hoops
	Open space		Grassy area with no other materials present
Nicaise, 2011 Memory Park	Amphitheater/ cement path	120 m^2	Wheeled toys (e.g. tricycles), basketball, socio-dramatic props
	Grass field	364 m^2	Portable equipment, like balls, balancing beams, open space
	Playground	300 m^2	Ladders, see-saws, hide and seek structures
	Sandbox	32 m^2	Sand with toys, like shovels and pails
Nicaise, 2011 Cottage Playground	Dirt box	6 m^2	Dirt area with shovels
	Carpet	17 m^2	Socio-dramatic props and other small toys
	Asphalt cycle path	45 m^2 62 m^2	Looping path with tricycles
	Asphalt east	75 m^2	Basketball, socio-dramatic props, water and other small toys
	Playground	32 m^2	Ladder, slides, climbing structures
	Sandbox		Sand with toys, like shovels and pails

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Nicaise, 2012 Pre-intervention	Cement path Playground Grass Sandbox	Not reported	Linear path Large fixed equipment, plastic climbing and sliding structures No further description No further description
Nicaise, 2012 Post-intervention	Cement path Playground Grass Sandbox	Not reported	Looped path Removal of two plastic climbing and sliding structures Addition of a hill No further description
Pawlowski, 2016	Schoolyard Field	Not reported	Asphalt-paved square enclosed by buildings. In the northern part, the square consisted of a zone with two marked four square pitches. In the middle of the square, a basketball zone, a small multi court, and a picnic table. The southern part consisted of a small area with gravel, big stones, and balancing bars, two small marked soccer pitches, and a ramp for skateboarding. Set up for soccer with four marked soccer fields and goals in different sizes.
Saint Maurice, 2011	Playground Soccer field Basketball court Baseball field Green space Blacktop	Not reported	No further description
Sallis, 2001	Court Field	Not reported	Space with permanent marks, such as basketball courts No markings
Smith, 2014	Drama Gathering place Open area Path Equipment Sand area	Average across centers was 8030 ft^2 overall and 640 ft^2 for each zone	No further description

Table 3.3. (cont'd)

Study	Locations Reported	Area	Description of Location
Springer, 2013	Playscape Field Track Blacktop	Not reported	No further description
Willenberg, 2010	Bitumen with court markings/goals	Not reported	Hard surface area with basketball and netball courts
	Bitumen with play-line markings only		Hard surface area with hopscotch and down-ball areas
	Fields with boundary markings/goals		Soccer fields
	Fixed equipment with no improvements		No further description
	Fixed equipment		No further description
	Plain bitumen		Hard surface area with no permanent improvements
	Plain field		Grassy area with no permanent improvements
Wood, 2014	Playground	Not reported	Concrete areas surrounded by school buildings
	Field		Grassy area surrounded by trees and bushes

Table 3.4. Percent of time or observation intervals spent in each location and spent in sedentary behavior and moderate-to-vigorous activity in each location

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Andersen, 2015	Grass Multi-court Solid surface Natural Playground	16[c] 22[c] 64[c] 6[c] 9[c]	31 33 47 38 26	27 22 12 18 26	Boys participated in more MVPA and girls participated in more sedentary behavior in all locations, but no differences in time spent in each location Children spent more time in each location than adolescents. Adolescents more sedentary and children more active in all locations, except natural and grass, respectively	Percent of time spent in that location calculated as average time in that location divided by average time spent on the schoolyard overall

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Clevenger, 2018	Court Fixed equipment Field	46.2 29.7 24.1	26.7 25.9 26.1	41.2 40.9 42.3	Boys spent more time on the court and girls spent more time on fixed equipment. Girls more sedentary on court and more active on equipment compared to boys	

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Cosco, 2010	Dramatic play	11.9	11.8[c]	4.2[c]	Not reported	*Minutes in location* = % time in each location x total observation time for the center
	Open area	40.0	19.0[c]	35.8[c]		
	Pathway	32.4	17.6[c]	70.7[c]		
	Play equipment	15.2	28.3[c]	21.7[c]		
	Sand play	0.5	0.0	0.0		
	Porch/transition	0.0	0.0	0.0		
Cosco, 2010	Dramatic play	3.0	30.0[c]	13.3[c]	Not reported	*Minutes in location in intensity* = % time in the intensity in the location x total observation time for the center *Percent of location time in intensity*= Minutes in location in intensity divided by Minutes in location
	Open area	19.2	24.5[c]	40.1[c]		
	Pathway	11.1	65.8[c]	11.7[c]		
	Play equipment	42.7	34.0[c]	39.1[c]		
	Sand play	19.7	69.5[c]	2.0[c]		
	Gathering area	4.3	79.1[c]	20.9[c]		

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Dyment, 2008	Turf Asphalt Play structures Greened areas	Not reported	Not reported	65 and 84 56 and 67 66 and 50 41 and 38	Not reported	This is the percent of respondents that reported many or most students participating in moderate and vigorous intensity activity, respectively
Fjørtoft, 2009	Soccer field Asphalt	Girls: 9.9, Boys: 20.0 Girls: 90.1, Boys: 80.0	Not reported	Not reported	Boys used soccer area more than girls	School A
Fjørtoft, 2009	Forest Asphalt	Girls: 51.7, Boys: 32.1 Girls: 48.3, Boys: 67.9	Not reported	Not reported	Girls spent more time and were more active in the forest compared to boys	School B
Fjørtoft, 2010	Asphalt Playground Climbing equipment Ballgame area Basketball field Handball field Green areas	Not reported, but a lot of youths by the building or walking to a nearby market	Not reported	Not reported	Not reported	Gudeberg school

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Fjørtoft, 2010	Forest Soccer field Sports fields	Not reported, but a lot of people near the building and on the handball court	Not reported	Not reported, stated that the handball or ballgame area elicited highest heart rates and almost half of this time was MVPA	Girls more active than boys in the handball area	Begby school
Howe, 2018	Court Fixed equipment Field	44.2 29.7 27.3	21 13 39	68 71 41	Girls more sedentary than boys on the court, but more active on fixed equipment. Boys spent more time on the court and less time on equipment compared to girls.	

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Hustyi, 2012	Outdoor toys Fixed equipment Open space Control	Not applicable due to experimental design, but during the 'naturalistic baseline,' reported that children spent an equal amount of time in open space and outdoor toys, but only one child used fixed equipment (10% of time)	Not reported	Means not reported, but for each child, the fixed equipment condition elicited the most MVPA and 75% of children participated in no MVPA in control area.	Not reported	
Larson, 2014	Fixed equipment Outdoor toys Open space	Not applicable due to experimental design	Not reported	Means not reported, but six of the eight participants elicited the most MVPA on fixed equipment, while the remaining two were equally active in open space	Not reported	

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Nicaise, 2011	Amphitheater/cement path	27.6[c]	51.9	20.2	Not reported	Memory park Percent of time calculated as number of observation intervals for a location divided by total observation intervals
	Grass field	19.9[c]	32.7	30.7		
	Playground	47.9[c]	50.5	18.4		
	Sandbox	4.5[c]	81.9	2.3		
Nicaise, 2011	Dirt box	1.7[c]	62.9	10.1	Not reported	Cottage playground Percent of time calculated as number of observation intervals for a location divided by total observation intervals
	Carpet	6.2[c]	72.3	5.5		
	Asphalt cycle path	11.1[c]	36.8	26.8		
	Asphalt east	36.2[c]	68.6	6.7		
	Playground	30.3[c]	52.4	20.3		
	Sandbox	14.5[c]	72.8	3.6		
Nicaise, 2012	Cement path	Not reported	82.1	7.9	Not reported	Before renovation
	Playground		95.1	4.9		
	Grass		89.5	11.5		
	Sandbox		Not reported	Not reported		
Nicaise, 2012	Cement path	Not reported	67.3	32.7	Not reported	After renovation
	Playground		72.6	27.4		
	Grass		73.5	26.5		
	Sandbox		Not reported	Not reported		

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Pawlowski, 2016	Schoolyard	For low and middle PA groups, higher median time spent on schoolyard compared to field	Low PA group: 50.0[c] Middle PA group: 25.0[c] High PA group: 6.9[c]	Low PA group: 11.4[c] Middle PA group: 22.0[c] High PA group: 3.8[c]	Not reported, but girls tended to play on the schoolyard compared to the field	Percent estimated as median time in an intensity in a location divided by median time in a location
	Field	High PA group had a higher median time spent on field compared to schoolyard	Low PA group: 0.0[c] Middle PA group: 11.9[c] High PA group: 7.1[c]	Low PA group: 50.0[c] Middle PA group: 11.9[c] High PA group: 39.5[c]		
Smith, 2014	Drama Gathering place Open area Path Equipment Sand area	Not reported	Not reported	Not reported, but equipment was positively related to activity levels, while gathering place was inversely related	Not reported	

Table 3.4. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Springer, 2013	Playscape Field Track Blacktop	40.8 22.3 1.5 34.3	Not reported	62.7 67.4 Not reported 63.5	Girls spent more time on playscape, while boys spent more time on field and blacktop. Differences in activity by location by sex were not reported.	
Wood, 2014	Playground Field	N/A due to experimental design	Not reported	28 39	Playing on the field seemed to 'close the gap' between boys and girls (more similar activity levels)	

[c] indicates that the value was estimated for this review using available information (i.e., not directly reported in the original article); **PA**: physical activity; **MVPA**: Moderate-to-Vigorous Physical Activity

Table 3.5. Percent of children in each location and percent of children engaged in sedentary behavior and moderate-to-vigorous activity in each location (studies using the System for Observing Play and Leisure Activity in Youth)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Anthamatten, 2014	Basketball Play equipment Tetherball Swings Hard-surface Play field Unprogrammed	Not reported, but reported high utilization in swing, hard-surface, and play equipment, but low utilization in play field	Not reported	45.2 47.8 41.7 66.6 27.9 27.4 4.4	Boys spent more time than girls in basketball and play field areas, while girls spent more time in play equipment. Boys were more active in play equipment, hard-surface and play field areas, while girls were more active in swing areas	Utilization was determined as the ratio between percentage of children observed in a zone to the percentage of the total area of that zone Level 3 used for MVPA
Barnas, 2018	Functional movement obstacle course Basketball Walking track and balance corner Soccer Kickball Castle ball	Not reported	Not reported	Functional movement obstacle course highest amount of “very active” observations, least “very active” observations at kickball	Functional movement obstacle course elicited highest amount of “very active” for girls, basketball highest for boys	Before zoning intervention Level 3 used for MVPA

Table 3.5. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Barnas, 2018	Basketball Knock-out/Hopscotch-in Balance corner and 4-square corner switch Imagination/free-play Functional movement obstacle course Drop that cookie!	Not reported	Not reported	Drop that cookie! highest amount of "very active" observations, least "very active" observations at knock-out/hopscotch-in	Drop that cookie! highest amount of "very active" observations for boys, imagination/free-play highest for girls	After zoning intervention Level 3 used for MVPA
Black, 2015	Blacktop Grass Painted markings Tetherball Basketball courts Manufactured equipment	35 14 17 3 5 25	51 55 79 47 33 66	49[c] 46[c] 20[c] 54[c] 67[c] 34[c]	Largest differences in tetherball (boys more sedentary than girls, 51 vs. 30%) and basketball (girls more sedentary than boys, 60 vs. 33%)	'School K' Added percent of time in moderate to percent of time in vigorous Level 2 and 3 used for MVPA
Black, 2015	Blacktop Grass Painted markings Tetherball Basketball courts Manufactured equipment Dirt Jog/Walk track Volleyball courts	14 6 2 0 0.9 5 0.8 72 0.2	37 53 40 0 44 39 93 0.9 38	63[c] 47[c] 60[c] 0 56[c] 61[c] 7[c] 99[c] 63[c]	Boys less sedentary in blacktop, grass, painted markings, but more sedentary on manufactured equipment and dirt compared to girls and tended to be more active at most locations	'School B' on a 'Jog and Walk Stars' day Added percent of time in moderate to percent of time in vigorous Level 2 and 3 used for MVPA

Table 3.5. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Black, 2015	Blacktop Grass Painted markings Tetherball Basketball courts Manufactured equipment Dirt Jog/Walk track Volleyball courts	35 33 5 1 5 14 4 2 0.3	44 58 55 43 50 59 86 45 75	56[c] 42[c] 45[c] 57[c] 50[c] 42[c] 14[c] 54[c] 25[c]	Boys less sedentary and more active in most areas, except dirt, when compared to girls	'School B' on a non-'Jog and Walk Stars' day Added percent of time in moderate to percent of time in vigorous Level 2 and 3 used for MVPA
Brink, 2010	Hard surface structured Hard surface unstructured Soft surface structured	Not reported	Not reported	65.7 52.2 67.9	More active boys in all settings, except hard surface unstructured	Non-learning landscapes schools (i.e., not renovated) Level 2 and 3 used for MVPA
Brink, 2010	Hard surface structured Hard surface unstructured Soft surface structured Soft surface unstructured	Not reported	Not reported	62.2 58.7 71.2 66.8	More active boys in all settings	Learning landscapes schools (renovated, not necessarily recently) Level 2 and 3 used for MVPA

Table 3.5. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Dyment, 2009	Green area Play equipment Paved Court Thoroughfare Courtyard Oval	33 11 30 7 13 5	28 30 56 44 51 35	72[c] 70[c] 44[c] 56[c] 49[c] 65[c]	Girls spent more time on equipment and courtyard. Girls more sedentary and less active in all locations, but had more vigorous intensity on oval compared to boys.	Australia Added percent of time in moderate to percent of time in vigorous Level 2 and 3 used for MVPA
Dyment, 2009	Concrete steps Play equipment Green area Open field Treed hill Open asphalt Paved court	6 10 14 15 9 33 14	43 26 35 29 42 34 23	57[c] 74[c] 65[c] 71[c] 57[c] 64[c] 76[c]	Boys spent more time on court. Girls more sedentary and less active in all locations, but more moderate intensity on concrete steps compared to boys.	Canada Added percent of time in moderate to percent of time in vigorous Level 2 and 3 used for MVPA
Farley, 2008	Installed play structure Basketball Equipped concrete Grass and concrete Field	Not reported	35[c] 37[c] 35[c] 30[c] 33[c]	65 63 65 70 67	Girls tended to spend more time on play structure, but less time on basketball court compared to boys. Boys and girls participated in different types of activities.	Percent of time spent being sedentary was calculated as 100 minus the percent of time walking or very active Level 2 and 3 used for MVPA

Table 3.5. (cont'd)

Study	Locations	% of Time	% Sedentary	% MVPA	Group Differences	Notes
Saint Maurice, 2011	Playground Soccer field Basketball court Baseball field Green space Blacktop	Not reported, but soccer field had the most boys, while basketball and schoolyard had highest number of girls	Not reported, says there were no differences in sedentary behavior by area	Not reported	Girls=43.9, Boys=41.9 Other not reported, but stated that boys were more active than girls except in playground and basketball court	Level 3 used for MVPA
Sallis, 2001	Court Field	Not reported	Not reported	Not reported	Not reported, but the manuscript figures show that boys were more active on the court than the field, with little differences seen in girls by location	Unclear what levels were used to define MVPA
Willenberg, 2010	Bitumen with court markings/goals	Not reported	38	62	Boys more active and less sedentary at all locations, but the differences from girls were larger in some areas, like all types of bitumen, and smaller in some areas, like fixed equipment	Level 2 and 3 used for MVPA
	Bitumen with play-line markings only		49	51		
	Fields with boundary markings/goals		44	55		
	Fixed equipment with no improvements		47	53		
	Fixed equipment		43	56		
	Plain bitumen		48	52		
	Plain field		44	56		

[c] indicates that the value was estimated for this review using available information (i.e., not directly reported in the original article); **MVPA**: Moderate-to-Vigorous Physical Activity; for each study using SOPLAY, the levels (sedentary, walking, or very active) used to calculate MVPA are reported

Discussion

In response to our primary research question, this systematic review of 24 studies provides evidence that physical activity participation varies by location within the schoolyard, with studies demonstrating a maximum between-location difference in moderate-to-vigorous physical activity of, on average, 20 to 30 percentage points. This variation in physical activity by schoolyard location is supported by Gibson's theory of affordances, which posits that the environment affords specific behaviors, and this subsequently drives our actions (Gibson, 1977). For example, studies of both preschoolers and children supported that moderate-to-vigorous physical activity was often highest in grassy or open spaces (Cosco et al., 2010; Nicaise et al., 2012; Nicaise et al., 2011) and fields (Brink et al., 2010; Springer et al., 2013). This may be because open spaces afford running games. Similarly, spaces that afford sitting, such as sandboxes (Cosco et al., 2010; Nicaise et al., 2011), benches (Farley et al., 2008), or gathering places (Cosco et al., 2010; Smith et al., 2014), tended to elicit more sedentary behavior. These differences by location lead to differences in overall outdoor physical activity levels, which may then impact daily/habitual physical activity, resulting in long-term effects that remain to be studied.

The information from this review can be used to develop activity-promoting schoolyard interventions, but there are limitations of the available literature that prevent us from drawing definitive conclusions at this point in time. As play preferences, cognitive and motor development, and the physical design of the schoolyard are different in preschool-aged children compared to children and adolescents (e.g., in elementary or middle school), we will first discuss these results separately, then discuss methodological limitations of this research, and potential points of intervention and future research.

Preschoolers

In McWilliams et al.'s (2009) best-practice guidelines for childcare centers, it is recommended that programs provide open/grassy areas, a track for wheeled toys, and a variety of fixed equipment. In the present review, results support that each of these locations promoted moderate-to-vigorous physical activity and minimized sedentary behavior in preschool-aged children. Similar to results from studies of children and adolescents, type of location is important (e.g., open area), but specific design features of that location also impact physical activity levels and make comparisons between schoolyards (and studies) complex.

Both Nicaise et al. (2012) and Cosco et al. (2010) provide support for grassy or open areas promoting activity, but they illustrate how the design of these areas impacts the magnitude of the activity-promoting benefits. For example, Nicaise et al. (2012) added a hill to an existing grassy field and reported an increase in moderate-to-vigorous physical activity in the field from 12 to 27% of observed intervals. Thus, the same grassy area elicited different levels of physical activity, due to a change in the design. Cosco et al. (2010) compared two schoolyards and found that in both schools, open areas promoted activity, but children were more active in the open area on the schoolyard with more open areas. This may be because larger location size reduces child density (i.e., crowding), promoting physical activity (Cardon, Van Cauwenberghe, Labarque, Haerens, & De Bourdeaudhuij, 2008; Gubbels et al., 2011; Van Cauwenberghe, De Beaurdeaudhuij, Maes, & Cardon, 2012). In contrast to these studies, Hustyi et al. (2012) and Larson et al. (2014) did not find that the open, grassy area was the most activity-promoting in their experimental comparison with fixed equipment, but it is important to note that they used small (n=4-8), overlapping samples and provided children with no equipment with which to play in the open area. Thus, studies support that grassy or open areas promote physical activity, but the impact of these areas on activity levels is affected by available equipment and the size and design of the grassy or open area. More research is needed in a large number of schools that can account for these other variables.

Similar evidence for the importance of location design is demonstrated for tracks/paths, another location that is recommended for inclusion in childcare schoolyards (McWilliams et al., 2009) and whose presence/absence has been correlated with overall physical activity (Gubbels et al., 2012). Cosco et al. (2010) and Nicaise et al. (2011) both reported on two schoolyards, one with a looped path and one with a more linear path, and supported that the looped path encouraged more moderate-to-vigorous physical activity (27-71%) compared to the linear path (12-20%). Similarly, Nicaise et al. (2012) reported greater participation in moderate-to-vigorous physical activity on a path that had been renovated to be looped instead of linear (33 vs. 8%). In contrast to these studies, Smith et al. (2014) did not find an impact of paths on physical activity participation while statistically controlling for the use of a wheeled toy. As it has been suggested that looped paths afford more use of wheeled toys (e.g., tricycles), controlling for this behavior would nullify the impact of having an activity-promoting track. Overall, physical activity clearly varies by location within the schoolyard, but design of the location and provided equipment also have an important influence.

In line with our finding that fixed equipment can promote physical activity (Cosco et al., 2010; Hustyi et al., 2012; Larson et al., 2014), prior studies have reported positive correlations between the provision of fixed equipment and overall physical activity (Gunter, Rice, Ward, & Trost, 2012; Nielsen, Taylor, Williams, & Mann, 2010; Ridgers et al., 2010; Sugiyama et al., 2012; Taylor et al., 2011; Willenberg et al., 2010). However, studies have also reported inverse or null relationships (Cardon et al., 2008; Dowda et al., 2009; Vanderloo et al., 2014). Reasons for these disparate findings are that the types of equipment considered as ‘fixed equipment’ often vary and are not analyzed separately, and equipment is sometimes coded as present or absent, with disregard for the quantity of a specific type of equipment. In Cosco et al. (2010), one schoolyard had more pieces of fixed equipment (5 vs. 1), and different types of fixed equipment (e.g., swings, merry-go-round) compared to a second schoolyard, and this was reflected in the percent of time (43 vs. 15%) and moderate-to-vigorous activity (39 vs. 22%) in the fixed equipment areas. While variability in schoolyard design makes comparisons difficult, it is worthwhile to consider physical activity by schoolyard location because this provides information about children's actual use of available equipment.

There are a few limitations of previous research on preschool samples. Studies of preschool samples were of lower quality compared to studies in children or adolescents, and none investigated sex differences in where children were physically active on the schoolyard. However, studies with no measure of physical activity (i.e., not in this review) demonstrate that where preschool-aged children play during outdoor time differs by sex (Harper & Huie, 1998; Harper & Sanders, 1975; Holmes & Procaccino, 2009), warranting further research in this area. Again, there is substantial variability in where children play between schools (Harper & Huie, 1998) and this is likely impacted by a number of factors that need to be considered (e.g., supervision, child density, season). The preschool years also represent a time of rapid cognitive and motor skill development, wherein children transition from egocentric and solitary play to prosocial and cooperative play (Parten, 1932) and even among 3-, 4-, and 5-year-olds, there are vast differences in their motor behaviors (Herrington & Lesmeister, 2006). Not only are there few studies of this age group (overall or by sex), but we have no information on age-related changes or how motor, cognitive, or social development impacts or is impacted by where children play and are physically active on the schoolyard (Herrington & Lesmeister, 2006). Finally, only three groups of researchers have conducted work in this area, representing only two areas of the United States (North Carolina and California), resulting in limited generalizability to other countries, regions, or types of childcare programs. Clearly, more research is needed in this age group.

Children and Adolescents

Previous studies have correlated the availability of open space and/or portable or fixed equipment with overall recess physical activity levels in children and adolescents (Haug, Torsheim, Sallis, & Samdal, 2010; Haug, Torsheim, & Samdal, 2008; Nielsen et al., 2010; Taylor et al., 2011). These findings align with the results from the present review, wherein fields (Brink et al., 2010; Springer et al., 2013) and fixed equipment (Anthamatten et al., 2014; Brink et al., 2010; Howe et al., 2018) promoted activity in children, and sport-specific courts, like handball courts, tended to promote physical activity in adolescents (Fjørtoft et al., 2010; Sallis et al., 2001). In the one study that directly compared children to adolescents, children were more active than adolescents in all locations, except the grass, which was often used to play soccer and nullified the difference between age groups (Andersen et al., 2015). Age group differences should be verified by further research, but are supported by changes in motor skills, play preferences, and perceived affordances with age (Malina, Bouchard, & Bar-Or, 2004; Piaget, Cook, & Norton, 1952; Roberton & Halverson, 1984; Wortham & Frost, 1990).

During elementary school, children are moving from the preoperational stage to the concrete operational stage as described by Piaget's stages of cognitive development (Piaget et al., 1952). This transition marks the shift from egocentrism and a focus on dramatic play to the ability and desire to play more structured games and sports (Roberton & Halverson, 1984; Wortham & Frost, 1990). In parallel, motor skills and motor competence increase with age (Malina et al., 2004) and as such, complexity of play may increase, with increased participation in object control games, like sports or other recess-type ball games. For these reasons, by the time adolescence is reached, many youths choose to participate in sport-type games during recess, which is supported by the findings of the present review. Qualitative research also supports that adolescents believe the provision of sport-specific areas is important for activity-promoting environments (Hidding, Chinapaw, & Altenburg, 2018).

Similar issues exist in research on children and adolescents as in studies of preschool-aged children. While we will not repeat them here, we reiterate that the number of youths in a location and their physical activity levels will be impacted by the type of location overall, but specific features of the location's design should be considered when comparing between studies (e.g., size, child density, amount of provided or type of equipment).

Differences by Sex

It has been widely acknowledged that boys are more active than girls during outdoor time (Ridgers et al., 2012), but the present review adds that there are sex differences in both where girls play and where girls are physically active on the schoolyard compared to boys. The difference in physical activity between boys and girls was smaller in some schoolyard locations (e.g., fixed equipment), and while only one study investigated differences by weight status, it similarly showed that differences in physical activity by weight status were mitigated in some locations (fixed equipment, field) (Howe et al., 2018). This has important implications for the design of schoolyards that promote physical activity in the populations most at need, including girls and overweight/obese youth.

There were also locations in which there was a large disparity between the physical activity levels of boys and girls, potentially explaining why girls accumulate less physical activity during recess overall. Boys often dominated sport-related areas, like the blacktop (Anthamatten et al., 2014; Black et al., 2015; Clevenger et al., 2018; Howe et al., 2018; Sallis et al., 2001), and this is likely because boys and girls participate in different types of activities overall (Howe et al., 2018; Springer et al., 2013) and within this location (Black et al., 2015; Crum & Eckert, 1985; Dyment et al., 2009). These differences in activity type are illustrated by the studies that included smaller 'sub-locations' (e.g., tetherball, basketball) (Black et al., 2015; Clevenger et al., 2018; Saint-Maurice et al., 2011), but missed by studies that defined the blacktop/court area very generally (every study that demonstrated boys were more active than girls in this setting)

(Anthamatten et al., 2014; Black et al., 2015; Clevenger et al., 2018; Howe et al., 2018; Sallis et al., 2001). As boys tend to participate in more sports (Farley et al., 2008), while girls tend to 'walk and talk' or play other games (e.g., four square) (Farley et al., 2008), this results in boys being more active in the court area overall. This is supported by previous research that has correlated participation in sport during recess to boys' moderate-to-vigorous activity while suggesting that girls participated in more walking behavior (Powell, Woodfield, & Nevill, 2016). Similarly, the availability of a hard surface (e.g., blacktop) has been correlated to boys', but not girls', physical activity levels during recess (Cardon et al., 2008). However, when individual settings are considered, like the basketball area in Saint Maurice et al. (2011), boys and girls are similarly active. Thus, boys tend to be more active on blacktop/court areas overall because they tend to spend time in sport-specific areas, like playing basketball. While girls may spend less time in sport-specific areas (e.g., basketball), they are similarly active to boys when they are in that specific location. In future studies, individual settings should be explored separately to truly understand differences in time and intensity of play by sex across locations (e.g., Black et al., 2015).

Qualitative work helps to elucidate why girls and boys choose to play in different areas of the schoolyard or participate in different activities within a location. First, there may be differences in the activities that children want to participate in while on the schoolyard. A study in 3- to 6-year-old children reported that girls wanted to play on fixed equipment (e.g., swings), while boys chose more running and chasing types of games (Kılıçgün, 2014). This aligns with our finding that girls tended to spend more time on fixed equipment than boys (Anthamatten et al., 2014; Clevenger et al., 2018; Farley et al., 2008; Howe et al., 2018; Pawlowski et al., 2016; Springer et al., 2013). If there are inherent differences in the choice of activity by sex, the goal should be to provide adequate quantity and quality of space and materials for girls to participate in their preferred type of play. However, it may be that girls (or other groups of children) want to play in a particular area, but they cannot due to other reasons. For example, Pawlowski et al. (2016) reported that boys tended to play and specifically, play soccer, in the field more than girls, and when girls did spend time in the field, they often stood on the sidelines watching soccer because boys would not pass the ball to them if they did play, a phenomenon that has been reported in other studies as well (Caro, Altenburg, Dedding, & Chinapaw, 2016). Older children have also reported that they try to force younger children to leave the soccer area (Pawlowski et al., 2016). Similarly, observations by Harten et al. (2008) suggest that boys tend to take up more space and not allow children with lower motor skills to participate in sport-related games, while girls played more inclusive (e.g., taking turns) and imaginative games. Thus, girls, younger children, and those with poorer motor skills may be prevented from playing in some spaces, particularly sport-specific areas that promote the most physical activity.

It may also be that there is insufficient space or equipment. Caro et al. (2016) reported that youth elected to participate in more sedentary behaviors because of a lack of outdoor facilities or play opportunities that appealed to them, and Pawlowski et al. (2016) reported this tendency predominantly in girls and adolescents. Thus, when the preferred play space is inadequate (e.g., small, not enough equipment) or not available (e.g., because adolescents/boys do not let them play there), youth defer to a less active type of play simply because they have 'nothing better to do.' These findings, in combination with those from the present review, suggest that sex differences in overall physical activity can be attributed to a complex relationship between spatial characteristics of the environment and social processes.

Methodological Differences and Limitations

Despite confirming that physical activity levels are not uniform across the schoolyard, we cannot make a definitive consensus as to which schoolyard locations are most used by youth or promote the most activity due to differences in sample characteristics (e.g., age), schoolyard characteristics (e.g., available equipment, size, child density, supervision), and other methodological differences. One common difference between schoolyards is differences in size, either overall or of specific schoolyard locations, and this can impact where children spend their time. Most studies did not account for differences in size (area) of schoolyard locations and often reported that children spent the most time in the largest area (Andersen et al., 2015; Cosco et al., 2010; Nicaise et al., 2011). A few studies (Anthamatten et al., 2014; Farley et al., 2008) accounted for the size of a specific location; and we recommend that future studies employ similar practices, while still reporting the unadjusted values.

A variety of methods for measuring physical activity by schoolyard location was used in the reviewed studies. The OSRAC-P, SOFIT, Behavior Mapping, GPS plus accelerometry or heart rate, accelerometry alone, and video direct observation are methods that involve tracking of individual participants, and outcomes are calculated as percent of outdoor time or observation intervals spent in a location or percent of location time or intervals spent in a specific activity intensity. In contrast, the SOPLAY method uses group-based scans to record the number of children in a location and the number of children within each location participating in each level of activity intensity, so outcomes are calculated as the percent of children located within a location and percent of children within a location engaging in a specific activity intensity. Thus, comparisons of specific values across studies with different methods should not be done.

Additionally, there is variability among studies using the SOPLAY method in how moderate-to-vigorous intensity activity was reported. In SOPLAY, three activity intensity levels are used (sedentary, walking, or very active). Of the nine studies that used SOPLAY, three defined moderate-to-vigorous physical activity as just the “very active” category, and the remainder of studies defined the three categories as sedentary, moderate, and vigorous, respectively, or did not describe definitively how they classified moderate-to-vigorous physical activity. Studies using the OSRAC-P have consistently defined moderate-to-vigorous activity as a level 4 or 5 (out of 5), which includes moderate intensity translocation or arm movements, skipping, jumping, or fast translocation. This is comparable to studies using behavior mapping, as both methods were derived from the CARS. These are important considerations when interpreting results.

Studies using accelerometry in conjunction with GPS all used the Evenson cut-points to classify activity intensity, while one study using accelerometry alone (an experimental study) used the Treuth cut-points. As it has been established that the choice of cut-point affects the estimate of physical activity intensity (Trost, Loprinzi, Moore, & Pfeiffer, 2011), this is an important difference between studies. All accelerometer studies have relied on a hip-worn monitor, which may miss some types of schoolyard activities, like swinging, monkey bars, or activities that only use upper-body movements, like playing in the sand (Storli & Hagen, 2010). Therefore, this may specifically impact our estimates of physical activity participation in fixed equipment, sensory areas, or in some types of blacktop/asphalt games (e.g., tetherball, four square) and more work should be completed to determine how to best capture these behaviors. Finally, one study involved a survey of teachers, principals, and parents. It is unknown how comparable this questionnaire is to direct observation or a monitor-based approach. Overall, more research is needed to establish the comparability of direct observation (both individual or scan-based approaches) to monitor-based and survey-based approaches to assess physical activity by schoolyard location.

Regardless of the measurement tool used, another issue is what defines a ‘schoolyard location.’ Oftentimes, locations are delineated by physical boundaries, such as a change in surface type (e.g., wood chips to asphalt), but other times, they are chosen for convenience (e.g., what can be seen by a stationary observer). One issue alluded to earlier is that these locations sometimes encompass several smaller locations, acting as nested structures. For example, some studies used the asphalt, court, or bitumen area as one location, while others divided this area into smaller locations, like tetherball, basketball, or bitumen with court markings (as opposed to bitumen with play markings). We recommend that the smallest functional unit be used as a location, as it has been demonstrated that physical activity and sex-related differences are evident at this level (Black et al., 2015; Clevenger et al., 2018; Farley et al., 2008) and amalgamation of these areas reduces between-location differences in physical activity estimates (Clevenger et al., 2018; Farley et al., 2008).

There are other methodological issues to consider when interpreting research on youth's schoolyard behaviors. Day-to-day reliability in recess physical activity levels has been demonstrated (Ridgers, Stratton, Clark, Fairclough, & Richardson, 2006), but it is unknown if there is between-day variability in where children are physically active or spend time on the schoolyard. Several studies in the present review conducted measurements on one day (Cosco et al., 2010; Dyment & Bell, 2007; Fjørtoft et al., 2009; Fjørtoft et al., 2010; Smith et al., 2014; Willenberg et al., 2010), while others collected data over multiple days (Andersen et al., 2015; Anthamatten et al., 2014; Barnas et al., 2018; Black et al., 2015; Brink et al., 2010; Clevenger et al., 2018; Dyment et al., 2009; Howe et al., 2018; Pawlowski et al., 2016; Sallis et al., 2001), months (Saint-Maurice et al., 2011; Springer et al., 2013), or years (Farley et al., 2008). More research is needed on the impact of time of year or weather as previous research on overall recess activity levels has demonstrated an inverse relationship between temperature and vigorous intensity activity (Ridgers et al., 2010). It makes sense conceptually that children may spend more time in shaded areas as temperature increases and there is some evidence to suggest that where children play changes by season (Harper & Huie, 1998). This may impact physical activity participation, as some schools only have shaded seating areas, while others have a variety of shaded areas from which children can choose (Herrington & Lesmeister, 2006). Finally, there are a number of factors outside the scope of the present review for which the impact on physical activity by schoolyard location should be further investigated (e.g., child density, supervision).

Potential Interventions

The overarching goal of this line of research is to design schoolyards and develop outdoor time protocols that promote physical activity in all youth and the findings of this review can inform the development of these activity-promoting interventions. One potential avenue is schoolyard redesign, although this can be the most expensive intervention option. Specifically, the addition or expansion of schoolyard locations that have been shown to increase physical activity participation or the removal of settings that promote sedentary behavior. This was done by Nicaise et al. (2012), who changed a linear path to a looping path, added a hill to a grassy area, and removed two pieces of fixed equipment (to create more open space, while retaining large/main pieces of fixed equipment) and demonstrated not just increased overall participation in moderate-to-vigorous physical activity approximately one semester after the schoolyard redesign, but in physical activity in those specific locations. Another, potentially less expensive option, was implemented by Black et al. (2014), who reported that moderate-to-vigorous physical activity (overall and specifically on the track) was higher at a school on days in which they had a jogging and walking program (87%) versus typical days (46%). Measuring physical activity by schoolyard location in these interventions allows researchers to identify what, specifically, works, and therefore, what was a good allocation of resources for promoting physical activity.

Another point of intervention may be to minimize settings that promote sedentary behavior, but before doing so, it is important to consider that physical activity is not the only purpose of outdoor time, particularly in young children (Alexander, Barnett, & Fitzpatrick, 2017). Outdoor time is also important to develop gross and fine motor skills, promote both object manipulation and locomotion skills, and provide opportunities for pretend, social, and symbolic play (Wortham & Frost, 1990). Thus, settings that may be less active in nature, but that allow children to participate in some beneficial activity, such as cooperative play, or direct interaction with natural materials, should be retained. Qualitative work provides important information in addition to physical activity by schoolyard location. For example, areas like sand or water play, have been reported as important to both children and teachers (Herrington & Lesmeister, 2006). However, seating areas where the predominant activity is sitting and talking could be reduced to promote children, for example, playing or walking and talking during outdoor time. This is supported by qualitative research in adolescents, who report that not encouraging seated activities is important when designing an activity promoting space (Hidding et al., 2018).

It should be noted that our review only includes studies of schoolyard physical activity, but many schools do not even provide outdoor time to their students, which may be a larger and more pressing issue. Additionally, we only included outdoor locations, but there were studies in which students were allowed to stay inside during provided recreation time, which is a potential point of intervention. A study in Danish 4^{th} graders reported that only 24% of schools required children to be outside during break time (i.e., recess) (Pawlowski, Tjørnhøj-Thomsen, Schipperijn, & Troelsen, 2014). Studies by Pawlowski et al. (2016a and 2016b) reported large numbers of youths, particularly adolescents, girls, and the least active youth, reporting staying inside the school buildings because of a lack of appealing outdoor facilities. Additionally, in Pawlowski et al. (2016), Caro et al. (2015), and Powell et al. (2016), children were observed or have reported waiting for a turn to play while on the schoolyard. Thus, a simple point of intervention would be to not allow youth to stay indoors, but a more long-term solution may be to provide enough equipment, and the types of equipment children want, so that all children will, by choice, be engaged in outdoor activities. Regardless of the type of intervention, care should be taken to solicit the opinion and input of the individuals using the space, namely the students (Cunningham & Jones, 1996; Cunningham & Jones, 1998; Zamani, 2017).

Limitations of the Review

As with any review, there is a possibility that literature, particularly in languages other than English, may be missed. While we did a search of ProQuest to identify grey literature on this topic and did not find any, there still may be unpublished work missed by our search.

Future Research

In the studies included in the present review, 40% of provided outdoor time, on average, was spent in moderate-to-vigorous physical activity, supporting the need for sustainable activity-promoting schoolyard interventions. While it is true that there are benefits to recess other than physical activity, youth have reported various reasons for not participating in physical activity during outdoor time, and it is not always because they prefer to do other activities. Rather, they cite insufficient equipment or space, too many children present, or children who do not allow others to play with them. Thus, youth may want to be active during outdoor time, but cannot for reasons outside of their control. Schoolyards should be designed to provide an equitable opportunity for play so that all children can be physically active. This review contributes to our knowledge about what schoolyard locations promote physical activity in children overall, and specifically, in girls and adolescents.

Based on this review, we identify the following areas for potential future research:

- Intervention studies that modify the schoolyard environment (e.g., provision of additional equipment, changes in child density, schoolyard redesigns) should assess the intervention's impact on duration and intensity of play within schoolyard locations.
- Why differences in physical activity participation by sex are exacerbated in some locations but mitigated in others, and why different groups use different areas of the schoolyard should be explored, along with other individual and group differences (e.g., changes with age and motor skill development).

- Information is needed on day-to-day variability in where and how actively children play and more research is needed on how other factors impact where and how actively children play, such as social interaction or group dynamics, weather, quantity and quality of provided equipment, or teacher supervision. Feasible methods for assessing physical activity by schoolyard location should be further developed to facilitate this research in a large number of schools.

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CHAPTER 4: COMPARISON OF PRESCHOOLERS' ACTIVITY TYPE AND SCHOOLYARD LOCATION

Abstract

Contextual factors (e.g., activity type, physical location) influence preschoolers' physical activity behaviors during provided outdoor time. Methods to capture this context may entail recording the activity type via direct observation (e.g., the Observational System for Recording Activity in Children, OSRAC) or the physical location via monitor-based approaches (e.g., Global Positioning Systems) of a target child. Often, the activity type and location are the same; however, there could be occasions when the activity type does not reflect the location. Understanding inconsistencies between activity type- and location-based methodological approaches would facilitate comparisons across studies. The overarching purpose of this study was to compare a location- vs. activity type-based approach to understanding children's schoolyard behavior. Preschoolers' (N=50) location and activity type were video coded on a second-by-second basis and matched with accelerometer vector magnitude (VM, counts/s) for one outdoor period (average 43 min). Within each location, there was a median of 5 observed activity types, but the predominant activity typically matched the expected activity type (e.g., 66.9% fixed equipment play in the fixed equipment location). Children spent the majority of outdoor time in open space (activity type or location; 37.6-48.9%), but there was a disparity in the setting that promoted the highest VM between methods (teacher arranged activity type, but the fixed equipment location) based on linear mixed models. Activity types elicited varying levels of VM depending on schoolyard location (e.g., open space in open spaces vs. on paths: 40.9 vs. 60.7 counts/s). Researchers should consider their research question when choosing a methodological approach (location, activity type, both). While the two approaches are not interchangeable, some similar patterns were observed (e.g., percent of time spent in each location/activity type).

Introduction

For at least fifty years there has been interest in how the schoolyard physical environment impacts young children's behavior, as outdoor time is a key opportunity for children to engage in physical activity in addition to motor, cognitive, and social development through exploration and free-play (Cosco, Moore, & Islam, 2010; Harper & Huie, 1998; Harper & Sanders, 1975; Hustyi, Normand, Larson, & Morley, 2012; Nicaise, Kahan, Reuben, & Sallis, 2012; Nicaise, Kahan, & Sallis, 2011; Pellegrini, 1987; Sanoff, 1995; Smith et al., 2014). Much of this research is founded on the theory of affordances, which posits that we perceive our environment as opportunities for action, and this subsequently drives our actions (Cosco, 2006; Gibson, 1977). As such, features of the schoolyard's physical environment (location) impact the types of activities in which children engage and this influences physical activity participation (Smith et al., 2014). To date, many studies that focus on preschoolers' physical activity, specifically, have been observational in nature (Cosco et al., 2010; Nicaise et al., 2011; Smith et al., 2014), but information about how the physical environment impacts behavior has also been used to inform the redesign of preschool schoolyards (Nicaise et al., 2012). Despite evidence that modification of the environment can be used to impact children's physical activity, there is a paucity of quality research in this age group.

More research is needed on how personal characteristics (e.g., motor skills, sex) and aspects of schoolyard design (e.g., number and type of equipment) interact to influence where and how actively children play, but methodological burden has hindered research in this area. As no two children, schoolyards, or childcare programs are alike, there is a need to develop a method that could be used to collect continuous, individual-level data on a large-scale in a variety of childcare programs with differing schoolyard designs. Monitor-based approaches, like the combination of Global Positioning Systems receiver units (GPS) and accelerometers or heart rate monitors, have been used in children and adolescents (Andersen, Klinker, Toftager, Pawlowski, & Schipperijn, 2015; Clevenger, Sinha, & Howe, 2018; Fjørtoft, Kristoffersen, & Sageie, 2009; Fjørtoft, Löfman, & Thorén, 2010; Pawlowski, Andersen, Troelson, & Schipperijn, 2016) and may provide a valuable surrogate to more established direct observation approaches that can be time-consuming and often cannot feasibly provide continuous, individual-level data. One limitation of this type of monitor-based approach is that location is often the only type of context measured. Location is certainly important, as Smith et al. (2014) reported that 23% of the variance in children's physical activity could be explained by characteristics of the schoolyard setting in which a child was located. However, there are multiple afforded activities within each schoolyard location (e.g., both ball/object play and running games are afforded in grassy fields), and these distinctions are not captured when only measuring location (Kyttä, 2002). There is also evidence in older children that there are differences between sexes in physical activity within schoolyard locations and this may be due to children of different sexes participating in different types of activities within locations (Crum & Eckert, 1985; Dyment, Bell, & Lucas, 2009; Farley, Meriwether, Baker, Rice, & Webber, 2008). Thus, only measuring location may mask important sex differences in activity type. Lastly, only assessing location reduces comparability with prior work using direct observation, which typically codes for other types of context (Brown et al., 2006; McKenzie, 2002), not location.

One commonly-used direct observation tool in the preschool population is the Observational System for Recording Physical Activity in Children-Preschool Version (OSRAC-P), which includes 12 outdoor context codes referred to as 'activity type' in the current investigation: ball and object, fixed equipment, game, open space, pool or water play, portable equipment, sandbox, snacks, sociodramatic props, teacher arranged gross motor, time out, and wheeled object (Brown et al., 2006). These codes indicate the type of activity, not the location, so a child could be in a grassy field or on a concrete basketball court playing with a ball and this would be recorded in both situations as 'ball and object.' Nicaise et al. (2011) modified the

OSRAC-P to measure both activity type and location and found some disparities, indicating that, as may be expected, location and activity type are not synonymous. For example, children were located in the sandbox area for 221 intervals (each 30-s), but in regard to activity type, children were only participating in sand play for 212 intervals (Nicaise et al., 2011). Thus, there were at least 9 intervals, which equates to 4.5 minutes, in which a child was located in the sandbox, but not participating in sandbox play (Nicaise et al., 2011). Due to their study design, we cannot identify what the child was doing for those 9 intervals. As the disparity between activity type and location is likely smaller in the sandbox compared to locations with a greater number of afforded activities, like an open grassy area (Kyttä, 2002), this discordance should be explored in other common schoolyard locations (e.g., open space). Understanding the activity types in which children engage within a location, overall and by sex, and how results are impacted by the choice of methodological approach would provide insight in to the potential limitations of physical activity measures that only assess location or activity type, and facilitate our understanding of the comparability of results from studies using different methods.

The overarching purpose of this study was to compare a location- vs. activity type-based approach to characterizing children's schoolyard physical activity. We identify the percent of preschoolers' time spent in various activity types within schoolyard locations and descriptively compare physical activity (as vector magnitude) while participating in activity types in different schoolyard locations. Finally, we compare physical activity across either schoolyard locations or activity types to understand how study results would be impacted by methodological approach. It was hypothesized that children would participate in multiple activities within each schoolyard location, but the majority of time within a location would be spent on one predominant activity (e.g., fixed equipment play while on the fixed equipment) and that vector magnitude for a given activity type would vary by the location in which the activity occurred. While we hypothesized that there would be differences in vector magnitude by either location or activity type, we hypothesized that model fit would not be significantly different when using location or activity type as fixed effects.

Methods

Participants and Setting

Three Mid-Michigan preschools were recruited to participate in this study via phone/email contact. Parents of 2- to 5-year-old children completed consent forms and verbal assent was provided by children prior to participation. The Michigan State University Institutional Review Board approved this study protocol prior to school/participant recruitment. Multiple classes participated at each school- two classes participated at schools one and two, and both classes used the same schoolyard. Three classes participated in the third school, but one class used a different schoolyard. Prior to data collection, each of the four schoolyards was visited in person to identify schoolyard locations (described in Table 4.1), defined as an area with a variety of materials that is delineated in some way, often by its physical boundaries or surface type (Sanoff, 1995). On the day of data collection, information about the weather (e.g., temperature), available equipment (e.g., the teacher brought out additional sociodramatic props), and the number of children present was recorded (Table 4.2).

Table 4.1. Description of each schoolyard and schoolyard locations

Location	Description
Schoolyard 1	
Fixed Equipment	One large structure with a slide and climbing area; Large spinning structure with net to climb; Four small spring-based structures; One large teeter-totter that could comfortably fit 4 children/side
Open Space	Mulch surrounding all other areas
Seating	Two benches, one primarily used for storage (e.g., clipboards, water)
Schoolyard 2	
Fixed Equipment	One large structure with three slides; Three smaller pieces of equipment (e.g., a pretend stationary fire truck)
Open Space	Grass field, farthest from door; Grass field to the side of the school building; Concrete sidewalk areas in front of the school door; Mulch surrounding the fixed equipment
Seating	Plastic table (child-size)
Sandbox	One large sandbox that had to be uncovered by teachers before use
Sensory	Water table in grass on the side of the building; Mud kitchen with sociodramatic toys
Path	Looped path that surrounded the mulch/fixed equipment areas
Schoolyard 3	
Fixed Equipment	One large structure with a slide and bridge; One small house; Teepee made of sticks. Children were not always provided access to this area (see text).
Open Space	Grass field which had some natural materials (e.g., mud, portable logs)
Seating	A ‘gathering place,’ of a wooden stage where some children would remove their shoes
Sandbox	A very large sandbox with a Mud Kitchen including sociodramatic props
Schoolyard 4	
Fixed Equipment	Several connected structures, including climbing areas and monkey bars; A separate swing structure (not preschool-sized)
Open Space	Large grassy field; Mulch surrounding fixed equipment
Seating	Metal picnic table (not child-size)
Path	Linear sidewalks, not used for wheeled toys

Table 4.2. Descriptions of the weather, number of children, and additional equipment present during each observation period

Observation	Temperature (°C)	Number of Children	Provided Equipment
Schoolyard 1			
1	26.7	11 (24)	No additional equipment, although one child brought a book
2	27.8	6 (13)	Balance boards, scoop ball sets, books and a blanket to sit on for reading, wagon, animal masks
Schoolyard 2			
3	19.4	3 (9)	Chalk, tricycles and other wheeled toys (always outside), watering cans for plants, tree cookies
4	25.0	10 (16)	Ribbon sticks, chalk, tricycles and other wheeled toys (always outside), watering cans for plants, tree cookies, tambourine, trucks to push around, hula hoops
5	25.6	1 (14)	Chalk, tricycles and other wheeled toys (always outside), tree cookies, parachute (tarp), bat and ball
Schoolyard 3			
6	26.1	9 (15)	Portable log and wooden planks, numerous toys in the sandbox and kitchen area (e.g., trucks, buckets, dishes)
7	29.4	2 (23)	Portable log and wooden planks, numerous toys in the sandbox and kitchen area (e.g., trucks, buckets, dishes)
Schoolyard 4			
8	27.8	8 (31)	Bat and ball, soccer balls, chalk

Number of children reported as [number of study participants (total number of children present on the schoolyard on the observation day)]

Video Observation

For one outdoor period per class, the schoolyard was video-recorded with three GoPro Hero Session cameras (San Mateo, CA, USA), collecting video at 1080p using a wide-angle view at 30 frames/s. Video camera times were synced to the same cell phone using the GoPro mobile application, and video cameras were started simultaneously using a GoPro Smart Remote. Start and stop times of each video were verified using the GoPro studio desktop application.

Location of each child was coded continuously via video observation using Behavioral Observation Research Interactive Software (BORIS; version 7, Torino, Italy) (Friard & Gamba, 2016). This software allowed for all three videos to be time-aligned and played simultaneously and for children's location to be coded along with "code modifiers." In the present study, code modifiers were the 'outdoor activity contexts' as defined in the OSRAC-P. For example, 'teacher arranged' activity was coded 'when the teacher has planned a gross-motor activity, has arranged the space (with or without materials), is leading the activity, and remains an active participant in the activity' (Brown, 2012). Coding rules as outlined in the OSRAC-P manual (Brown, 2012), were followed, including the hierarchal rules (e.g., if a child is participating in both ball/object and sociodramatic prop play, 'ball/object' is coded as it is of a higher order). However, in one schoolyard, the sandbox contained a large kitchen area; while the OSRAC-P mandates that all play in a sandbox be coded as sand play, we coded this behavior as 'sociodramatic' as children were standing on, but not interacting with, sand.

Time-aligned videos were watched simultaneously, and every time a focal child changed location or activity type, the location was coded by pressing the assigned key (e.g., 'g' for grass) and the activity type was chosen from a drop-down list of options as a modifier to this location code. The software records the start (onset) time for the new behavior and the stop (offset) time for the previous behavior, and this is used to calculate the duration of each event. Each child was coded individually, allowing for continuous observation of location and activity type throughout the entire outdoor period. One graduate-level observer that trained using the OSRAC-P manual and practice videos coded all videos. A second trained observer coded a subset of data (~25% of the sample), and second-by-second agreement among observers was 81.5%.

Measurement of Physical Activity

Children wore an Actigraph wGT3X-BT accelerometer (ActiGraph LLC, Pensacola, FL) at the right hip, secured by an elastic belt, for the outdoor period. The Actigraph wGT3X-BT is a triaxial (vertical, anteroposterior, and mediolateral) accelerometer, which was initialized to measure raw acceleration at a sampling rate of 30 Hz and data were downloaded as re-integrated counts using ActiLife software (version 6.13.3). Vector magnitude (the square root of the sum of the squared activity counts from each axis) was calculated for each 1-s epoch.

Data Analysis

For descriptive analysis, data were aggregated to the group level (both overall and by sex) as the purpose of this study was not to assess individual behavior and because this is similar to prior direct observation research (Brown et al., 2009). Because each schoolyard had a unique design, we collapsed locations into several common locations (e.g., different pieces of fixed equipment were all recoded as fixed equipment). Cramér's V was used to assess the strength of association between location and activity type (Cramér,1946). Percent of observation time in each location and percent of time in each location spent in each activity type overall and by sex were calculated. Additionally, mean vector magnitude (counts/s) for each activity type within each location was calculated.

Finally, two linear mixed models were fit using the lme4 package in R (Bates, Sarkar, Bates, & Matrix, 2007), with location or activity type as the fixed effect and participants nested within schools as random effects with varying intercepts, with vector magnitude (counts/s) as the dependent variable. Additionally, a null model with only random effects was fit for comparison. Pairwise differences in vector magnitude between locations or activity types were examined using Tukey post hoc tests in the emmeans package, with significance set as $p<0.01$ (Lenth, 2018). The model fits were compared overall using Vuong's likelihood ratio tests (Vuong, 1989).

Results

Fifty children (28 girls, 3-5 years of age), from eight classrooms in three licensed childcare centers, participated in this study. Because one classroom used a different schoolyard than other classrooms in their school, this resulted in four schoolyards being represented, which are described in Table 4.1 and illustrated in Figures 4.1-4.4. Children provided, on average, 42.9 + 32.6 minutes of outdoor data. In school 3, the recorded outdoor period was their only outdoor time for the day, but in the other two schools, this was one of multiple daily outdoor periods (randomly chosen by the primary investigator).

Cramér's V was 0.625, indicating an association between location and activity type. Percent of time spent in each location and percent of time spent in each location in each activity type are found in Table 4.3 overall and by sex in Table 4.4 (girls) and Table 4.5 (boys). There was a median of 5 types of activities represented in each location. The majority of time was spent in the open spaces location (48.9%) and activity type (37.6%). While 94.5% of time in the sandbox was spent participating in sand play, other locations were more diverse; for example, in the path location, the majority of time was spent using sociodramatic props, which accounted for 52.7% of time in this location. While we did not analyze differences by sex, there were potential differences in activity type within locations by sex. For example, boys participated in more 'open space' in the track/path area compared to girls (50.5 vs. 11.9%), while girls seemed to prefer sociodramatic props in this location compared to boys (74.0 vs. 22.8%).

Model coefficients can be found in Table 4.6 and while both mixed models (with either location or activity type as the fixed effect) performed better than the null model, there was no difference in model fit between the location or activity type model. There were significant differences in vector magnitude between locations (Table 4.7) and between activity types (Table

4.8). Of note, the fixed equipment location (47.1 counts/s) resulted in higher vector magnitude compared to pathways (41.3), open spaces (40.8), sensory areas (39.1), or seating areas (34.4), while the teacher arranged activity type (56.2) resulted in greater vector magnitude compared to all other activity types (37.1-47.3). Table 4.9 outlines mean vector magnitude in activity types within different locations. For example, open space activities elicited a mean vector magnitude of 40.9, 60.7, 35.0, or 88.4 counts/s depending on the location- open spaces, path, seating, or sensory locations, respectively.

Table 4.3. Percent of time within each schoolyard location spent in each activity type

	Activity Type									
Schoolyard Location	Open Space	Socioprops	Fixed Equipment	Ball or Object	Sandbox	Wheeled Toys	Teacher Arranged	Portable Equipment	Other	**Overall**
Open Space	63.4	15.1	-	14.4	-	1.3	2.8	2.3	0.8	48.9
Fixed Equipment	-	18.5	66.9	7.7	-	5.7	1.2	-	-	29.0
Path	27.9	52.7	-	1.7	-	17.6	-	-	-	10.8
Sandbox	-	5.5	-	-	94.5	-	-	-	-	5.8
Seating	81.7	16.6	-	0.2	-	0.8	-	-	0.6	4.3
Sensory	10.0	78.9	-	-	0.1	1.0	-	2.3	7.7	1.3
Overall	37.6	20.5	19.4	9.5	5.5	4.2	1.7	1.1	0.5	

Table 4.4. Percent of time within each schoolyard location spent in each activity type for girls

	Activity Type									
Schoolyard Location	Open Space	Socioprops	Fixed Equipment	Ball or Object	Sandbox	Wheeled Toys	Teacher Arranged	Portable Equipment	Other	**Overall**
Open Space	64.1	16.4	-	12.8	-	1.1	4.5	0.4	0.7	51.2
Fixed Equipment	-	15.2	78.7	4.9	-	0.1	1.1	-	-	22.8
Path	11.9	74.0	-	-	-	14.1	-	-	-	11.8
Sandbox	-	6.5	-	-	93.5	-	-	-	-	7.3
Seating	76.4	21.4	-	0.4	-	0.9	-	-	1.0	5.1
Sensory	5	81.4	-	-	0.2	1.4	-	1.3	10.7	1.8
Overall	38.2	23.7	17.9	7.7	6.8	2.3	2.5	0.2	0.6	

Table 4.5. Percent of time within each schoolyard location spent in each activity type for boys

Schoolyard Location	Activity Type: Open Space	Socioprops	Fixed Equipment	Ball or Object	Sandbox	Wheeled Toys	Teacher Arranged	Portable Equipment	Other	**Overall**
Open Space	62.6	13.3	-	16.5	-	1.5	0.7	4.6	0.8	46.3
Fixed Equipment	-	20.8	58.4	9.7	-	9.6	1.4	-	-	36.0
Path	50.5	22.8	-	4.2	-	22.5	-	-	-	9.5
Sandbox	-	3.4	-	-	96.4	-	-	-	-	4.1
Seating	91.1	8.1	-	-	-	0.8	-	-	-	3.3
Sensory	22.8	72.4	-	-	-	-	-	4.8	-	0.8
Overall	37.0	16.8	21.0	11.5	4.0	6.3	0.8	2.2	0.4	

Table 4.6. Results of three mixed models for vector magnitude (counts/s), with participant nested within schools as random effects and no (Model 1), location (Model 2), or activity type (Model 3) fixed effects.

	Model 1 Random Only					**Model 2** Location					**Model 3** Activity Type			
	Estimate	*SE*	*t*	*p*		*Estimate*	*SE*	*t*	*p*		*Estimate*	*SE*	*t*	*p*
Intercept	42.2	2.3	18.4	<0.001	Intercept	40.8	2.3	17.5	<0.001	Intercept	40.7	2.3	17.6	<0.001
					Loc. 2	6.3	0.5	13.9	<0.001	Type 2	-3.7	0.5	-6.8	<0.001
					Loc. 3	0.5	0.7	0.7	0.482	Type 3	6.6	0.5	13.4	<0.001
					Loc. 4	3.4	1.0	3.5	<0.001	Type 4	5.9	0.7	8.1	<0.001
					Loc. 5	-6.4	0.8	-8.1	<0.001	Type 5	2.6	1.0	2.6	0.008
					Loc. 6	-1.7	2.3	-0.8	0.451	Type 6	2.3	1.1	2.1	0.035
										Type 7	15.5	1.3	11.9	<0.001
										Type 8	-0.4	1.5	-0.3	0.797
										Type 9	3.0	2.7	1.1	0.271

NS=not significant; Locations are: open space (reference), fixed equipment (2), pathway (3), sandbox (4), seating area (5), or sensory area (6); Activity types are: open space (reference), socioprops (2), fixed equipment (3), ball/object (4), sand play (5), wheeled toy (6), teacher arranged (7), portable equipment (8), or other (9). The most commonly observed location and activity type served as the referent group.

Table 4.7. Pairwise differences in marginal means (± SE) for vector magnitude (counts/s) across schoolyard locations

Location	**Vector Magnitude (counts/s)** Mean ± SE	**Pairwise Differences**
1. Fixed equipment	47.1 ± 2.4	3,4,5,6
2. Sandbox	44.2 ± 2.5	4,6
3. Pathway	41.3 ± 2.4	1,6
4. Open space	40.8 ± 2.3	1,2,6
5. Sensory area	39.1 ± 3.3	1
6. Seating area	34.4 ± 2.4	1,2,3,4

Means are marginal means; Pairwise differences are significant at $p<0.01$

Table 4.8. Pairwise differences in marginal means (± SE) for vector magnitude (counts/s) across activity types

Activity type	**Vector Magnitude (counts/s)** Mean ± SE	**Pairwise Differences**
1. Teacher arranged	56.2 ± 2.6	2,3,4,5,6,7,8,9
2. Fixed equipment	47.3 ± 2.3	1,5,6,7,8,9
3. Ball/object	46.6 ± 2.4	1,7,8,9
4. Other	43.7 ± 3.6	1
5. Sand play	43.4 ± 2.5	1,2,9
6. Wheeled toy	43.1 ± 2.5	1,2,9
7. Open space	40.7 ± 2.3	1,2,3,9
8. Portable equipment	40.4 ± 2.7	1,2,3
9. Socioprops	37.1 ± 2.4	1,2,3,5,6,7

Means are marginal means; Pairwise differences are significant at $p<0.01$

Table 4.9. Mean vector magnitude (counts/s) in each activity type within each schoolyard location

Activity Types within Locations	Vector Magnitude (counts/s)
Open space	
Open space	40.9
Socioprops	41.4
Ball/object	49.7
Wheeled toys	36.5
Teacher arranged	46.8
Portable equipment	26.5
Other	39.8
Fixed equipment	
Socioprops	38.1
Fixed equipment	44.7
Ball/object	34.0
Wheeled toys	54.9
Teacher arranged	74.4
Path	
Open space	60.7
Socioprops	32.2
Ball/object	61.4
Wheeled toys	30.6
Sandbox	
Socioprops	42.6
Sandbox	37.6
Seating	
Open space	35.0
Socioprops	21.5
Ball/object	10.5
Wheeled toys	30.3
Other	26.5
Sensory	
Open space	88.4
Socioprops	30.1
Sandbox	3.5
Wheeled toys	0.0
Portable equipment	91.9
Other	83.7

Discussion

Understanding children's behavior on the schoolyard can help inform interventions to promote physical activity or other behaviors beneficial to cognitive, social, or motor development. While recent research in this age group is sparse, a number of studies have explored preschoolers' schoolyard behavior, by assessing either the type of activity or play in which a child is engaged (Brown & Burger, 1984; Brown et al., 2009; Howie, Brown, Dowda, McIver, & Pate, 2013; Soini et al., 2014) or the child's schoolyard location (Harper & Huie, 1998; Harper & Sanders, 1975; Holmes, 2012; Holmes & Procaccino, 2009). While locations afford specific types of activities (Gibson, 1977; Kyttä, 2002), the two terms are not interchangeable. Studies rarely measure both constructs (Dyment et al., 2009; Farley et al., 2008; Maxwell, Mitchell, & Evans, 2008), largely focus on types of play (e.g., constructive, parallel) other than physical play, and none have compared schoolyard location with activity type as measured in the OSRAC-P, a method often used by physical activity researchers (Brown et al., 2009; Howie et al., 2013; Hustyi et al., 2012; Larson, Normand, Morley, & Hustyi, 2014; Nicaise et al., 2012; Nicaise et al., 2011; Pate, McIver, Dowda, Brown, & Addy, 2008). The present study aimed to compare activity type (as operationalized by the OSRAC-P) and schoolyard location with the overarching goal of informing the methodology and interpretation of future research in this area. We report that the two approaches are not interchangeable, but rather, provide cumulative information. However, some information was consistent between methodological approaches (e.g., most common location/activity type) and our findings suggest that using either location or activity type results in similar model fit for predicting vector magnitude.

While we supported our hypothesis that children participated in multiple activities within each location, the predominant activity was spent in one expected activity type (e.g., fixed equipment in the fixed equipment location). Additionally, both approaches identified open spaces, followed by fixed equipment as the most common locations and activity types. These finding are in line with previous location-based studies (Cosco et al., 2010; Nicaise et al., 2012; Nicaise et al., 2011) and in studies using an activity type-based approach (Brown & Burger, 1984; Brown et al., 2009; Howie et al., 2013; Soini et al., 2014). This congruency between approaches illustrates that the overall findings about what children 'do' during outdoor time are similar, regardless of the methodological approach used.

Some activity types (e.g., fixed equipment, sand play) only occurred in a finite number of locations, which was to be expected. For these activity types, results from location-based and activity type-based approaches are comparable. Conversely, the present study also suggests that some information may be missed when using an exclusively activity type-based approach, as some activity types occurred in multiple locations. For example, play with sociodramatic props took place in all six locations, so simply recording that children participated in play with sociodramatic props disregards important information about where this behavior occurred. Similarly, information is missed when only location is considered, as multiple activity types can occur within a location. For example, the fixed equipment location encompassed fixed equipment, sociodramatic, ball/object, teacher arranged, and wheeled toy activity types, but the most prevalent activity type was, as expected, fixed equipment play (66.9%). Research using location-based approaches (e.g., Andersen et al., 2015; Clevenger et al., 2018; Fjørtoft et al., 2009; Fjørtoft et al., 2010; Pawlowski et al., 2016) would not be able to readily capture these differences in activity type within schoolyard locations without collecting or using some additional information.

Future research using location-based approaches may be able to better capture some of the variability in activity type within locations by including teacher report of additional provided equipment (e.g., chalk). For example, on paths, it may be surprising that the most common activity type was sociodramatic props, but this was because, at one schoolyard (schoolyard 4), children used chalk to draw on the path for much of their outdoor time, while another (schoolyard 2), children had access to wheeled toys, like tricycles, that only a small number of children chose to access. In another school, children were provided with animal masks during one observation, so they were coded as participating in sociodramatic props for much of their fixed equipment time. Alternatively, at the same schoolyard, but during a different observation, no additional equipment was provided to children. Collecting information on the equipment provided to children may provide additional context when only measuring children's location (e.g., when no equipment is provided, being located on fixed equipment likely means you are participating in fixed equipment play, but this may be more variable when other portable equipment is available). Future studies using activity type-based approaches, like the OSRAC-P, may use a modified version that includes location like that used by Nicaise et al. (2011) and Nicaise et al. (2012). Additionally, studies that have used location-based approaches (e.g., GPS plus accelerometry) have not used all available information, but activity type could be classified using machine learning algorithms informed by speed, body angle, or acceleration-based metrics. For example, wheeled riding toys could be discerned from open space activities while a child is located on the track based on speed and posture (sitting vs. standing). While the development of such algorithms is outside the scope of this paper, we demonstrate that classifying activity type, in addition to schoolyard location, is important in preschool-aged samples during outdoor time.

Our finding that activity type and location are not equivalent is supported by Nicaise et al. (2011), who used a modified version of the OSRAC-P, so they could code both location and activity type (called context). While the authors did not report the percent of time spent in various activity types within each location, there was a disparity between time in locations and time spent in the corresponding activity type. For example, in one school, 604 intervals were spent on the asphalt cycle path, but only 166 intervals were spent using wheeled toys. In line with our findings, this suggests that much of the time in the path location is spent participating in other activities (e.g., open space), but we also report that much of the time spent in that activity type (wheeled object) does not occur on the cycle path (e.g., children may take the wheeled toys in to the grass). The limited use of wheeled toys in the present study, however, may be related to childcare rules, as children had to retrieve and return wheeled toys, which may limit and/or alter children's use (Soini et al., 2014). It is currently recommended that childcare programs provide children with a path for wheeled toys (McWilliams et al., 2009), and the presence of a path/track has been associated with physical activity participation (Gubbels et al., 2012). However, we reported the lowest levels of physical activity when children participated in wheeled toy play on the track, suggesting that the relative importance of the location (path) versus the piece of equipment (activity type) should be further explored so that program directors and interventionists can effectively allocate limited funds and resources.

While the purpose of this study did not include drawing conclusions about sex differences in the locations or types of activities in which children engage, we explored sex differences as another avenue for understanding the impact of not measuring both schoolyard location and activity type. For example, while boys participated in less fixed equipment play as an activity type compared to girls, they spent more time located on the fixed equipment. This illustrates a key issue with measuring just location or activity type. However, this finding may be highly dependent on the included schoolyards, provided equipment (specifically, loose parts), or other variables, like weather or teacher supervision. Specifically, we observed a couple of boys reading books in a shaded part of the fixed equipment at one school, a behavior that may not occur in cooler months or when this sociodramatic prop is not provided. As previous research in older children and adolescents has demonstrated that girls seem to prefer fixed equipment compared to boys (Anthamatten et al., 2014; Clevenger et al., 2018; Farley et al., 2008; Howe, Clevenger, Plow, Porter, & SInha, 2018; Pawlowski et al., 2016; Springer, Tanguturi, Ranjit, Skala, & Kelder, 2013), we reiterate that this finding that boys spent more time on the fixed equipment is not meant to be conclusive, but rather, illustrates that there may be sex differences in location and activity type and these may not always be consistent between methodological approaches. Another observed difference by sex was that boys tended to use the pathways for open space activities (e.g., running) more than girls. While this likely depends on number and type of provided equipment and an individual's motor skills, it is supported by qualitative work in 3- to 6-year-old children demonstrating that boys tended to choose more running and chasing types of games compared to girls (Kılıçgün, 2014). These findings provide information as to the limitations, but also the potential, of measuring just activity type or location.

A secondary aim of the present study was to compare vector magnitude (counts/s) between schoolyard locations and activity types for the purpose of understanding how methodological approach would impact study outcomes. Not all locations and activity types are directly comparable, but there are two findings of note. First, vector magnitude is similar between locations and activity types that are comparable. For example, fixed equipment (47.1 vs 47.3 counts/s), sandbox (44.2 vs. 443.4), and open space (40.8 vs. 40.7). Second, the conclusions that would be drawn from the two methodological approaches are slightly different, despite similar model fit. The location-based approach suggests fixed equipment is a location that affords physical activity, while seating areas are associated with lower physical activity levels, both findings that are supported by previous research (Cosco et al., 2010; Hustyi et al., 2012; Larson et al., 2014; Smith et al., 2014). The activity type-based approach suggests that teacher arranged activities, followed by fixed equipment, stimulate physical activity, which are findings also supported by prior research (Brown et al., 2009; Howie et al. 2013). As teacher arranged activity only occurred for 2.5% of observation time (similar to the 2.6% reported by Brown et al., 2009), it is likely a trivial issue that location-based approaches do not inherently collect this information, although future methodological advancements could be developed (e.g., use of Bluetooth proximity tagging) to capture this type of activity. This difference between methods is one example of the need for researchers to consider their research question prior to choosing a methodological approach.

Lastly, our finding that vector magnitude during a specific type of activity varied by schoolyard location is in line with Gibson's theory of affordances (Gibson, 1977) and has important implications for potential interventions. For example, it is recommended that childcare centers provide paths for wheeled toys (McWilliams et al., 2015), but we report that vector magnitude was actually lowest during wheeled toy use while children were located on paths. Instead, they seemed to be more active when participating in open space or ball/object activities (e.g., running games) in this location. Previous researchers have reported high moderate-to-vigorous physical activity levels while participating in wheeled toy use, which has been assumed to occur on paths. However, researchers have not actually investigated where wheeled toy use occurs or reported the physical activity levels elicited during other types of activities that take place within the path location. Our findings suggest that the addition of a path that only affords wheeled object use may not promote increases in physical activity, but this needs to be studied in larger samples before conclusions may be drawn. Of note, only a small number of schools had wheeled objects available in the present study, and children at those schools were generally younger and therefore, may not have been as physically active while engaging with wheeled toys. However, the finding that physical activity varies by activity and location supports that measuring both activity type and location may be important in future studies.

In the future, researchers should consider the pros and cons of location-based versus activity type-based approaches. Observational scales like the OSRAC-P have been shown to be reliable and when using video observation, can provide continuous, individual-level data on important context of play behaviors. The OSRAC, and similar scales, also allow for comparable measurements between schoolyards, despite differences between schools in the types of specific activities in which children engage (e.g., multiple types of play are collapsed to one sociodramatic play code). Conversely, using a location-based approach may also be amenable to assessing a variety of playgrounds as the locations of interest can vary from playground to playground. While we collapsed the data into common locations for clarity in the present paper, we were able to identify time spent using specific pieces of, for example, fixed equipment (e.g., spinning net, swings). This approach aligns with recommendations by Pellegrini (1987) that children's behavior should be explored at a micro-level, then aggregated into macro-level categories to allow for ethological variability between children and schools. Being able to measure locational differences is important because recognizing what children actually use on the schoolyard can inform future schoolyard redesign and identify where limited financial resources and space should be allocated. For example, Nicaise et al. (2012) removed some small pieces of fixed equipment, which increased the amount of open space and subsequently increased physical activity in one preschool. Combining measures of both location and activity type could identify if children used these structures prior to their removal and explain why this intervention was effective for promoting physical activity participation.

It is important to note that these findings are not meant to provide a representative indication of where children spent their outdoor time, as we used a small number of children and schools and only one outdoor period. We noticed that types of teacher involvement and portable or sociodramatic equipment brought to the playground varied substantially between outdoor periods, both within and between days (not shown), and this impacted the types of activities children participated in within the schoolyard locations. Thus, our findings may not represent where children habitually spend their outdoor time, but our goal was to encompass a variety of schoolyard locations and types of equipment to provide an indication as to the number and types of activities in which children participate while in various locations. A strength of the present study was the use of video direct observation, which allowed us to review and code multiple behaviors to be as accurate as possible.

We can conclude that schoolyard location and activity type are not synonymous, but provide cumulative information that together may better inform our understanding of children's behavior during provided outdoor time. While there is some discrepancy between activity type and location, the overall patterns in children's behavior were similar. For example, open spaces were the most prevalent activity type and the location in which children spent the majority of their time and both approaches supported that fixed equipment facilitates physical activity. This suggests that studies focusing on activity type (e.g., OSRAC-P) may be comparable to those focusing on location, but caution should be exercised for some activity types or locations and when assessing group differences.

Figure 4.1. Diagram of schoolyard 1. Bolded lines indicate the fence enclosing the schoolyard.

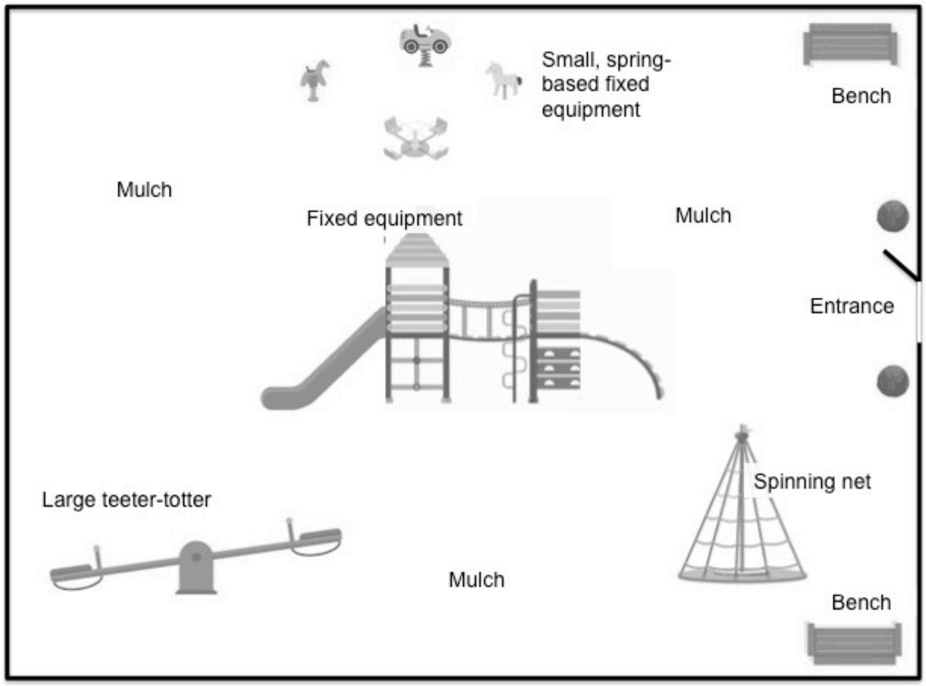


Figure 4.2. Diagram of schoolyard 2. Bolded lines indicate barriers enclosing the schoolyard.

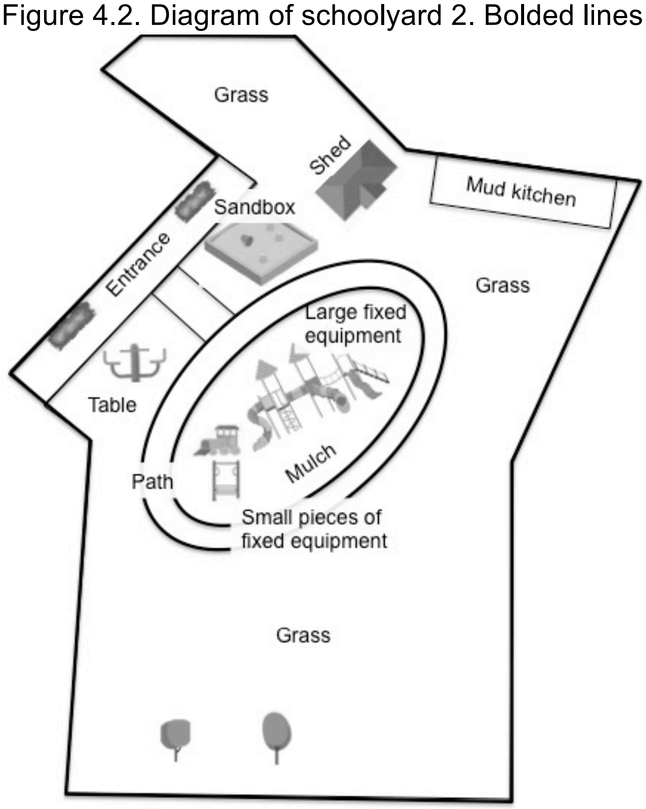


Figure 4.3. Diagram of schoolyard 3. Bolded lines indicate the fence enclosing the schoolyard.

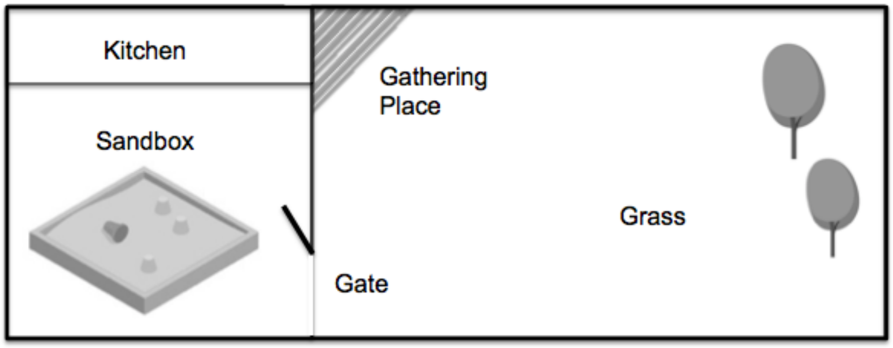
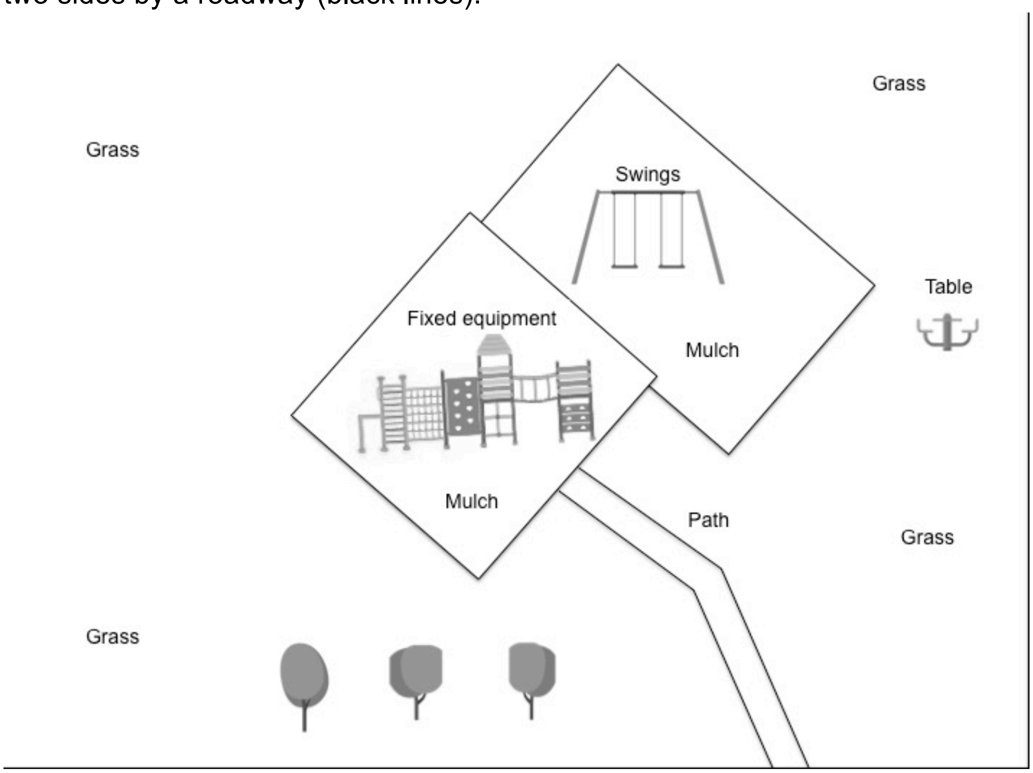


Figure 4.4. Diagram of schoolyard 4. The schoolyard was not enclosed, but was restricted on two sides by a roadway (black lines).



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CHAPTER 5: USE OF A SPATIOTEMPORAL APPROACH FOR UNDERSTANDING PRESCHOOLER'S SCHOOLYARD ACTIVITY

Abstract

Global positioning systems (GPS) plus accelerometry has been used in samples of older children and adolescents to understand how physical activity varies by schoolyard location. However, previous studies have not accounted for temporal changes in where and how actively children play when analyzing these data. The purpose of this study was to use a spatiotemporal approach to hot spot analysis to identify where clusters of physical activity occur on the schoolyard throughout the outdoor period. Preschool-aged children (N=34) at two preschools wore a QStarz BTQ1300-ST GPS (5-s epoch) and an ActiGraph wGT3X-BT accelerometer (15-s epoch) at the waist during 2-3 outdoor periods over the course of one day. A spatiotemporal weights matrix was generated so that points within a specified distance band in meters (space) and 3 minutes (time) were considered neighbors. Global Moran's I was used to determine if space-time clustering in vector magnitude (VM) counts was present, then the Getis-Ord G* statistic was calculated to detect locations of significant hot (high VM counts) and cold (low VM counts) spots. There was evidence of global (overall) clustering for all measurement periods. Some locations afforded both high and low levels of physical activity, just at different points in time, resulting in locations with both hot and cold spots during a single outdoor period (intraperiod), and variation in the location of clusters between outdoor periods (interperiod). Similar to research in older youths, we demonstrated that physical activity varies by schoolyard location, but we highlight the importance of the temporal component, as the location of physical activity hot spots changed over the course of provided outdoor time. Future research can use this approach to identify locations and times that may be salient points of intervention during provided outdoor time.

Introduction

It is recommended that preschool-aged children obtain at least 180 minutes per day of total (light-to-vigorous) physical activity (Commonwealth of Australia, 2010; UK Chief Medical Officers, 2011; Tremblay et al., 2017; United States Department of Health and Human Services [USDHHS], 2018). As 59% of children under 5 years of age attend regular center-based childcare, this is an important setting in which to accumulate physical activity (Corcoran & Katrina, 2019). While it is widely recognized that outdoor time during childcare provides a daily opportunity for free-play physical activity and promotes higher levels of physical activity compared to indoor time, preschoolers still spend 28 to 66% of provided outdoor time in sedentary behavior (Brown, et al., 2009; Gubbels et al., 2011; Sugiyama, Okely, Masters, & Moore, 2012; Trost, Fees, & Dzewaltowski, 2008). Activity levels during outdoor time vary substantially among preschools (Gubbels et al., 2011; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004; Tandon, Saelens, Zhou, Kerr, & Christakis, 2013; Vanderloo et al., 2014), which suggests there may be contextual factors or aspects of the environment that affect this behavior.

The physical environment has a salient influence on physical activity during the preschool day (Bower et al., 2008; Dowda et al., 2009; Sugiyama et al., 2012). In the outdoor environment, preschoolers have been shown to be more physically active on schoolyards rated as higher quality (Bower et al., 2008; Gubbels et al., 2011), that are adequately sized (Boldemann et al., 2006; Clark et al., 2002; Dowda et al., 2009), have portable equipment (Berg, 2015; Dowda et al., 2009; Gunter, Rice, Ward, & Trost, 2012), grassy spaces (Berg, 2015), or fixed equipment (Gunter et al., 2012; Sugiyama et al., 2012). Many of these studies have involved correlating a variable (e.g., total area, availability of a slide, number of pieces of portable equipment) with overall physical activity levels. Unfortunately, fewer researchers have investigated where preschoolers actually spend their outdoor time and how physically active they are in various locations within the schoolyard. This approach can inform us as to what features of the schoolyard children are actually using during outdoor time overall and while being physically active.

The available literature in preschool-aged samples supports that physical activity varies with a child's location on the schoolyard (Cosco, Moore, & Islam, 2010; Hustyi, Normand, Larson, & Morley, 2012; Larson, Normand, Morley, & Hustyi, 2014; Nicaise, Kahan, & Sallis, 2011; Smith et al., 2014) and that modification of these locations (e.g., addition of a slope to a grassy field) can promote increases in physical activity participation (Nicaise, Kahan, Reuben, & Sallis, 2012). Further, Smith et al. (2014) reported that 23% of the variance in children's physical activity could be explained by attributes of the child's location within the schoolyard (e.g., open area, sand area). Studies of older children and adolescents note that in some locations within the schoolyard, the commonly seen disparity in physical activity by sex is reduced (Black, Menzel, & Bungum, 2015; Clevenger, Sinha, & Howe, 2018; Howe, Clevenger, Plow, Porter, & Sinha, 2018; Saint-Maurice, Welk, Silva, Siahpush, & Huberty, 2011; Willenberg et al., 2010). Thus, information about schoolyard locations that promote physical activity is needed and could inform the design of schoolyards and interventions that promote physical activity in all children, including those who typically demonstrate lower physical activity levels (e.g., girls).

While research on the locational context of preschoolers' physical activity patterns is warranted, measuring physical activity and its context is difficult due to the complexity and brevity of children's movements (Oliver, Schofield, & Kolt, 2007). Direct observation can provide context to physical activity, but it is difficult to obtain continuous, individual-level data using this time-consuming method that depends heavily on researcher reliability (Oliver et al., 2007). Monitor-based approaches can provide continuous, individual-level data on the intensity, duration, and location of children throughout the school day. A few studies have used Global Positioning Systems (GPS) receiver units in combination with accelerometers (Andersen, Klinker, Toftager, Pawlowski, & Schipperijn, 2015; Clevenger et al., 2018; Pawlowski, Andersen, Troelsen, & Schpperijn, 2016) or heart rate monitors (Fjørtoft, Kristoffersen, & Sageie, 2009; Fjørtoft, Löfman, & Thorén, 2010). However, this method has not been used in preschools, where schoolyards may be smaller and denser. A variety of approaches for analyzing these data have been used, including visualization (e.g., grid maps; Fjørtoft et al., 2010) and statistical approaches (e.g., hot spot analysis; Pawlowksi et al., 2016) (Clevenger et al., 2018). While the development of a consistent method is critical to ensure comparability between studies, the methods used to date have one major limitation. That is, they do not allow for spatially relevant information to vary over time. For example, hot spot analysis has been used to identify clusters of high accelerometer counts (Clevenger et al., 2018; Pawlowski et al., 2016), but it does not identify whether these clusters are present over the entire outdoor period, or just during a particular time (e.g., at the beginning of outdoor time). McKenzie et al. (1997) and Holmes (2012) demonstrated that physical activity participation varies over the course of the outdoor period, so it is likely that children's location would also vary over time. A spatiotemporal method could be used to identify what areas of the schoolyard elicit high levels of physical activity at various time points during the outdoor period.

The purpose of this study was to use a spatiotemporal approach to hot spot analysis to identify where and when clusters of physical activity occur on the schoolyard. We hypothesized that clustering would be present, but the location of clusters would change over the course of a given outdoor period (intraperiod), or between outdoor periods (interperiod).

Methods

Participants and Setting

Michigan State University Institutional Review Board approved this protocol. Licensed preschool centers were recruited from the Mid-Michigan area, and informed consent forms were sent home to parents of children in classrooms containing 2-5 y olds. Prior to participation, each child provided verbal assent. Children with no apparent disease or condition that would alter physical activity participation were eligible to participate. On the day of data collection, weather (e.g., temperature) and provided equipment (e.g., the teacher brought out hula hoops) were recorded. For each outdoor period, prior deprivation was recorded (amount of time since the last outdoor play period), as previous research has indicated this may impact physical activity participation (Pellegrini, Huberty, & Jones, 1995; Smith & Hagan, 1980).

Measurement of Physical Activity

Children wore an Actigraph wGT3X-BT accelerometer (ActiGraph LLC, Pensacola, FL) at the right hip, secured by an elastic belt, for the entire school day. The Actigraph wGT3X-BT is a triaxial accelerometer that measures raw acceleration (g's) ranging from ±8 g's in three planes (vertical, anteroposterior, and mediolateral), which is filtered and summed over a user-specified epoch to create activity counts. Accelerometers were initialized to collect raw acceleration at a sampling rate of 30 Hz and data were downloaded as re-integrated counts using ActiLife software (version 6.13.3). Vector magnitude (the square root of the sum of the squared activity counts from each axis) was calculated for each 15-s epoch. Vector magnitude was used because it is an orientation-independent metric, and a 15-s epoch was used as it is the most commonly used epoch length in studies of preschool-aged samples (Migueles et al., 2017).

Measurement of Schoolyard Location

Each child also wore a QStarz BTQ1300ST GPS receiver unit (QStarz International Co., Ltd., Taipei, Taiwan) secured to the same elastic belt as the accelerometer. Location (as latitude and longitude) was recorded at a 5-s epoch and relevant almanac and ephemeris data were downloaded to each GPS device prior to data collection to decrease time to initial signal acquisition. This monitor has been used previously in the schoolyard setting (Andersen et al., 2015; Pawlowski et al., 2016) and in a review of 6 portable GPS receivers, the QStarz was more sensitive and accurate, operated on more channels, acquired a signal faster (from a cold, warm, and hot start), and stored more data points than the other monitors (Duncan et al., 2013). The manufacturer-reported error for this unit is <3 m (QStarz, 2019). Data were downloaded using the QSports software (version 3.76) and exported as a 'csv' file.

Data Analysis

To detect potential environmental factors that would cause additional GPS error, we used Trimble Global Navigation Satellite System (GNSS) Planning Online software (version 1.2.0.0, Trimble Terrasat GmbH, Germany) to identify positional dilution of precision (PDOP), ionospheric index (including potential scintillation and total electron content), and number of satellites in view on the dates and times of measurement. The Ap index, as an indicator of planetary geomagnetic disturbance, was obtained from the German Research Centre for Geosciences. All metrics were within accepted ranges (e.g., PDOP was <2, ionospheric index of 1, ≥6 satellites in view, and Ap ≤8), indicating higher-than-expected positional error was unlikely.

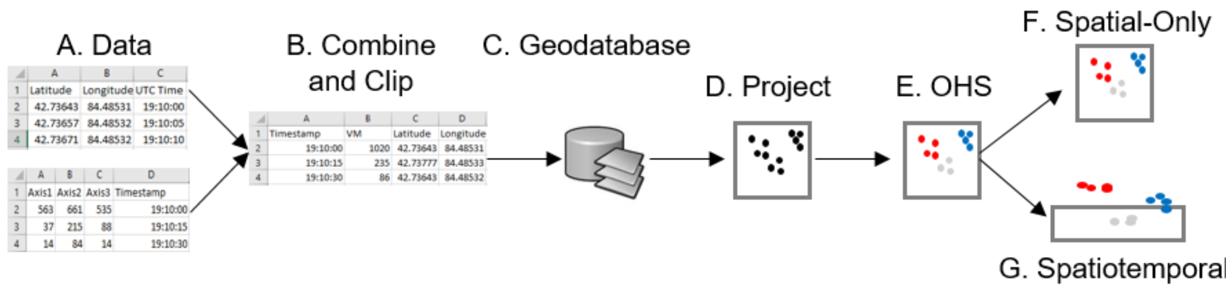
Workflow is diagramed in Figure 5.1. For both accelerometer and GPS data, outdoor time was isolated prior to analysis based on start and end times determined using video observation of the schoolyard. Accelerometer and GPS data were matched based on time stamp in R (R Core Development Team, Vienna, Austria). Because the GPS unit does not allow the user to set a specific start time, there were some GPS time stamps that did not directly match accelerometer time stamps (e.g., 12:10:01 vs. 12:10:00). Exact matches between the two data sets were completed first; then for accelerometer data points without a corresponding GPS point, latitude and longitude were assigned based on the closest GPS point, as long as the two time stamps were within 1 minute of each other. The resulting dataset consisted of vector magnitude counts and a corresponding GPS-determined location for each 15-s epoch for each child.

These data were combined for each class (group-level analysis) and were loaded into ArcMap (ESRI, Redlands CA, version 10.5.1) and converted to the WGS 1984 UTM Zone 16 N projected coordinate system. Global Moran's I was used to assess whether significant global (overall) clustering was present in the data (Moran, 1950). Similar to previous research

(Clevenger et al., 2018), the Optimized Hot Spot Analysis tool in ArcMap (ArcMap, 2019) was used to determine the distance band within which features would be considered neighbors. This value was allowed to vary between schoolyards due to their varying sizes (i.e., on a larger schoolyard, neighbors may be farther apart than on a smaller schoolyard).

For each classroom on each schoolyard, two final hot spot analyses were conducted- 1) spatial-only and 2) spatiotemporal. For the spatial-only models, the distance band determined by the Optimized Hot Spot Analysis tool was used with inverse distance weighting, so that features within the distance band were considered neighbors, but features closer together were conceptualized to be more similar than features further apart. For the spatiotemporal models, a spatiotemporal weight matrix was generated, using the determined distance band and allowing features within three minutes of each other to be considered neighbors. While no prior research has compared the impact of using different distance bands or time windows in this setting, multiple combinations were explored to ensure that the clusters locations were consistently found and not simply an artifact of our chosen distance band and time window. Using this spatiotemporal model, features had to be neighbors both spatially and temporally to be included as part of a hot or cold spot. For all hot spot analysis, the Getis-Ord Gi* statistic (Getis & Ord, 1992) was used to determine significant (p<0.05) hot and cold spots, and the false discovery correction was used to account for multiple comparisons and autocorrelation (Caldas de Castro & Singer, 2006). For both spatial and spatiotemporal models, mean vector magnitude within hot and cold spots was determined.

Figure 5.1. Diagram of workflow for analyzing GPS plus accelerometer data. GPS data were cleaned (A) and combined with accelerometer data for each 15-s epoch based on time-stamp, and non-outdoor times were removed (B). Files were stored in a geodatabase (C) and then projected in ArcMap (D). Optimal hot spot analysis (OHS) was used to determine the distance band (E) that was subsequently used for the spatial-only hot spot analysis (F) and spatiotemporal hot spot analysis (G).



Results

Two licensed childcare centers volunteered to take part in this study, with 17 participants from each school. These two schools utilized a total of four schoolyards, which are described in Table 5.1. Each program provided children with multiple (2-3) outdoor periods per day, allowing us to identify temporal patterns both within outdoor periods (intraperiod) and across outdoor periods (interperiod) within a single day. All measurement days occurred in the summer when mean temperatures ranged from 26 to 29 Celsius. One child was absent during the morning outdoor period at one school, but otherwise, all children were present for all outdoor periods, with an average daily outdoor time of 123 min/day (range 94-169 min). These outdoor periods were part of the regular classroom schedule and no changes to scheduling or timing of these outdoor periods were imposed by our study. Descriptors about outdoor period duration, the amount of prior deprivation (indoor time), and classroom activities that took place before the outdoor period are described in Table 5.2. For exploratory purposes, trends and averages in vector magnitude counts/15-s over the course of each outdoor period are also described in Table 5.2.

Table 5.1. Descriptions of each schoolyard

Schoolyard	Description of settings	Description of use
1	Mulch surface enclosed by a fence with one large piece of fixed equipment at the center Four small, spring-based pieces of equipment, a large teeter-totter, and a spinning net for climbing were also present	Classes 1 and 2 used this classroom every day for the first and last recess periods of the day, and often, for the pre-lunchtime recess period as well
2	Larger than schoolyard 1, and covered in grass (some slope), save for a large, open sandpit There was also a small seating area in the northeast corner, primarily used by teachers	Occasionally used by class 2, and more rarely (not in the present study period), class 1 (based on teacher's choice and school schedule)
3	A certified 'nature explore classroom.' Three primary areas that could be closed off by teachers when classes needed to be separated. The grassy area was primarily open, save for some portable logs and planks. The sandbox area was large, with a play kitchen and numerous toys. The fixed equipment area was comprised of rubber flooring with one large piece of fixed equipment. Additionally, a small house and teepee were present.	Used by classes 4 and 5 twice a day, and class 3 once per day. Teachers would sometime block off one portion, which separated the fixed equipment from the sandbox and grass area.
4	A large (3-acre) park used also for the oldest preschoolers, comprised of a seating area (picnic table), large grassy areas, fixed equipment (including swings) on mulch, and linear sidewalks that children primarily used for drawing with chalk. Teachers would typically bring 1-2 balls or other portable equipment.	Used by class 3 once per day, and rarely (depending on school schedule) used by class 5. Children had to walk (approximately 5 minutes) to use this schoolyard.

Table 5.2. Vector magnitude during each outdoor period

	Duration (min)	Prior Deprivation (hours)	Preceding Activities	Vector Magnitude (counts/15-s) Min-max	Average	Trend Notes
Class 1, Obs. 1	56	-	Arrival	0-3617	354	No change
Class 1, Obs. 2	20	2.0	Large and small group	0-4209	455	Slight increase
Class 1 Obs. 3	69	4.0	Free-choice and snack	0-3930	809	Steady increase
Class 2, Obs. 1	18	-	Large and small group	0-5315	699	No change
Class 2, Obs. 2	60	1.5	Lunch and rest	0-7214	662	Slight increase
Class 1 Obs. 3	91	2.0	Large and small group	0-2527	629	Slight decrease
Class 3, Obs. 1	28	-	Snack and group	0-1784	583	Steady decrease
Class 3, Obs. 2	66	3.0	Small group and quiet play	0-3518	562	No change
Class 4, Obs. 1	52	-	Snack and small group	0-3643	594	No change
Class 4, Obs. 2	59	5.0	Nap and snack	0-2662	576	Slight increase
Class 5, Obs. 1	47	-	Arrival	0-2070	407	Slight decrease
Class 5, Obs. 2	47	3.0	Nap and snack	0-2209	580	Steady decrease

Data loss was approximately 5% (e.g., due to no signal acquisition). There was evidence of global clustering at all schoolyards during all measurement periods (all $p<0.0001$). Distance bands used for hot spot analysis ranged from 7 to 10 m and generally increased with overall playground size. In the spatial-only hot spot analysis, 22 and 21% of features, on average, were classified as significant ($p<0.05$) hot and cold spots, respectively, while 15 and 21% were classified as hot and cold spots, respectively, when using a spatiotemporal approach (Table 5.3). Average vector magnitude within hot spots was 689 vs. 942 counts/15-s and 310 vs. 276 counts/15-s within cold spots for spatial-only and spatiotemporal approaches, respectively (Table 5.3).

Figures 5.2 to 5.6 illustrate the results of both spatial only (right side) and spatiotemporal (left side) hot spot analyses for each school for each outdoor period. Spatial-only analyses revealed that hot spots were often located on the fixed equipment (Figure 5.2, 5.3, 5.4, 5.5, and 5.6) or grass (Figure 5.3, 5.6) and cold spots located in the mulch (Figure 5.2, 5.3), sandbox (Figure 5.3, 5.4), or on the sidewalk (Figure 5.4). One class had no spatial-only clustering present (class 3, schoolyard 3, Figure 5.4), but there were small spatiotemporal clusters present on the sandbox and in the mulch (Figure 5.4).

Figures 5.2 to 5.6 also illustrate the locations of spatiotemporal hot and cold spots over the course of each outdoor period ($p<0.05$), with time on the y-axis (i.e., as you move vertically, more time has elapsed). Hot and cold spots could occur in the same location depending on the time period. For example, in Figure 5.2, both hot and cold spots were located on the fixed equipment, with an initial cold spot at the beginning of the first outdoor period, followed by a hot spot, and then a cold spot at the beginning of the pre-lunch outdoor period, followed by a hot spot. In the final outdoor period, there was only a hot spot in this location. In this same class, there was a persistent cold spot in the mulch in the morning observation only.

Table 5.3. Percent of intervals classified as hot or cold spot and mean vector magnitude for spatial only or spatiotemporal hot spot analyses

		Spatial Only Model		**Spatiotemporal Model**	
		Percent of intervals	**VM**	**Percent of intervals**	**VM**
Class 1, yard 1	Hot	42.4	652 ± 516	25.4	807 ± 558
	Cold	26.2	115 ± 294	27.0	113 ± 276
Class 2, yard 1	Hot	21.6	866 ± 902	16.5	1117 ± 1128
	Cold	10.0	418 ± 397	13.4	368 ± 365
Class 2, yard 2	Hot	40.0	837 ± 493	19.2	966 ± 528
	Cold	26.4	360 ± 378	20.2	275 ± 331
Class 3, yard 3	Hot	0.0	-	2.6	1000 ± 352
	Cold	0.0	-	4.1	344 ± 290
Class 3, yard 4	Hot	15.7	965 ± 528	14.7	1035 ± 551
	Cold	53.2	415 ± 454	25.6	320 ± 444
Class 4, yard 3	Hot	25.0	745 ± 548	10.9	888 ± 615
	Cold	8.0	299 ± 352	8.0	299 ± 352
Class 5, yard 3	Hot	23.8	759 ± 406	16.7	784 ± 381
	Cold	23.0	251 ± 289	51.0	214 ± 300

Figure 5.2. Significant (p<0.05) spatiotemporal hot and cold spots for classroom 1 on schoolyard 1

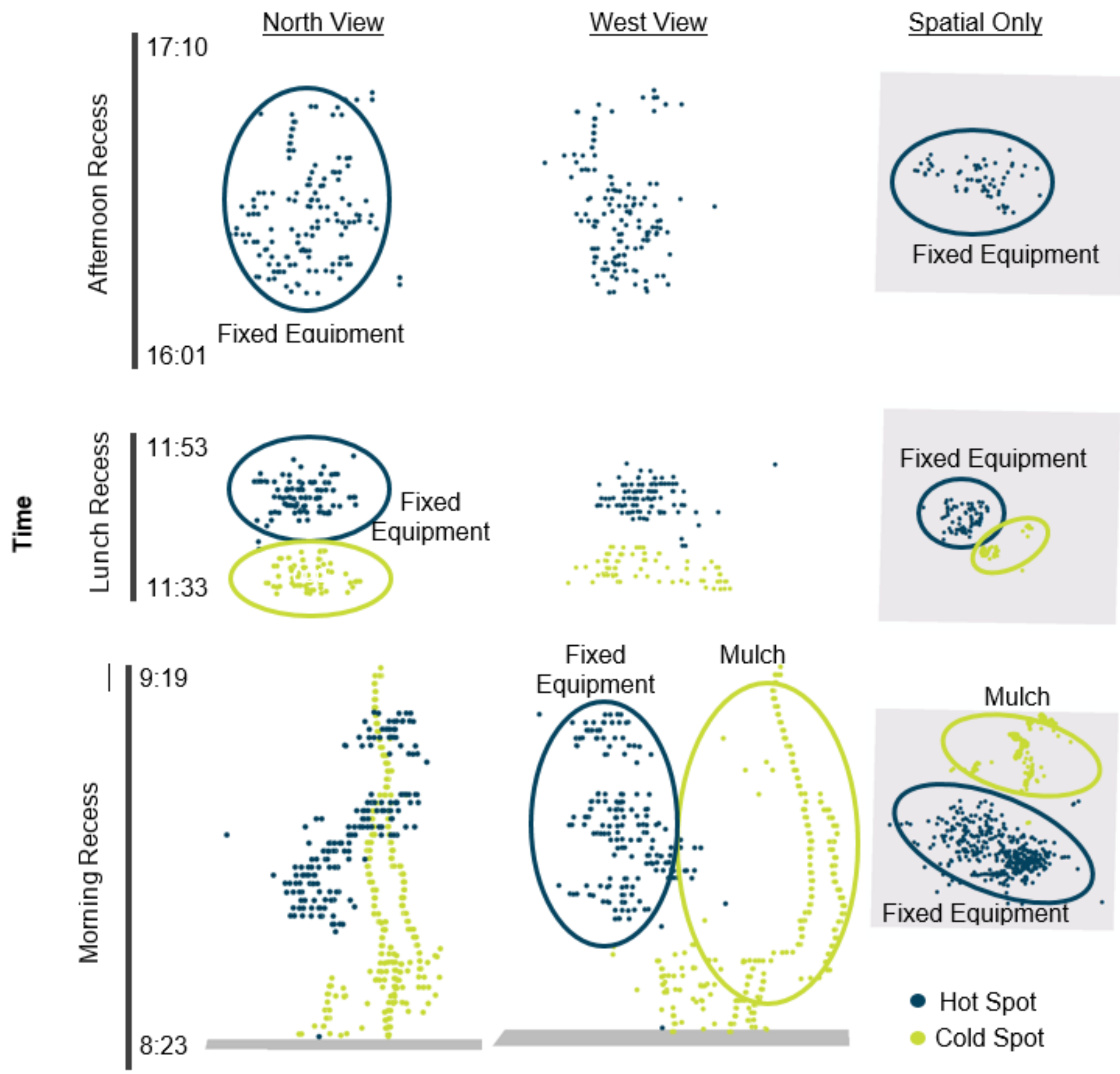


Figure 5.3. Significant (p<0.05) spatiotemporal hot and cold spots for classroom 2 on schoolyard 1

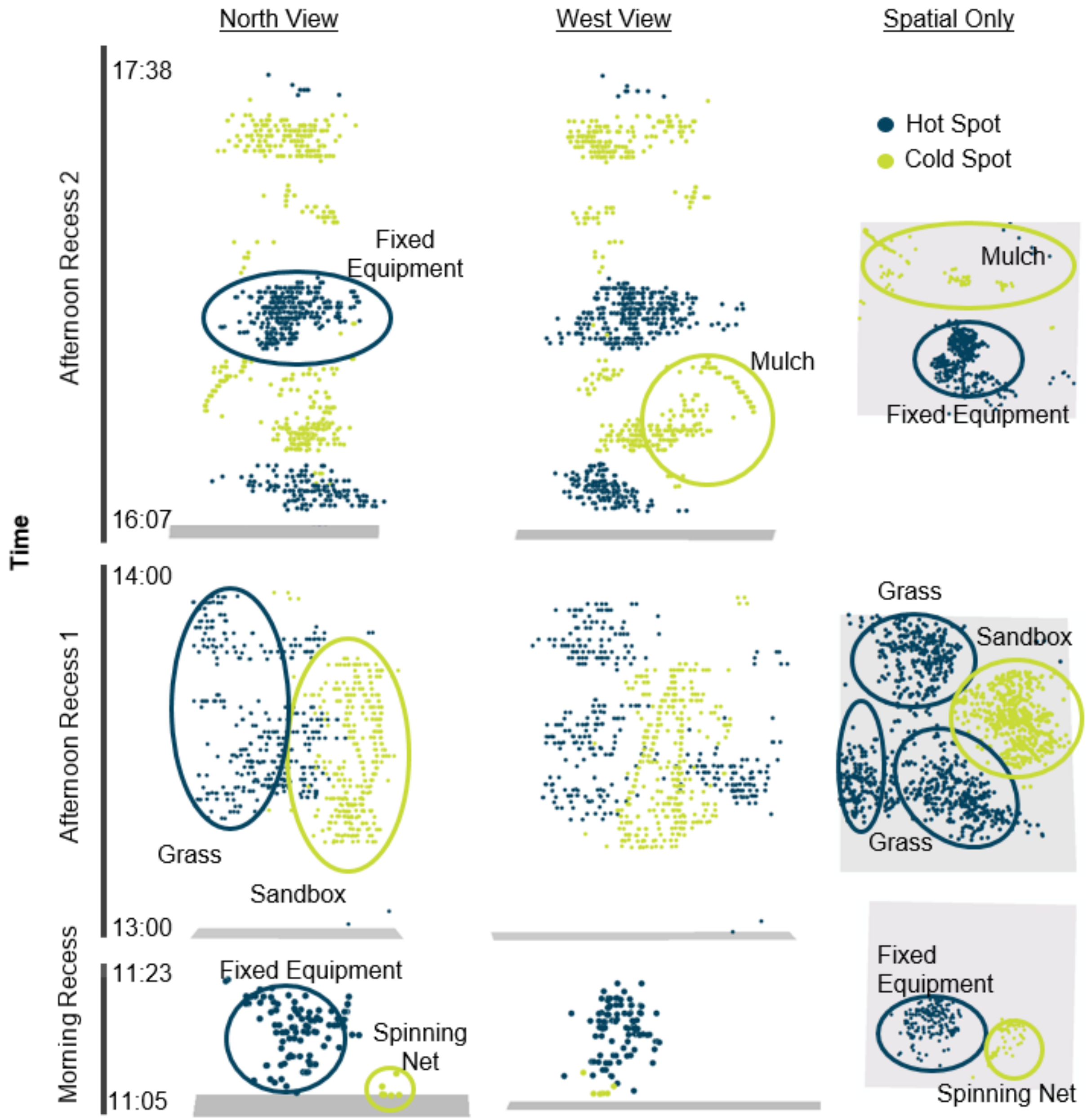


Figure 5.4. Significant ($p<0.05$) spatiotemporal hot and cold spots for classroom 3 on schoolyards 3 (morning) and 4 (afternoon)

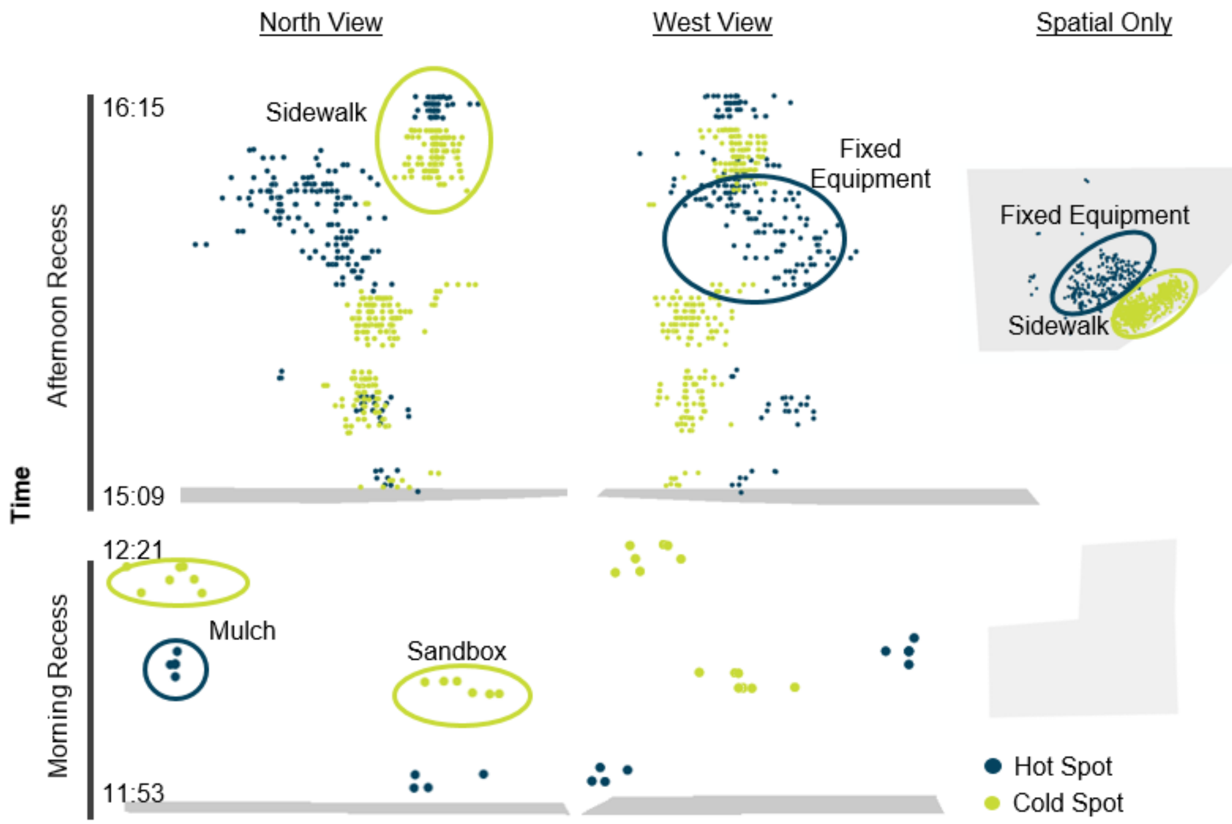


Figure 5.5. Significant ($p<0.05$) spatiotemporal hot and cold spots for classroom 4 on schoolyard 3

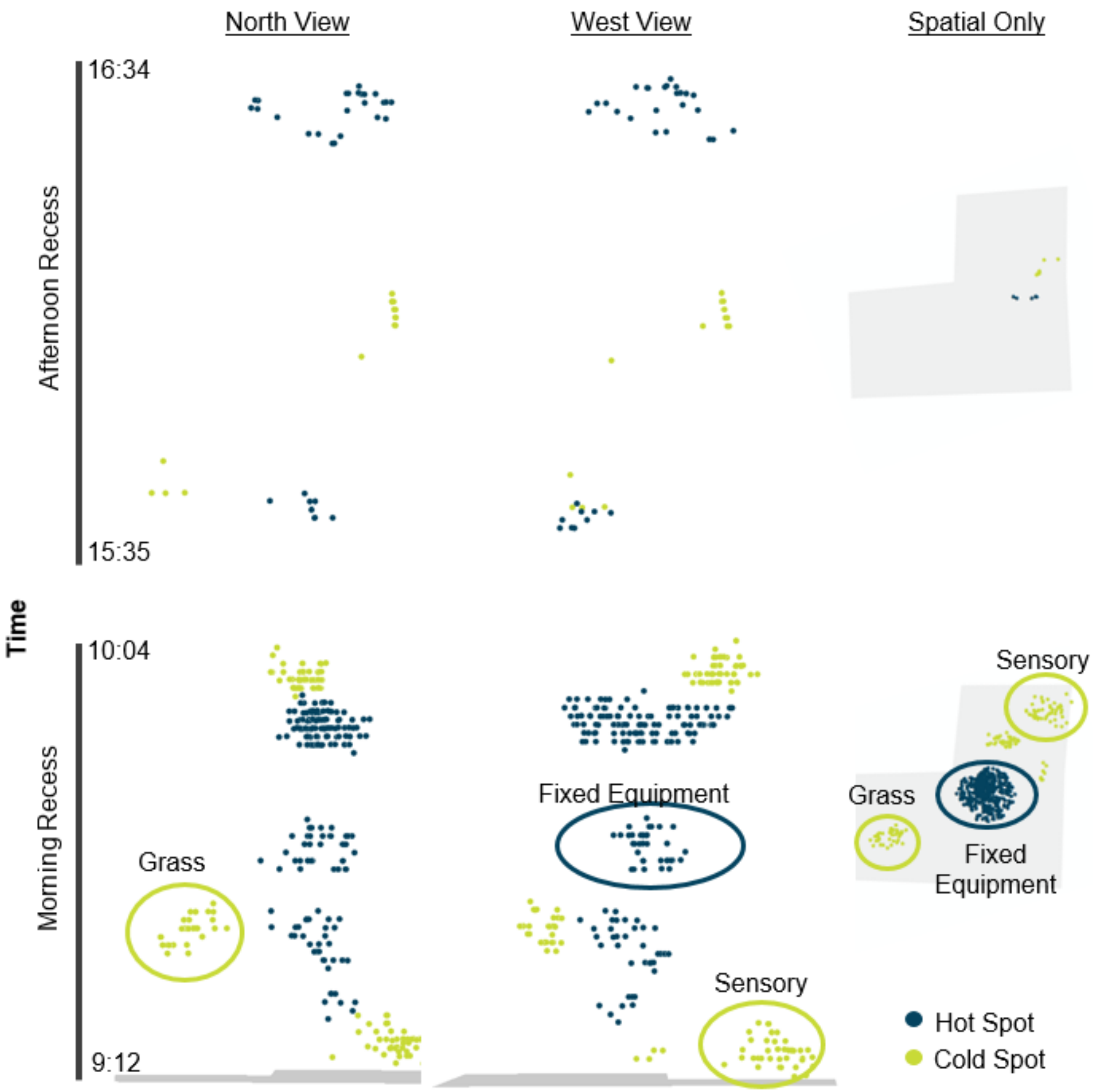
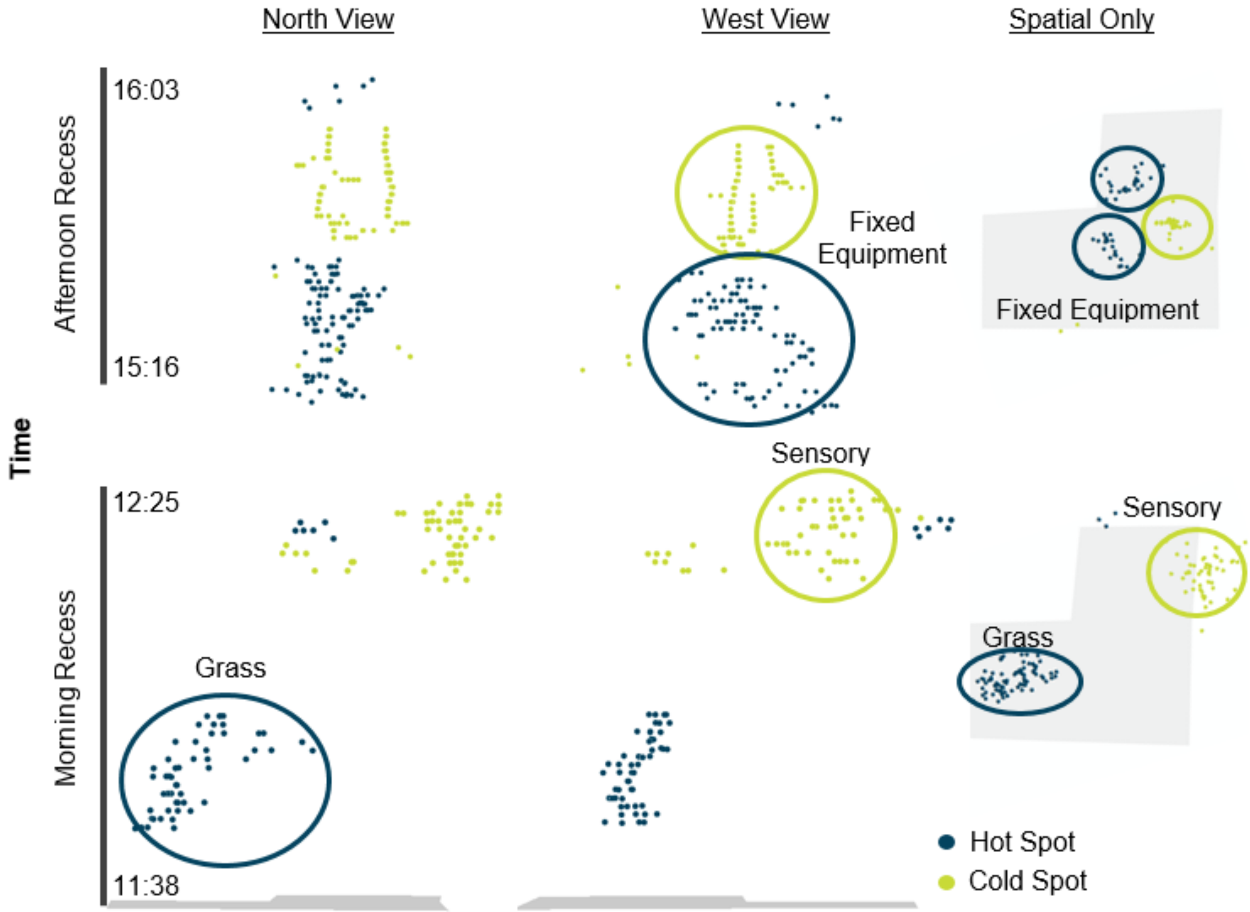


Figure 5.6. Significant (p<0.05) spatiotemporal hot and cold spots for classroom 5 on schoolyard 3



Discussion

The use of GPS plus accelerometry is a promising methodology for understanding where and how actively youth are during provided school outdoor time. A number of methods have been used to analyze GPS plus physical activity data, and while it was recently concluded that the most promising of these methods is hot spot analysis (Clevenger et al., 2018), the lack of incorporation of temporal information when modeling spatial relationships is a serious limitation of studies that have used the hot spot method in this setting (Clevenger et al., 2018; Pawlowski et al., 2016). As such, we demonstrated the use of hot spot analysis using spatiotemporal weight matrices and found support for our hypothesis that the location of clusters of high or low activity counts (i.e., hot and cold spots) changed over the course of a day (interperiod) or outdoor period (intraperiod).

In previous research using hot spot analysis (Clevenger et al., 2018; Pawlowski et al., 2016), data were aggregated across entire outdoor periods and only spatial information was used to identify nearby neighboring features. Both prior studies included older children and/or adolescents on one schoolyard and identified hot spots of high activity counts on four square courts (Clevenger et al., 2018; Pawlowski et al., 2016), in fields (Clevenger et al., 2018; Pawlowski et al., 2016), or on fixed equipment (Clevenger et al., 2018). Similar to this previous research, we were able to identify significant clustering in preschool-aged samples on multiple schoolyards, but found that the location of hot and cold spots varied on different schoolyards (e.g., compare Figure 5.2 and 5.3 to Figure 5.4, 5.5, and 5.6). Schoolyards differ in the type, design, and size of available settings, which afford unique activities and therefore, result in varying physical activity levels, so this finding was expected. Our results support the need to use this methodology on a large number of schoolyards that vary in their design.

All but one schoolyard had fixed equipment available, and when it was available, it typically elicited high levels of physical activity (as evidenced by the presence of hot spots), which is in line with observational and experimental research in this age group (Cosco et al., 2010; Hustyi et al., 2012; Larson et al., 2014). The only schoolyard that had fixed equipment, but did not have a hot spot in that location was schoolyard 3 for one class, but this is likely related to the fact that teachers at that school would often block the fixed equipment off for approximately half of provided outdoor time so that other classes could play in that area. Changes in scheduling, so that multiple classes were not outside at the same time, may promote additional physical activity in children at this school, which is feasible according to a prior intervention (Van Cauwenberghe, De Bourdeauhuij, Maes, & Cardon, 2012).

Previous research has demonstrated that open spaces (Cosco et al., 2010; Nicaise et al., 2011) and sloped grass areas (Nicaise et al., 2012) promote physical activity in preschoolers, which was supported in only a third of our observations. In contrast, we found that some open spaces contained clusters of low vector magnitude counts (e.g., Figure 5.2, 5.3). For example, on schoolyard 1, which was entirely comprised of fixed equipment and open mulch, children liked to pace or to stand by the fence to talk, watch cars pull in to the parking lot, or to watch children on other schoolyards play. This finding is similar to previous research in older children that demonstrated that a lack of options on the schoolyard resulted in children congregating by a fence to socialize (Holmes, 2012). Lack of running games or other active behaviors on the mulch may also be related to the surface type (Cosco et al., 2010), a topic that could be further explored using a combination of GPS plus accelerometry in a large number of schoolyards. Interestingly, schoolyard 4 (Figure 5.4) had a very large grassy field as it doubles as a city park, but there was not a hot spot in this area. It may be that the schoolyard size was too large for preschoolers and therefore, they did not travel far distances during provided outdoor time. This result is also supported by the fact that preschoolers at that school rarely used the swings, likely because they were sized for older children, not preschoolers. Thus, the impact of equipment and location size could be further explored. Use of GPS and accelerometry would be able to identify, for example, changes in space use with age or motor skill development.

In addition to differences between schoolyards, we found that cluster locations could also vary on the same schoolyard between different classes (e.g., compare Figure 5.5 to Figure 5.6) and within the same class during different times of the day (e.g., Figure 5.2). For example, class 1 had three outdoor periods on schoolyard 1, all with different cluster patterns. In the early morning outdoor sessions, which occurred soon after children arrived at school, there was an initial cold spot (Figure 5.2) and a prolonged cold spot in the mulch area, where children could watch other classes arrive at school. Vector magnitude was generally low during this outdoor period (Table 5.2). In all three time periods, there was a hot spot in the fixed equipment area, but this was often intermixed with cold spots in that same location. However, at the last outdoor period of the day, children had a prolonged hot spot, with no cold spots, and vector magnitude was generally high and increasing throughout the outdoor period (Table 5.2). This may be related to the fact that it had been four hours since the children's last outdoor break. This is in line with play deprivation theory, which posits that longer confinements result in a rebound effect, whereby children are more active when allowed outdoors (Pellegrini et al., 1995; Smith & Hagan, 1980). This relationship between the timing of different outdoor periods is also evident in the other class (class 2) in the same school. Class 2 did not have a morning recess period, and when they went outside pre-lunch, they had no large cold spots, while the class with the morning recess period had both hot and cold spots during this pre-lunch break. There was only a two-hour deprivation before class 2's last outdoor break of the day, where they demonstrated a more oscillating hot/cold spot pattern and vector magnitude levels (Table 5.2) compared to class 1. These incidences provide support for further investigation of the impact of prior deprivation on children's behavior during outdoor time.

In contrast to our supposition that longer periods of prior deprivation result in hot spots at the onset of outdoor time, class 3 had a three-hour break between outdoor periods, but still had large cold spots at the onset of their time on schoolyard 4 (Figure 5.3). This may be because they had to walk to that schoolyard (approximately 5 min), expending some of their 'pent up' energy before arriving at the schoolyard. As this could be related to other factors (e.g., teacher involvement, provided additional equipment, indoor physical activity levels, weather), future researchers should explore how the length of deprivation impacts activity levels on the schoolyard. Similarly, some research has suggested that differences in physical activity between outdoor periods (e.g., morning vs. afternoon) may be impacted by seasonal variation (Soini et al., 2014). We posit that the methodology described in this study could be used to explore how where children are active is impacted by the outdoor schedule or time of year.

Researchers have suggested that the length of outdoor time impacts children's activity level, with longer outdoor periods resulting in lower levels of physical activity (Cardon, Van Cauwenberghe, Labarque, Haerens, & De Bourdeauhuij, 2008). In the present study, outdoor time ranged from 18 to 91 minutes for an individual session, but we did not find that longer outdoor periods elicited lower vector magnitude levels. Similarly, McKenzie et al. (1997) and Holmes (2012) have demonstrated that children tended to be less physically active as the recess period elapsed. However, we found that this trend of declining physical activity throughout the outdoor period was not always present (Table 5.2), but rather, activity level sometimes increased or did not change. This likely depends on a number of factors, including the length of prior deprivation, provided equipment, or teacher involvement. Regardless of the physical activity trend, we extend this work by demonstrating that where children were being active also changes over the course of the outdoor period. One important example is fixed equipment, which has been reported to elicit physical activity. However, fixed equipment can also result in cold spots (e.g., Figure 5.2, 5.6) at certain times during the outdoor period. Future researchers may investigate the timing of these cold spots, identify what children are doing on the fixed equipment during these times, and if warranted, develop intervention strategies to mitigate unwanted behavior. In contrast, there was one schoolyard (Figure 5.3) in which the spatial relationships were fairly consistent over time. As can be seen in Figure 5.3, the sandbox had a temporally consistent cold sport, while the grass had a consistent hot spot throughout the outdoor period. Thus, in this schoolyard, the grassy area was able to consistently promote physical activity, a potentially promising point of intervention.

One concern when using hot spot analysis is whether this statistical test is capable of discerning 'high' activity counts from 'low' activity counts. When using spatiotemporal weight matrices in place of spatial only models, the difference in vector magnitude between hot and cold spots became more pronounced (Table 5.3). This may be beneficial because what constitutes 'hot' and 'cold' will depend on the distribution of the data and if all children are fairly active, then the cold spots may not be sedentary, but rather just less intensely active (i.e., light activity), or if overall activity levels are lower, hot spots may not correspond to moderate-to-vigorous intensity activity. While there is no universally accepted method to classify vector magnitude in 15-s epochs into physical activity levels in preschoolers, a few cut-points exist and can provide a point of reference for interpreting our findings. Butte et al. (2014) classifies sedentary behavior in 3- to 5-year-old children as less than 205 counts/15-s, while 977 and 1528 are cut-points for light-to-moderate activity and moderate-to-vigorous intensity activity, respectively. Additionally, Jimmy, Seiler, & Maeder (2013) and Costa, Barber, Cameron, & Clemes (2014) define the moderate intensity activity cut-point as 738 and 1086, respectively. Using these cut-point values as a reference point, it is clear that the spatiotemporal approach better separated hot and cold spots, making them better align with sedentary-to-light versus moderate-to-vigorous activity levels. Regardless, caution should be used when interpreting any hot spot analysis and hot and cold spots should be thought of as higher versus lower intensity areas, not necessarily moderate-to-vigorous versus sedentary areas.

The present study was not without limitations. Namely, we focused on two high-quality childcare centers located near a major university, so socioeconomic status and available resources may have been different from other childcare centers. Both programs that participated in this project provided above-average levels of outdoor time (Tandon et al., 2013; Vanderloo, Tucker, Johnson, & Holmes, 2013). Data collection occurred in the summer, which may have impacted where and how actively children played (e.g., when it is warm, children may have cold spots in the shade toward the end of recess). However, future research could use this GPS plus accelerometry approach to understand how weather impacts the timing of hot and cold spots on the schoolyard. This method may also be more appropriate for use in older children and/or adolescents, as the purpose of outdoor time in the preschool age group is not just intense physical activity, but also the development of fine and gross motor skills, social skills, and for cognitive restoration and development. Finally, there may be important group differences not revealed when analyzing data from all children at one time, so differences between individual and groups of children should be further studied. In particular, it is of interest to explore whether the same cluster patterns are found for children not meeting physical activity guidelines, girls, or overweight/obese children.

Numerous researchers, teachers, and policy makers are interested in utilizing outdoor time to promote the health and well-being of young children. Prior research has demonstrated that the childcare one attends accounts for up to half of the variability in children's daily physical activity (Gubbels et al., 2011; Pate, McIver, Dowda, Brown, & Addy, 2008; Tandon et al., 2013; Vanderloo et al., 2014), irrevocably demonstrating that there are some important contextual or environmental factors within the childcare that impacts children's behavior. Intervention strategies have been developed in an attempt to capitalize on these factors and have included schoolyard redesign (Nicaise et al., 2012), provision of additional outdoor time (Alhassan, Sirard, & Robinson, 2007) or equipment (Cardon, Labarque, Smits, & De Bourdeaudhuij, 2009), or providing structured, in place of unstructured, outdoor periods (Frank, Flynn, Farnell, & Barkley, 2018). These approaches have had mixed results, potentially due to our incomplete understanding of how the environment influences children's physical activity behaviors. Use of GPS plus accelerometry in future studies will allow researchers to identify not just where and how actively children play on schoolyards of varying design, or with different outdoor schedules or intervention strategies, but also when these behaviors are occurring (e.g., the start of outdoor time). In the present study, we identified interperiod and intraperiod changes in the location of hot and cold spots, supporting the importance of considering the impact of both spatial and temporal influences on children's schoolyard physical activity levels.

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CHAPTER 6: OVERALL DISCUSSION AND CONCLUSIONS

Promoting physical activity in youth, particularly young children, has the potential to reduce the burden of disease and disorders caused by inactivity over the course of the lifespan. As children and adolescents attend childcare or school from 3-5 years of age until 16-18 years of age (McFarland et al., 2017), this is a promising point of contact for those who wish to promote health behaviors (e.g., teachers, researchers) in this population. Outdoor time provided during the childcare or school day is of particular interest because it is the greatest contributor to school day physical activity (Guinhouya et al., 2009; Mota et al., 2005; Ridgers, Stratton, & Fairclough, 2006), and provides children with a unique opportunity for autonomous play. Therefore, understanding how the design of the school outdoor environment (i.e., schoolyard) impacts children's behavior during provided outdoor time is paramount to those who wish to promote physical activity (or other play behaviors).

The focus of this dissertation was the physical environment (i.e., schoolyard locations), which may promote specific activity types that drive children's physical activity participation. Thus, we posit that children's participation in physical activity varies by schoolyard location because locations afford specific types of activities. The first aim of this dissertation was to systematically review the literature on children and adolescents' physical activity by schoolyard location (Chapter 3) to ascertain if there was evidence that physical activity varies by schoolyard location and to identify future research directions. The reviewed studies (N=24) provided substantial evidence that schoolyard location impacts participation in sedentary behavior and moderate-to-vigorous physical activity, which is line with Gibson's theory of affordances (Gibson, 1977; Heft, 1988; Kyttä, 2002). Specifically, studies of both preschoolers and children supported that moderate-to-vigorous physical activity was often highest in grassy or open spaces (Cosco, Moore, & Islam, 2010; Nicaise, Kahan, Reuben, & Sallis, 2012; Nicaise, Kahan, & Sallis, 2011) and fields (Brink et al., 2010; Springer, Tanguturi, Ranjit, Skala, & Kelder, 2013), and this may be because open spaces afford running games. In adolescents, sport-specific areas promoted physical activity (Fjørtoft, Löfman, & Thorén, 2010; Sallis et al., 2001), which again, is likely because sports were afforded in these locations. Spaces that afforded sitting, such as sandboxes (Cosco et al., 2010; Nicaise et al., 2011), benches (Farley, Meriwether, Baker, Rice, & Webber, 2008), or gathering places (Cosco et al., 2010; Smith et al., 2014), tended to elicit more sedentary behavior. Despite providing support for the influence of schoolyard location, this review brought to light several gaps in research on this topic.

There are a number of influential factors (based on cross-sectional studies) that have not been studied or controlled for in prior research on physical activity by schoolyard location, like provided portable equipment (Berg, 2015; Dowda et al., 2009; Gunter, Rice, Ward, & Trost, 2012), teacher supervision (Brown et al., 2009; Cardon, Van Cauwenberghe, Labarque, Haerens, & De Bourdeauhuij, 2008), socioeconomic status (Harper & Huie, 1998), motor skills (Barbour, 1999), or weather-related variables (Soini et al., 2014), to name a few. Additionally, no two schoolyards or schoolyard locations are alike, so a number of types (sizes, compositions) of each location need to be compared (e.g., many fixed equipment layouts or designs). A major reason these variables have not been accounted for or studied directly is that previous studies have primarily included one (37.5% of studies) or two (29.2%) schools. There is substantial variability in the design of schoolyards, the type and quality of equipment, and the personal characteristics of the children, teachers, and school community that warrant similar research in a much larger sample of childcare and school programs.

One crucial finding of this systematic review was evidence for differences by age, sex, and potentially weight status in time and physical activity within schoolyard locations that could help explain deficits in physical activity participation in these girls, adolescents, or overweight youth. This information could be used to develop interventions that promote physical activity in these specific groups of youth. However, there are a number of individual characteristics and psychosocial variables we need to study further, such as motor skill development and perceived motor competence. Additionally, we have little information on the day-to-day, seasonal variability, or longitudinal changes in physical activity by schoolyard location in individual children (Harper & Huie, 1998; Soini et al., 2014). While we can conclude that physical location on the schoolyard clearly impacts children's participation in physical activity, there is a lot more research that needs to be done in this area. Understanding how schoolyard design impacts children's behavior is promising for the development of interventions that could promote sustained increases in physical activity with low burden on the teachers,

Methodological limitations have hindered progress in this area of research and prevented the development of activity-promoting interventions such as schoolyard redesign. Development of a low-burden method capable of capturing individual-level, continuous data on physical activity and its context would facilitate our understanding of methodological best practices (e.g., number of days of data collection) and the collection of data at a large number of schools that vary in schoolyard design and school-level attributes, while accounting for individual differences and exploring changes over time. One promising approach is the use of monitor-based methods, such as coupling accelerometry with a location-based measure, like Global Positioning Systems (GPS). This has been done successfully in samples of children and adolescents (Andersen, Klinker, Toftager, Pawlowski, & Schipperijn, 2015; Clevenger, Sinha, & Howe, 2018; Fjørtoft, Kristoffersen, & Sageie, 2009; Fjørtoft et al., 2010; Pawlowski, Andersen, Troelsen, & Schipperijn, 2016), but there is still much we do not know about how his method can and should be used in this research context.

One key issue of monitor-based approaches is that they, to date, have only been used to measure physical activity intensity and location. This is in contrast to some direct observation methods, like the Observational System for Recording Physical Activity in Children-Preschool Version (OSRAC-P), and may result in researchers missing key information, such as activity type. Thus, the second aim of this dissertation (Chapter 4) was to identify discordance between activity type and location in preschoolers, with the overarching purpose of understanding the limitations of approaches that focus on only location or conversely, only activity type. As expected, we found that children participated in several types of activities within each schoolyard location. However, some information gained from the two approaches was similar. For example, open space was the most common location and activity type and both approaches illustrate that fixed equipment elicited high levels of physical activity. In future studies, teacher report of additional equipment brought to the schoolyard on measurement days may help provide additional context when only location and physical activity intensity are measured. Additionally, GPS receiver units and accelerometers collect an abundance of information (e.g., signal variance, posture, speed) that can be used to better capture activity types within schoolyard locations. Through one or both of these methods, researchers may be able to use a monitor-based approach to understand physical activity by schoolyard location, minimizing the limitation that we would not know what children were actually doing within that location or while being physically active.

A second issue when using GPS plus accelerometry as a monitor-based approach for understanding physical activity by schoolyard location is that previously used methods for analyzing these data have used spatial-only models of the relationships between features. As prior work has illustrated that physical activity participation varies over the course of an outdoor period (intraperiod; Holmes, 2012; McKenzie et al., 1997) and between outdoor periods during different times of the day (interperiod; Soini et al., 2014), we hypothesized that the locations in which children were being more or less physically active may also change within or between outdoor periods. Thus, in aim 3 of this dissertation (Chapter 5), we explored a spatiotemporal approach for analyzing GPS and accelerometer data in preschoolers. We chose to use a variation of hot spot analysis because the hot spot method, in general, has been previously used by researchers in this field and is therefore likely available for use in future studies.

Comparing hot spot analysis using spatiotemporal weight matrices to spatial-only models of relationships between features, we identified that time is an important component to consider, in addition to location. Some locations, including fixed equipment, had corresponding hot and cold spots, depending on the time of day and/or the time within an outdoor period. In addition, our study, like studies identified in our systematic review, could explain many of our findings by understanding specific design features (e.g., nearby fences, type and number of fixed equipment, ground cover). This provides further support for research in this area that directly compares schools that have the same 'types' of schoolyard locations, but that vary in small, micro-spatial aspects (e.g., the connectedness of the fixed equipment). Further, there may be an influence of timing and duration of outdoor time that should be accounted for in future research, as suggested previously (Smith & Hagan, 1980).

This dissertation provides further evidence that location impacts schoolyard physical activity, and provides methodological insight that will inform future research in this area. However, there are some limitations of this dissertation, specifically, and of this line of research, broadly, that should be considered.

Limitations

Although future work should include other populations (e.g., children, adolescents), this dissertation focused on a small sample of preschool-aged children at three childcare programs. All of the included schools were licensed childcare centers that have been rated highly by the Great Start to Quality Initiative of the State of Michigan's Licensing and Regulatory Affairs (Great Start to Quality, 2019), with two of the programs being affiliated with Michigan State University. A clear and important next step is to expand this line of research into other types of childcare programs (e.g., home-based, religious, Montessori, Head Start) and lower quality programs. Similarly, studies should be conducted in elementary and middle schools, across different regions of the country and world.

Future work should also account for other potentially influential variables, like teacher supervision, the amount, type, and quality of provided equipment (Gubbels, Van Kann, & Jansen, 2012), child density (Cardon et al., 2008), or weather-related variables (Soini et al., 2014). Additionally, as suggested by our systematic review, child characteristics should be explored further, such as age, weight status, sex, or motor skill level. The monitor-based approaches that this dissertation aimed to inform could be used to collect individual-level data on a larger scale with less researcher burden, allowing us to better understand how these individual characteristics impact physical activity within schoolyard locations, but also how physical activity within schoolyard locations impacts outcomes, like motor skill development or competence.

The second and third aims of this dissertation illustrate that methods for analyzing GPS and accelerometer data should account for temporal variability, but also, that we may be missing key information about activity type when only measuring location. Therefore, these methods could be improved in future work. For example, our measure of activity intensity was activity counts vector magnitude, which was chosen because it combines data from all three accelerometer axes, thereby capturing more types of movement. ActiGraph activity counts are generated through a propriety algorithm (Brønd, Andersen, & Arvidsson, 2017), limiting comparability with other accelerometer brands, so future research may use raw acceleration metrics, such as Euclidean Norm Minus One or the horizontal vector. These metrics should also be used to better understand what children are doing, in addition to their activity intensity and location. For example, a combination of speed from the GPS and a sitting posture from the inclinometer inside an accelerometer may be used to indicate the use of wheeled toys, while the cyclical frequency pattern of running, in combination with being located on a paved track, would indicate running games or open space activities on the track. More work also needs to be done on the appropriate epoch, distance band, and time window for analyzing GPS and accelerometer data and how this impacts the number of neighbors per feature and the identification of spatiotemporal hot spots (i.e., the modifiable areal unit problem; Openshaw, 1981). Finally, the use of monitors will never be able to tell us why certain patterns exist, so this research may benefit from the incorporation of qualitative methods (Pawlowski, Andersen, Tjørnhøj-Thomsen, Troelsen, & Schipperijn, 2015; Pawlowski et al., 2016; Pawlowski, Tjørnhøj-Thomsen, Schipperijn, & Troelsen, 2014).

Conclusions

Many researchers, teachers, and community members are interested in promoting physical activity in children and adolescents, and while it is generally accepted that childcare or school is an ideal place for intervention, many previous intervention attempts require substantial teacher burden (e.g., to adhere to or implement a gross motor play intervention). Modification of the physical environment (e.g., addition of more open space or a looped path) may provide a solution capable of promoting physical activity long-term without undue burden to teachers or staff. However, we encourage future research in this area aimed at understanding the limitations (and strengths) of monitor-based approaches and the need to account for or better understand the limitless number of variables at play during outdoor time, with the overarching goal of developing and assessing environment-based interventions.

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