An Evaluation of a Playground Redesign on the Physical Activity and Behaviour of Children during Playtime

Nicola Diane Ridgers

A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Doctor of Philosophy

April 2007

ACKNOWLEDGEMENTS.

I would like to firstly thank my Director of Studies, Professor Gareth Stratton. I know it took you all quite a while to persuade me to start the PhD, and even longer to keep me motivated, on track and to guide me through it, but thank you for your support. Secondly, I would like to thank my supervisors Dr. Stuart Fairclough and Dr. David Richardson for their advice and support throughout the course of the research.

I would also like to thank Gary White, the Liverpool Sport Action Zone Manager who, along with Professor Gareth Stratton, was influential in securing the funding from Liverpool City Council Department for Life-Long Learning and Sport England for the research project.

I am also thankful to Professor Jos Twisk for his advice and insightful feedback concerning the statistical analyses conducted on the longitudinal data.

Thank you to all the schools who allowed me access to their schools, the teachers for their time and patience, and most importantly the children who participated in the project.

I would also like to acknowledge the assistance of numerous students and volunteers who assisted with the data collection over the past three years. Special thanks go to Adam Hale, Ruth McLoughlin, John Curley and Emily Clark for their assistance with recruitment and baseline data collection.

Lastly, I would like to thank my friends and family who have supported me over the course of my studies across the years. Mum, Dad and brother Paul - where would I be without your encouragement, advice, support, patience and love? Thank you.

ABSTRACT.

The promotion of physical activity to school age children is a public health priority. Playtime represents a school-based daily physical activity opportunity for children to be physically active. The aims of this thesis were to a) determine the day-to-day and seasonal effects on children's physical activity levels during playtime; b) quantify the physical activity levels of children during playtime and examine the contribution of playtime to current daily physical activity guidelines; and to c) evaluate the short-term (6-weeks) and longitudinal effects (6-months) of a playground markings and physical structures intervention on children's physical activity levels during playtime.

This research found that children's moderate-to-vigorous physical activity (MVPA) and vigorous physical activity (VPA) during playtime was not significantly different across consecutive days or seasons, though greater variability was observed for VPA. The results suggested that studies may not need to correct for day-to-day and seasonal effects on children's MVPA during school playtime. Boys engaged in significantly more MVPA and VPA during playtime than girls when physical activity was quantified using both heart rate telemetry and accelerometry, though no significant differences were observed between infant and junior children. This indicated that interventions are needed to promote physical activity to girls in this context. The intervention studies revealed that at 6-weeks, MVPA and VPA had increased by 4-4.5% and 1.3-2.5% respectively compared to the control group, though these increases were not significant. At 6-months, a statistically positive intervention effect was found across time for both MVPA and VPA ($p < 0.05$). Children in the intervention schools engaged in 4-4.5% and ~2.5% more MVPA and VPA than children in the control schools respectively.

The results indicate that developing school playgrounds is a suitable school-based intervention for increasing children's MVPA and VPA during playtime. Increases in playtime MVPA and VPA were sustained over time, indicating that playground markings and physical structures are an effective method for significantly increasing children's playtime physical activity levels in the longer-term.

CONTENTS

		PAGE
Abstract		iii
Chapter 1	**Introduction**	
	1.1 *The research problem*	2
	1.2 *Introduction to the national Sporting Playgrounds initiative*	3
	1.3 *Background*	6
	1.4 *Conceptual model for physical activity*	7
	1.5 *Organisation of the thesis*	9
Chapter 2	**Literature Review**	
	2.1 *Physical activity and health*	11
	2.2 *School as a health promotion context*	19
	2.3 *Physical activity levels during school playtime*	22
	2.4 *School playtime interventions*	35
	2.5 *Summary*	44
	2.6 *Aims of thesis*	44
Chapter 3	**Methodology**	
	3.1 *Recruitment of schools and participants*	48
	3.2 *Research design and settings*	50
	3.3 *Instruments*	51
	3.4 *Procedures*	56
	3.5 *Data analysis*	58
Chapter 4	**Day-to-Day and Seasonal Effects on Physical Activity Levels during Playtime**	
	4.1 *Introduction*	65
	4.2 *Method*	68
	4.3 *Results*	70
	4.5 *Discussion*	70
	4.6 *Conclusion and summary*	76
Chapter 5	**Physical Activity Levels of Primary School Children during Playtime**	
	5.1 *Introduction*	79
	5.2 *Method*	81
	5.3 *Results*	83
	5.4 *Discussion*	86
	5.5 *Conclusions*	91
Chapter 6	**Short-Term Effects (6-weeks) of a Playground Markings and Physical Structures Intervention on Physical Activity Levels during Playtime**	
	6.1 *Introduction*	94
	6.2 *Method*	96
	6.3 *Results*	99
	6.4 *Discussion*	103
	6.5 *Conclusions*	109

Chapter 7 **Evaluating the Long-Term Effects of a Playground Markings and Physical Structures Intervention on Children's Playtime Physical Activity Levels**

7.1 *Introduction* 113
7.2 *Method* 115
7.3 *Results* 117
7.4 *Discussion* 122
7.5 *Conclusions* 127

Chapter 8 **Critical Appraisal and Future Directions for Research into Children's Physical Activity Levels during Playtime**

8.1 *The research context and synthesis* 129
8.2 *Conceptual model* 135
8.3 *Summary* 138
8.4 *Conclusions* 138
8.5 *Précis* 140

References 142

Appendices Appendix 1 *Ethical approval* 168
Appendix 2 *Associated publications* 172

LIST OF TABLES

		PAGE
Table 2.1	*Summary of cross-sectional studies investigating physical activity levels during playtime*	24
Table 2.2	*Contribution of playtime to boys and girls' daily activity recommendations*	33
Table 2.3	*Contribution of playtime to children's daily activity recommendations*	34
Table 2.4	*Summary of playtime-based intervention studies*	36
Table 2.5	*Effects of playtime interventions on physical activity levels*	38
Table 3.1	*Summary of school indicators*	49
Table 4.1	*Descriptive data for participants with complete and incomplete data*	71
Table 4.2	*Physical activity levels during playtime by day and season*	72
Table 5.1	*Anthropometric characteristics of whole sample*	84
Table 6.1	*Anthropometric characteristics of whole sample at baseline and 6-weeks post-intervention*	99
Table 6.2	*Descriptive baseline physical activity data for complete and incomplete data sets*	100
Table 6.3	*Multilevel model analysis of playtime intervention effect*	101
Table 6.4	*Effect of playtime intervention on boys and girls' VPA assessed using heart rate*	102
Table 6.5	*Effect of playtime intervention on boys and girls' VPA assessed using accelerometry*	103

Table 7.1	*Anthropometric characteristics of whole sample at baseline, 6-weeks and 6-months post-intervention*	119
Table 7.2	*Raw physical activity data at each phase of the intervention*	120
Table 7.3	*Multilevel model analysis of playtime intervention effect*	121

LIST OF FIGURES

		PAGE
Figure 1.1	*Illustration of the Zoneparc playground*	5
Figure 1.2	*Conceptual model for the promotion of physical activity to youth*	8
Figure 3.1	*Overview of the research design*	52
Figure 3.2	*Positioning of heart rate monitor on participant*	58
Figure 3.3	*Positioning of accelerometer on participant*	58
Figure 4.1	*Stage of research design*	64
Figure 5.1	*Stage of research design*	78
Figure 5.2	*Boy's and girls' MVPA during playtime at baseline assessed using heart rate*	85
Figure 5.3	*Boy's and girls' MVPA during playtime at baseline assessed using accelerometry*	85
Figure 5.4	*Boy's and girls' VPA during playtime at baseline assessed using heart rate*	86
Figure 5.5	*Boy's and girls' VPA during playtime at baseline assessed using accelerometry*	86
Figure 6.1	*Stage of research design*	93
Figure 7.1	*Stage of research design*	112
Figure 7.2	*Boys and girls' MVPA assessed using heart rate across the study*	121

Figure 7.3 *Boys and girls' VPA assessed using heart rate across the study* 121

Figure 7.4 *Boys and girls' MVPA assessed using accelerometry across the study* 122

Figure 7.5 *Boys and girls' MVPA assessed using accelerometry across the study* 122

Figure 8.1 *Research directions using the conceptual model for the promotion of physical activity to youth* 137

GLOSSARY OF TERMS.

Children	This term covers the chronological age range 4-12 years.
Physical activity	Physical activity is defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen et al., 1985, p. 126).
Moderate physical activity (MPA)	MPA is defined as "[*an*] activity usually equivalent to brisk walking, which might be expected to leave the participant feeling warm and slightly out of breath" (Biddle et al., 1998, p.2).
Moderate-to-vigorous physical activity (MVPA)	MVPA is physical activity of at least moderate intensity that encompasses bouts of vigorous physical activity (VPA)
Vigorous physical activity (VPA)	VPA is defined as "[an] activity usually equivalent to at least slow jogging, which might be expected to leave the participant out of breath and sweaty" (Biddle et al., 1998, p. 2).
Physical Structures	This refers to permanent equipment introduced to the playgrounds through the redesigns. This includes fencing, goal posts for football and netball, cricket stumps and basketball hoops.
Playtime	The non-curriculum time allocated by primary schools between lessons for children to engage in leisure activities. This is a mandatory part of the school day in the United Kingdom where children spend the majority of their time outside on the playground (Blatchford, 1989). Playtime scheduling and duration typically varies across schools (Pellegrini, 1995).
Playground	School playgrounds are regarded as the outdoor area of the school available for children to use during their playtimes. They can encompass both grass and tarmac areas, and may contain playground markings and equipment for children to use. They form part of the school grounds.
Portable equipment	This refers to equipment that is brought on to the playground during playtime which children are free to use in different games. It includes equipment such as hula-hoops, football's, skipping ropes, and beanbags for example.

Recess	The international term used for playtime.
School:	
Infant school	Attended by children 4 to 7 years of age in the United Kingdom. The stage of schooling is termed Key Stage 1, and encompasses the school years 1-2.
Junior school	Attended by children 7 to 11 years of age in the United Kingdom. The stage of schooling is termed Key Stage 2, and encompasses the school years 3-6.
Primary school	Attended by children 4 to 11 years of age in the United Kingdom. Comprised of infant and junior school children (Years 1-6).
School grounds	The outdoor environment of schools, which supports both the formal and informal curriculum. They have both educational and recreational uses.
Unstructured physical activity	Opportunities for children to be freely physically active without the constraints of organised settings.

CHAPTER 1
Introduction

Introduction.

1.1 Research Problem.

The activities and behaviours that children engage in during childhood are broadly defined as play (Lindon, 2002). Despite the distinctiveness of play, there is no consensus for a definition of play within the empirical literature (Jenvey & Jenvey, 2002; Pellegrini & Smith, 1998; Rippe et al., 1993; Smith & Vollstedt, 1985). This is largely attributable to the multidimensional nature of play, which consists of behavioural, motivational and contextual components (Jenvey & Jenvey, 2002; Rippe et al., 1993; Rubin et al., 1983; Smith & Vollstedt, 1985). There is general agreement however that play is enjoyable (Lindon, 2002; Pellegrini & Smith, 1998), it includes a wide range of self-chosen activities undertaken for interest and satisfaction (Lindon, 2002), is flexible and spontaneous (Armitage, 2001; Smith & Vollstedt, 1985), minimally constrained by adult demands (Pellegrini & Smith, 1998), there is no end product, no time pressures, no fear of failure, and the activity appears to occur for its own sake (Macintyre, 2001; Pellegrini & Smith, 1998; Smith & Vollstedt, 1985; Titman, 1992).

A recent review found that parents were concerned that children today have fewer opportunities for play compared to previous generations (DCMS, 2004). The restriction of play opportunities can impact on the acquisition of life long skills developed when children are free to explore and manipulate the physical and social world in which they live (Bateson & Martin, 1999). Furthermore, since children's play often has a vigorous physical activity component (Casey, 2003; Pellegrini & Smith, 1998), the restriction of play opportunities could impact on the health and fitness of preschool and primary school children.

The promotion of physical activity to children has become a national public health priority (Biddle et al., 1998). Research indicates that levels of obesity are increasing in children (Chinn & Rona, 2001). In addition, concern has been expressed that considerable numbers of children do not participate in enough sustained physical activity to benefit cardiorespiratory fitness and health (Andersen et al., 2006; Armstrong & Welsman, 1997; Biddle et al., 2004; Sleap & Tolfrey, 2001), though the interpretation of physical activity levels has been found to depend on the thresholds used (Sleap & Tolfrey, 2001). Motorised transport, safety concerns, the restriction of play opportunities and sedentary leisure activities including television viewing and computer games have been espoused as contributing factors (Biddle et al., 1998; Strong et al., 2005). Sedentary behaviour has been described as a modifiable risk factor for life-style related diseases, and that reducing sedentary behaviour to less than two hours a day can benefit physical activity and health (Blair & Connelly, 1996; Riddoch & Boreham, 2000; Strong et al., 2005). While Riddoch and Boreham (2000) note that there is little evidence that clearly relates childhood physical activity to adult health, research has suggested that daily activity in adolescence can benefit adult aerobic fitness (Kemper et al., 2001), a decrease in activity between early adolescence and adulthood is related to unhealthy cholesterol levels (Twisk et al., 2002), and recently a negative relationship has been reported between clustering of cardiovascular risk factors and physical activity (Andersen et al., 2006). Since cardiovascular disease has its origins in childhood, it seems logical that the promotion of physical activity may induce a more favourable risk profile and benefit health in later life. Taken together, there is a need to identify contexts that can promote both play and physically active behaviours to children that may benefit child health (Blair & Connelly, 1996) and potentially reduce the clustering of cardiovascular risk factors (Andersen et al., 2006).

The school has been identified as a key setting for the promotion of health enhancing physical activity (Kohl & Hobbs, 1998). The traditional setting for this is physical education (PE; Wechsler et al., 2000), yet concern has been expressed that PE alone is unlikely to provide sufficient activity to significantly benefit health (Biddle et al., 2004). An alternative but complementary school setting to PE for children to engage in daily physical activity is playtime. Indeed, playtime presents one of the few opportunities that children can engage in unstructured play and physical activity outside with their peers (Pellegrini & Bohn, 2005). Playtime interventions may enable large numbers of children to be physically active during the school day (Stratton & Leonard, 2002). Such interventions have included playground markings (Stratton, 2000; Stratton & Mullan, 2005), fitness breaks (Scruggs et al., 2003), playtime games (Connolly & McKenzie, 1995), and providing games equipment (Verstraete et al., 2006). However, the effects of playtime interventions on boys and girls physical activity levels during playtime and the sustainability of the interventions have not been widely reported.

1.2 Introduction to the National Sporting Playgrounds Initiative.

In May 2002, the Department for Education and Skills (DfES) in partnership with Nike invested £10 million into the development of Sporting Playgrounds in 600 primary schools across England. The primary schools are situated within 27 Local Authorities (LA). Each LA's received funding to redesign school playgrounds based around the Zoneparc model designed by the Youth Sport Trust (YST) and Nike. Funding was allocated to the LA's based on indices of social and economic deprivation. This is a key aspect to the Sporting Playgrounds Initiative, for children who are of low socioeconomic status are likely to be at a disadvantage in the avaibility of activity programmes, and they have less access to facilities for physical activity engagement (Sallis et al., 1992; Sallis et al., 2000). Consequently, promoting physical activity to children of low socioeconomic status is public health priority target group (Cavill et al., 2001). More recent data has again shown that Liverpool is one of the most deprived districts in England based on the Index of Multiple Deprivation 2004 (Noble et al., 2004).

Initially in Liverpool, 20 schools each secured £20,000 funding from the national Sporting Playgrounds Initiative in order to redesign their playground environment based on the Zoneparc model. In addition, schools also receive portable equipment and resource cards, and training is provided to school staff in the promotion of playtime activities to children. The playground developments occurred between July 2003 and November 2004. This thesis will examine the longitudinal effects and sustainability of the playground redesign in 15 schools, as five schools did not receive the completed playgrounds within the timeframe of the project. The Zoneparc playground has two main aims:

1. Increase the physical activity levels of young people
2. Tackle social exclusion and playground issues in schools.

The Zoneparc model involves the division of the playground into three specific colour coded areas, these being the Red (Sports) Zone, Blue (Action) Zone and Yellow (Chill out) Zone. The zones were designed to contain dominant activities, provide a safe space for other activities to take place, and encourage children to participate in a number of activities, especially children who are intimidated by the playground context or excluded from games (DfES, 2005). The markings positioned in each zone are appropriate to the zones' overall objectives. An example of a Zoneparc playground is shown in Figure 1.1.

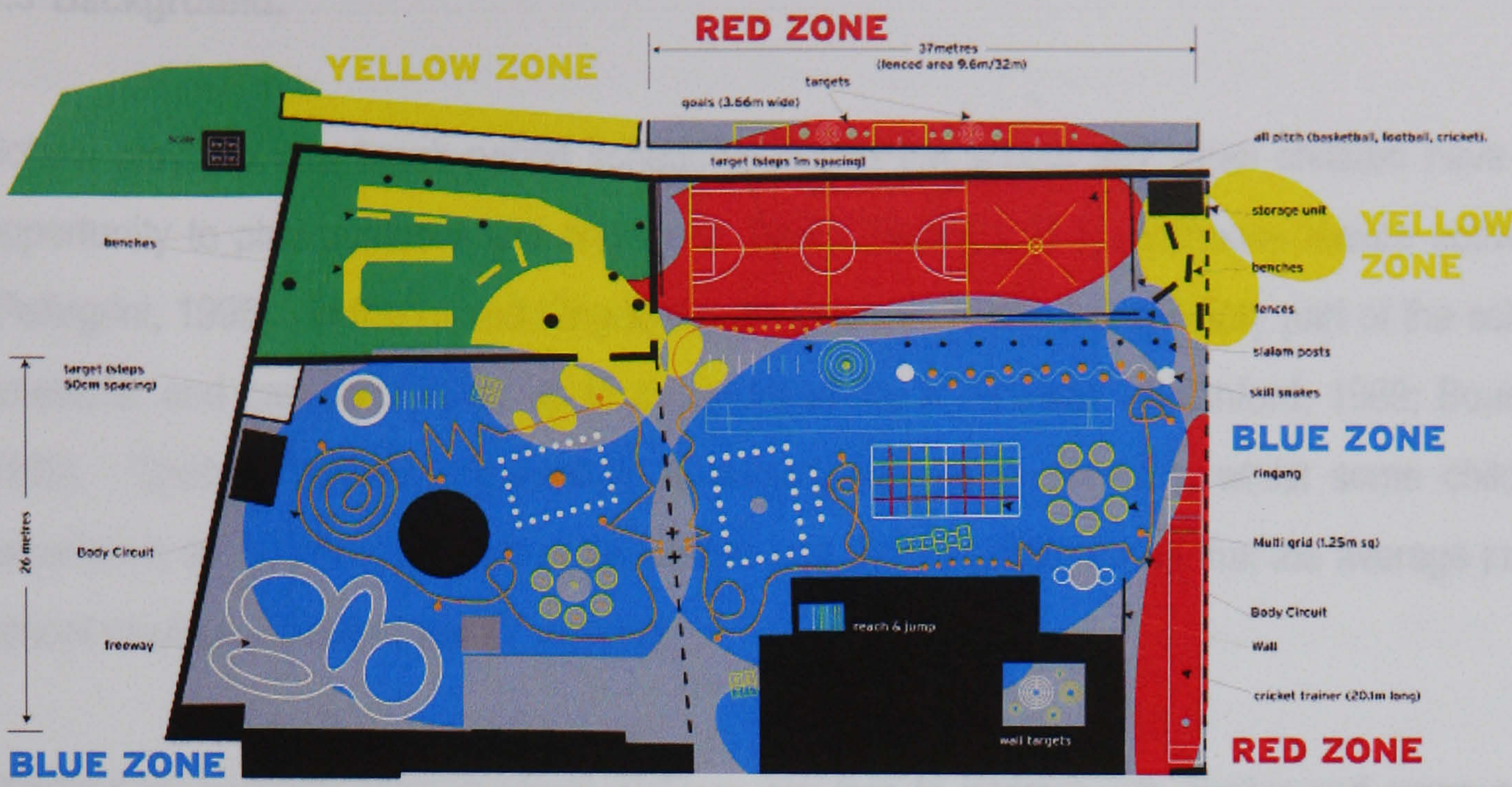


Figure 1.1: *Diagram of the organisation of a Zoneparc Playground (Source: www.dfes.gov.uk/pess/content (accessed 15/09/2003).*

The Red Zone is the sports zone, where children can engage in activities such as football, basketball, cricket and tennis. This area is often enclosed using fencing so that the domination of ball games such as football on the playground are restricted and children can engage in other activities in the available space (DfES, 2005). The Blue Zone is the action zone, where children can engage in games and activities such as target work, fitness and skills. Typical markings in this area of the playground include clocks, compasses, hopscotch, targets, jump lines and number snakes (Youth Sport Trust, 2002). Such markings can be used for playground games, which develop children's fundamental movement skills during playtime. The Yellow Zone is classed as the chill out zone, where children can engage in non-active games such as word games, clapping games, and board games such as chess and draughts (DfES, 2005).

The design of the Zoneparc playground meet a number of criteria that were suggested to enrich a child's play environment (National Playing Fields Association, 2000). These criteria include a varied physical environment, represented by the three distinctive zones; challenge, indicated by the various activities offered by playground markings and structures; movement, which is a central aim to the design; and opportunities for social interaction, which are catered for by the inclusion of the Yellow Zone.

1.3 Background.

School playtime is a break period scheduled during the school day when children have the opportunity to play outdoors and engage in freely chosen and spontaneous leisure activities (Pellegrini, 1995). In the United Kingdom (UK), playtime forms a mandatory part of the school timetable, and can account for up to a quarter of the school day (Blatchford, 1989; Boulton, 1992). Children typically experience a morning and lunch playtime, whilst some children experience an afternoon playtime. Blatchford and Baines (2006) found that the average junior school playtime duration was 77 minutes.

Playtime is a unique context where children are free to interact with similar and same-aged peers in a variety of activities, which are relatively free from adult control (Blatchford, 1999a, 1999b; Pellegrini & Blatchford, 2002). Furthermore, playtime has an important role in children's physical, social, emotional and cognitive development (Pellegrini & Bohn, 2005; NAECS/SDE, 2002), affording children the opportunity to develop physical skills and confidence in their movement, and build positive peer relationships (Evans, 1996). Children can also learn social skills such as sharing, cooperating, turn taking and respect for rules (NAECS/SDE, 2002).

Despite this, concern has been expressed that playtime detracts from curriculum time, and encourages antisocial behaviour and aggression on the playground (Pellegrini & Smith, 1993). Research has suggested that 75% of reported incidents of bullying at school occur on the playground (Whitney & Smith, 1993), and aggressive behaviour during playtime is the most pressing problem outside the classroom (DES, 1989). Furthermore, the Elton Committee described lunchtime as the single biggest behavioural problem school staff face during the school day in the UK (DES, 1989). These combined issues have lead to playtime durations being reduced in schools (Pellegrini & Bohn, 2005; Blatchford & Sumpner, 1998), and in some states and larger school districts in the United States of America, playtime has been abolished (Chmelynski, 1998). This is of concern, as from an educational perspective, no scientific data exists to show that reducing playtime whilst increasing tuition increases learning (Pellegrini & Blatchford, 2002). Playtime is thought to facilitate school learning by providing breaks in instruction, where children are more attentive after playtime than before, and promoting social and emotional development, which is an important for successful cognitive performance and school adjustment (Pellegrini & Bohn, 2005). In addition, playtime may benefit children's health, as it is a suitable context to encourage physically active play behaviours (Pellegrini & Smith, 1998), which could contribute towards daily physical activity guidelines.

The conflicting views concerning the nature and importance of playtime has added to the ongoing debate as to the role of playtime in schools (Blatchford, 1989). However, relatively little empirical research has investigated children's behaviour, physical activity levels and experiences of playtime (Blatchford, 1998), and with most studies employing cross-sectional designs, how these variables change across time are not widely known. Moreover, research has generally focused on social factors or physical activity levels during playtime. There is a need for research to examine these aspects in combination, using longitudinal designs to establish the effects of playtime, and playtime interventions on children's physical and social experiences within the primary school playtime context.

1.4 Conceptual Model for Physical Activity.

Physical activity is a complex set of behaviours, influenced by a number of determinants, which affect the frequency, intensity, duration and type of children's activity (Sallis & Patrick, 1994). These determinants can be placed into five main categories: physiological and developmental, psychological, behavioural, social and physical environment (Biddle et al., 2004; Kohl & Hobbs, 1998; Sallis et al., 2003). Of these five categories, environmental effects are the least researched component of health promotion in schools (Sallis et al., 2003; Wechsler et al., 2000), yet since pupils are reported to accumulate up to 30% of their daily physical activity at school (Myers et al., 1996), environmental interventions such as playground markings and the introduction of portable and fixed equipment may have large cumulative and sustained effects in children (Sallis et al., 2003). Moreover, it has been stated that an individual's environment is critical in determining their behaviour, for it provides messages as to what are acceptable and unacceptable behaviours (Cohen et al., 2000). Children's subsequent physical activity behaviour during playtime is an interaction between themselves and their environment (Cohen et al., 2000). Environmental effects therefore are an important consideration within this thesis.

The promotion of physical activity to youth was conceptualised by Welk (1999), who examined the effects of determinants and their interactions with other factors on children's physical activity. The determinants were classified into four main factors:- demographic, predisposing, enabling, and reinforcing (Welk, 1999). While playtime can influence both enabling factors, which allow children to be physically active, and reinforcing factors, which reinforce children's activity behaviours (Welk, 1999), the current thesis will focus on enabling factors. Within a playtime context, enabling factors include environmental determinants such as equipment and space, whilst reinforcing factors include social determinants such as peer and school staff influences [Figure 1.2]. It is suggested that the identification of modifiable determinants are important in the development of successful interventions that may benefit childhood physical activity levels and health (Kohl & Hobbs, 1998). Wechsler et al. (2000) recommended that in order to promote physically active behaviours to children during playtime, schools should provide equipment, space and suitable facilities, all of which can be classified as enabling factors. In addition, enhancing access to suitable facilities should increase opportunities for physical activity and physical activity play (Kahn et al., 2002). Reinforcing factors such as support and activity prompts from school staff may also be key to health promotion in a playtime context (McKenzie et al., 1997a). However, the extent to which these factors combine to influence children's physical activity behaviours during playtime has not been reported and warrants further empirical attention.

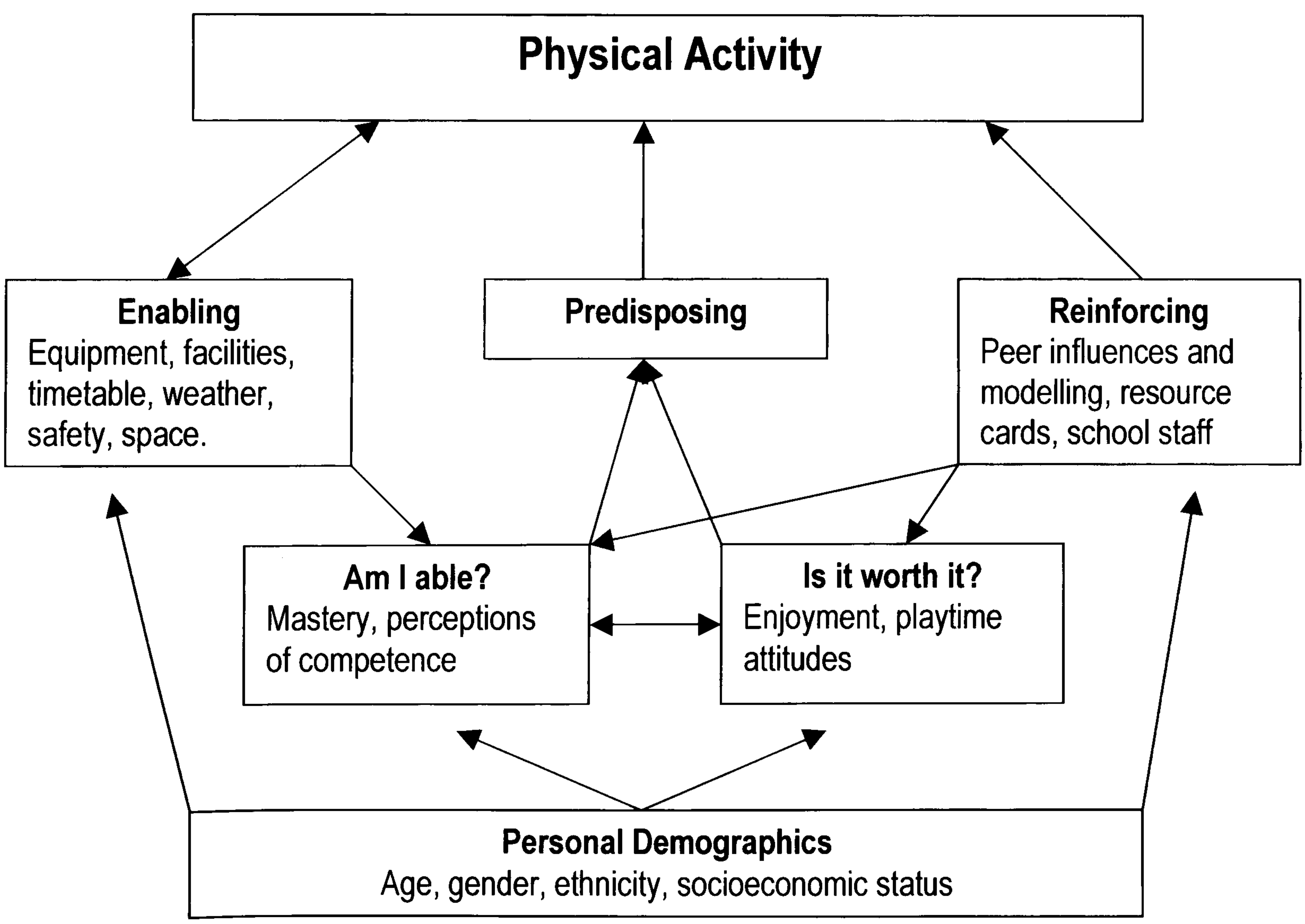


Figure 1.2. *Conceptual diagram of Welk's (1999) Youth Physical Activity Promotion Model applied to primary school playtime.*

1.5 Organisation of the Thesis.

The central theme of the thesis is on physical activity levels of primary school aged children during school playtime. A review of the literature is provided in **Chapter 2**. The key topics addressed are children's physical activity levels during playtime, the relative contribution towards daily physical activity guidelines, and the effects of playtime interventions on children's physical activity levels. The review attempts to critique the current literature, and provide directions for further research. The general method used throughout the research is detailed in **Chapter 3.** In addition, a review of the two methods of physical activity measurement used in the thesis to enable comparisons to previous research is provided. No empirical studies to date have examined the effects of day-to-day and season variability on children's physical activity and behaviour during playtime. **Chapter 4** critically examines this issue in detail. A descriptive cross-sectional study of children's physical activity levels during school playtime is reported in **Chapter 5**. This study details the physical activity levels of Liverpool school children during playtime, and analyses the contribution of playtime towards daily physical activity recommendations. The thesis then evaluates the short- and medium term effects of the playground markings and redesign intervention on the physical activity levels during school playtime using a longitudinal research design. These data are reported in **Chapters 6 and 7** respectively. The thesis concludes with a critical review of the research and presents future research suggestions in **Chapter 8.**

CHAPTER 2
Literature Review

2.0 Literature Review

2.1 Physical Activity and Health

Physical activity is an integral component of a healthy lifestyle. Whilst strong relationships have been established between physical activity and health in adults (Boreham & Riddoch, 2001), with higher levels of activity leading to reduced risks of hypertension, diabetes, obesity and osteoporosis for example (Blair & Connelly, 1996; Blair et al., 1989a; Blair et al., 1989b; Riddoch & Boreham, 1995) the relationship between physical activity and health in children is not so well established (Boreham & Riddoch, 2001). One of the underlying reasons with this can be attributed to measurement issues (Biddle et al., 2004). The onset of diseases such as coronary heart disease, stroke and osteoporosis is more likely to occur in adulthood, therefore the frequency of incidents cannot be easily related to physical activity levels in childhood in comparison to adulthood (Riddoch & Boreham, 1995; Boreham & Riddoch, 2001). Instead, research in paediatric populations focuses on disease risk factors such as bone mineral density, blood pressure, fatness and blood lipids as indicators of future health problems (Andersen et al., 2006; Brage et al., 2004; Klasson-Heggebø et al., 2006), though it should be noted however that the measurement of risk factors is complicated by the stage of the child's development (Raitakari et al., 1994). Despite this, recent cross-sectional research has reported that children's habitual physical activity is inversely related to metabolic syndrome (Brage et al., 2004), clustering of cardiovascular disease risk factors (Andersen et al., 2006), waist circumference, diastolic blood pressure (Andersen et al., 2006), insulin resistance (Brage et al., 2004), and triglycerides (Andersen et al., 2006; Brage et al., 2004). Curvilinear relationships have been reported between fitness and sum of skinfolds and systolic blood pressure in 9 year-old children (Klasson-Heggebø et al., 2006). In addition, positive relationships have been documented in primary school age children between physical activity and fitness (Brage et al., 2004), and physical activity and bone mineral density (Tobias et al., in press).

A second reason for the relationship between physical activity and health not being well-established in children can be attributed to a lack of longitudinal studies that have tracked children from childhood through into adulthood (Boreham & Riddoch, 2001), though large-scale studies such as the Amsterdam Growth and Health Longitudinal Study and the Northern Ireland Young Hearts Study have tracked physical activity, body composition, and fitness from childhood to adulthood (Boreham et al., 2004; van Mechelen and Kemper; 1995). These studies have demonstrated poor to fair tracking of anthropometric variables such as weight, body mass index and sum of skinfolds (Boreham et al., 2004), and physical fitness is related to a healthy cardiovascular disease risk profile (Twisk et al., 2002), though fitness demonstrated poor tracking in both males and females (Boreham et al., 2004). The results provide some indication as to the benefit of a physically active childhood on both child and adolescence health, though as the measurement of physical activity and health advances, these relationships may become clearer in future empirical studies.

In recent years considerable interest has been directed towards determining physical activity levels amongst paediatric populations. Blair and colleagues (1989a) hypothesised a number of relationships that linked childhood activity to childhood and adult health, and adult activity. Specifically, it is hypothesised that an active lifestyle in childhood will reduce the health risks associated with inactivity and benefit health in adult life (Blair & Connelly, 1996; Kohl & Hobbs, 1998), and levels of physical activity in childhood will track into adulthood (Malina, 1996). However, there is limited research evidence to support this notion. Malina (1996) reported that activity appeared to track weakly to moderately between childhood and adolescence, and weakly to moderately from adolescence into adulthood, whilst inactivity also appears to track across time (Malina, 1996; Kohl & Hobbs, 1998; Pate et al., 1996). van Mechelen and Kemper (1995) found low non-significant correlations for males and females when habitual physical activity was tracked from adolescence to adulthood, while Boreham et al (2004) reported that physical activity tracked better in males than females, though the tracking of activity from adolescence to adulthood was poor. In comparison, a 21-year tracking study recently found that high levels of physical activity in childhood significantly predicted high levels of physical activity in adulthood, despite low to moderate correlations being found (Telama et al., 2005). Whilst there is some concern that the low to moderate correlations indicate that activity may not track across time, this may be linked to the method of physical activity assessment, for studies using self-report have reported lower correlations than studies using objective methods (Kohl & Hobbs, 1998; Pate et al., 1996; Riddoch, 1998). One of the reasons underlying the low to moderate correlations reported in tracking can be attributed to the fact that physical activity is a complex set of multidimensional behaviours, which can be difficult to recall and self-report (Boreham & Riddoch, 2001; Sallis, 1994). Despite the seeming lack of tracking evidence, it appears logical that providing opportunities for physical activity in childhood could increase the likelihood of being physically active in both adolescence and adulthood, benefiting current and future health (Blair & Connelly, 1996; Strong et al., 2005).

2.1.1 Physical Activity Guidelines

There is a general consensus that the promotion of physical activity is a public health priority. In light of this, physical activity recommendations have been developed for young people, for they establish thresholds that enable researchers to determine whether children are sufficiently active to benefit health (Biddle et al., 1998; Sallis & Owen, 1999). Furthermore, they can establish priority target groups for health promotion measures (Cavill et al., 2001).

The recommendations that were proposed in a consensus statement in 1998 and further endorsed by the Chief Medical Officers Report (DH; 2004a) state that "all young people should participate in physical activity of at least moderate intensity for one hour per day" (Biddle et al., 1998, p. 3). In addition, a minimum recommendation of 30 minutes of at least moderate intensity was advised for young people who currently engage in little physical activity (Biddle et al., 1998). These recommendations focus on the accumulation of appropriate levels of physical activity each day, moving away from previous activity guidelines that focused on sustained bouts of moderate-to-vigorous physical activity (MVPA) with the objective of improving health and cardiovascular fitness (Riddoch & Boreham, 1995; Sallis & Owen, 1999; Sleap & Tolfrey, 2001; Welk et al., 2000). The previous recommendation stated that children should engage in sustained bouts of MVPA for 20 minutes or more, which was similar to adult recommendations (Welk et al, 2000). Research indicates that whilst sustained bouts of activity are important for cardiorespiratory fitness (Payne & Morrow, 1993), health benefits can be gained through the accumulation of at least moderate intensity physical activity across the day (Boreham & Riddoch, 2001).

However, concern has been expressed that the current recommendations have only a limited scientific basis, and the level of physical activity may not be enough to prevent weight gain in children (Andersen et al., 2006; Boreham & Riddoch, 2001). In a recent study, Andersen et al (2006) investigated the association between physical activity and the clustering of cardiovascular risk factors in children. It was found that there was a graded negative association between physical activity and the clustering of risk factors, with risk being raised in the first to third quintile of physical activity (Andersen et al., 2006). In the sample of 9 year old children, the it was reported that the time spent engaged in MVPA was 116 minutes in the fourth quintile, raising concerns that the recommendation on one hour of physical activity per day in at least moderate activity intensity (Biddle et al., 1998) may underestimate the daily activity required to prevent clustering risk factors in children (Andersen et al., 2006). Despite the study being cross-sectional in design, and monitoring children's physical activity levels using a one-minute epoch, which could arguably underestimate physical activity levels (Nilsson et al., 2002), this study highlights that primary school children may need to engage in double the current recommended activity guideline to benefit health.

One priority target group, which was identified in terms of needing interventions to encourage physical activity, were young people of low socioeconomic status (Biddle et al., 1998; Cavill et al., 2001). Children of high socioeconomic status have been found to be more physically active than their lower socioeconomic peers, as socioeconomic status is a key factor in the types of social and physical environments children are exposed to (Sallis et al., 1992; Wold & Hendry, 1998). Children of low socioeconomic status are thought to be at a disadvantage in access to programs and adequate facilities (Sallis et al., 1997; Sallis et al., 2000; Wold & Hendry, 1998). Access to appropriate physical activity environments can promote and encourage physically active behaviours (Cavill et al., 2001; Sallis et al., 1990). Whilst indicators of socioeconomic status have not been related consistently to children's physical activity levels (Sallis et al., 2000), there is concern that low socioeconomic status children are less likely to participate in lifetime physical activity (Wold & Hendry, 1998). The 2002 Health Survey for England (DH, 2003) reported higher participation in sports and exercise by younger people in the highest socioeconomic group compared to those in the lowest group. Therefore, there is a need for interventions to promote physical activity to children in these circumstances.

2.1.2 Children's Physical Activity Patterns

Children's physical activity patterns are distinctive. A study conducted by Bailey and co-workers (1995), which employed direct observation to analyse physical activity patterns, found that children's activity is sporadic, intermittent and highly transient. The results showed that the tempo of children's activity changes rapidly, where bursts of high intensity activity are interspersed with varying periods of low or moderate intensity activity (Bailey et al., 1995). The mean duration of high intensity activity was 3 seconds, whilst for low and moderate intensity activities it was 6 seconds. In addition, Bailey et al (1995) reported that no high intensity bouts lasted over 10 consecutive minutes. More recently, Baquet et al (in press) noted that over 75% of physical activity bouts lasted 4 seconds or less. These study support previous commentaries concerning children's activity patterns, which highlighted that children are unlikely to engage in sustained bouts of physical activity, though they may engage in a relatively large volume of intermittent activity (Corbin et al., 1994). Since children's activity is intermittent in nature, the results suggest that the accumulation of physical activity is important when determining whether children are physically active (Corbin et al., 1994; Welk et al., 2000).

2.1.3 Children's Physical Activity Levels

There is some debate as to whether children are sufficiently active in order to benefit current and future health. Concern has been expressed that children do not engage in sufficient activity to benefit cardiorespiratory health (Armstrong & Bray, 1991; Armstrong et al., 1996; Armstrong & Welsman, 1997; Cale & Almond, 1993; Gavarry et al., 2003; Janz *et al.*, 1992; Riddoch et al., 1991; Sleap & Warburton, 1996). However, a number of these studies investigated the percentage of children who engaged in continuous bouts of physical activity that lasted 20 minutes or more, which was in line with previous recommendations, rather than focusing on the accumulation of intermittent physical activity as suggested by Biddle and colleagues (1998). In comparison, a study by Sleap and Tolfrey (2001), which included light as well as moderate and vigorous physical activity threshold's, found that children exceeded current daily physical activity recommendations. Similarly, in their review of children's physical activity levels assessed by heart rate, Epstein et al (2001) concluded that children of all ages accumulated 30 minutes of MVPA a day, therefore achieving minimum daily activity guidelines (Biddle *et al.*, 1998). Riddoch and colleagues (2004) also reported that the majority of boys and girls in their study of European youth achieved optimal daily physical activity guidelines when activity was assessed using accelerometry. The effect of activity guidelines used to determine sufficient health enhancing activity was further emphasised by Welk and colleagues (2000) who examined previous empirical findings using current guidelines. They found that MVPA engagement ranged from 45-68 minutes for boys and 31-59 minutes for girls when activity was accumulated across the whole day. The lowest time spent in MVPA was 15 minutes (Janz et al., 1992). This suggests that the accumulation of physical activity as opposed to continuous bouts is an important consideration whilst investigating children's activity to benefit general health (Biddle et al., 1998; Welk et al., 2000), as this more closely reflects their intermittent and sporadic physical activity patterns (Bailey et al., 1995).

In accordance with the revised findings, it could be argued that the criteria used to determine whether children are sufficiently active enough on a daily basis influences the interpretation of children's physical activity levels (Riddoch & Boreham, 1995; Welk et al., 2000). These results suggest that children are at least meeting minimum activity guidelines (Biddle et al., 1998; Sleap & Tolfrey, 2001; Welk et al., 2000). However, despite these encouraging findings, the promotion of activity to children is still advised as "a sizeable proportion of young people continue to have what might be described as an 'inactive' lifestyle" (Biddle *et al.*, 2004, p. 684), which may be a contributing factor to the increasing levels of obesity in the UK (Chinn & Rona, 2001). Indeed, it has been estimated that 50% of children are not sufficiently active in order to gain subsequent health benefits (Andersen et al., 2006; Stone et al., 1998).

2.1.4 Determinants of Physical Activity Behaviour

Physical activity is influenced by a number of determinants. The term determinants refers to reproducible but not necessarily causal associations between an physical activity and factors such as age, which affect the frequency, intensity, duration and type of children's activity (Buckworth & Dishman, 2002; Gorely, 2005). Variations in physical activity behaviour follow variations in the determinants (Bauman et al., 2002). Sallis and co-workers (2000) undertook a comprehensive review of the factors that had been investigated with regard to children's physical activity to identify determinants that had consistent relationships with activity. These relationships could then inform the design and implementation of effective interventions with this age group (Sallis et al., 2000). Determinants are generally classed as either unmodifiable or modifiable determinants (Gorely, 2005). Unmodifiable determinants include factors such as age and sex, and these help to identify specific target groups for the interventions (Baranowski et al., 1998). In comparison, modifiable determinants can be specifically targeted by the intervention to induce changes and encourage greater engagement in physically activity behaviours (Baranowski et al., 1998).

Sallis et al (2000) reported that, of the unmodifiable determinants, gender was consistently related to physical activity levels, with boys generally engaging in more physical activity than girls. This suggests that school age girls are an important target group for physical activity interventions. A number of modifiable determinants were also found to be related to physical activity. Positive associations were reported between activity and previous activity levels, time spent outdoors, and access to facilities, whilst a negative association was found between perceived barriers and physical activity (Sallis et al., 2000). This indicates that increasing activity may lead to greater activity in childhood, whilst interventions that encourage children to spend time outdoors and increases their access to facilities may also be effective. These latter two findings could also decrease perceived barriers to physical activity engagement, which negatively effects activity (Sallis et al., 2000). Interestingly, social factors, such as peer influence, had no reported association with physical activity (Sallis et al., 2000). This latter finding may be attributable to a lack of knowledge about the mechanisms that reinforce physical activity behaviour, which make social factors difficult to assess (Welk, 1999).

The identification of time spent outdoors, access to facilities and perceived barriers as key determinants of children's of physical activity highlights the importance of the environment in which the individual resides on activity levels and behaviour. Physical activity behaviour is influenced by a reciprocal relationship between individual and environmental attributes (Cohen et al., 2000; King et al., 2002). The environment can either facilitate or inhibit physically active play behaviours, for example, through the provision of community sports centres, public playgrounds and play spaces whilst the individual interacts with the environment to make effective use of the opportunities provided (Green et al., 1996; King et al., 2002). The physical environment provides opportunities and clues about how to be physically active (Giles-Corti & Donovan, 2002). In addition, diverse environments enable children to explore, discover, fail, succeed and to interact with the environment itself (Titman, 1992). Essentially, the environment can enable, predispose or reinforce physical activity play behaviours (Green et al., 1996), indicating that this may be an important determinant that could be targeted by interventions to benefit physical activity and health (Owen et al., 2000). Traditional interventions that have been implemented have attempted to change social and individual factors, and these have had a relatively small effect on physical activity (Baranowski et al., 1998; Baranowski & Jago, 2005) whilst generally failing to consider the context in which the physical activity behaviour occurs (Giles-Corti & Donovan, 2002; Giles-Corti et al., 2005). It is therefore important to consider social, individual and environmental variables and their interactive effects on physical activity play. This is a central facet of social ecology, which focuses on social, individual and environmental variables that can inhibit or facilitate individual behaviour (Green et al., 1996; Sallis & Owen, 1999). Stokols (1996) describes the social ecological approach as "person-focused efforts to modify persons' health behaviour with environment-focused interventions to enhance their physical and social surroundings" (p. 283).

The Youth Physical Activity Promotion (YPAP) model is the first model that has adopted an ecological approach to the promotion of physical activity in youth (Welk, 1999). The YPAP model was designed in order to "characterize a variety of influences into a conceptual framework that can then be used to guide interventions and programs" (Welk, 1999, p. 7). It draws on the Precede-Proceed Model (Green & Kreuter, 1991) and a social ecological framework (McLeroy et al., 1988) where a given population's needs and characteristics are identified and considered before designing an intervention programme whilst acknowledging that the environment can directly and indirectly influence behaviour across a number of levels (Welk, 1999). This "bottom-up" approach highlights how the demographics of the population affect the likelihood of engaging in physical activity (predisposing factors), the significant others that can reinforce physical activity behaviour (reinforcing factors), and the aspects of the individuals environment that allow children to be active (enabling factors; Welk, 1999) across multiple levels of influence. Potential causal links between factors have been suggested by Welk (1999) based on prior research into the more easily modifiable determinants of youth physical activity. Whilst the YPAP model has been used as an underlying conceptual model for interventions that aimed to increase the physical activity levels of school children during playtime (Stratton, 2000; Stratton & Mullan, 2005), no validation of the model has been published to date (Rowe et al., 2003).

Using the YPAP model as a framework, it is possible to see that the environment is an important influence on physical activity behaviour. In ecological models, the environment is defined as the "space outside of the person" (Sallis & Owen, 2002, p. 462). The environment as a determinant of physical activity behaviour has received increasing interest in recent years, as it is suggested that individuals adapt their behaviours when changes occur in their social and physical environments (Spence & Lee, 2003). Indeed, interventions that target changes in the physical environment are being suggested, as there is great potential for these to impact on the physical activity levels and behaviour on a large number of people (Giles-Corti et al., 2005; Stokols, 1996; Wechsler et al., 2000). The main purpose of environmental interventions is to create opportunities for physical activity engagement, and to provide messages to the recipients about acceptable or unacceptable behaviours within the specific milieu (Cohen et al., 2000; Giles-Corti et al., 2005; Heath, 2003; Sallis & Owen, 1999).

An important consideration in the interaction between an individual and the environment and the effect on behaviour is the behaviour setting in which it takes place. Barker (1968) proposed that regular encounters with different environments lead to consistent patterns of behaviour. These environments were termed behaviour settings, and they stimulate predictable behaviour (Spence & Lee, 2003). Behaviour settings occur in particular physical locations and are often characterised by engagement in organised activities (King et al., 2002). Knowledge of different behaviour settings are important, for it is thought that behaviour is more accurately predicted from understanding the situation the person is in compared to knowing about the individual themselves (Barker, 1968; Sallis & Owen, 2002). Therefore, the identification of suitable behaviour settings to be targeted by interventions that aim to promote physical activity to children is important, as changes in the environment may stimulate physically active behaviours (Spence & Lee, 2003). The identification of suitable contexts for the promotion of physical activity could help to encourage and foster physically active behaviours (Sääkslahti et al., 2004) both in childhood and later in adulthood (Telama et al., 2005). Such contexts include the indoor and outdoor home environment, public playgrounds, sports facilities, community hall and commercial play areas (Owen et al., 2000). One recommended setting for both physical activity promotion and interventions aimed at increasing daily activity is the school environment (USDHHS, 2000). Children spend a substantial proportion of their day at school; therefore this context may play a critical role in the development of physical activity and health behaviours (Kohl & Hobbs, 1998; Stokols et al., 2003). Indeed, the school environment has been found to explain a significant amount of variance in youth physical activity (Fein et al., 2004). Consequently, the importance of the school environment in developing physical activity behaviours, and its potential to contribute towards daily activity guidelines, warrants attention.

2.2 The School as a Health Promotion Context

The Choosing Health White Paper (DH, 2004b) identified the need to increase children's physical activity opportunities in safe environments in their free time. A primary objective of Choosing Health (DH, 2004b) is to encourage physical activity in schools and establish health behaviours from an early age. The school has previously been identified as a logical setting for health promotion and the promotion of physical activity to young people (Biddle et al., 1998; Cavill et al., 2001; Kohl & Hobbs, 1998; Sallis et al., 1992; Welk, 1999), as school attendance is a generic part of childhood; therefore a substantial proportion of the child population can be reached. There are two main opportunities for children to be physically active in the primary school context. These are physical education (PE) lessons, and playtime (Sarkin et al., 1997). These are specific behaviour settings within the school environment, as they occur in specific locations and are characterised by patterns of behaviour (King et al., 2002). With regards to PE, the health education infrastructure that exists through the formal curriculum educates children about both the need for physical activity as well as developing their knowledge of how to physically active (Killen & Robinson, 1988; Sallis et al., 1992). PE has a number of diverse aims, including the promotion of children's physical, social, psychological and moral development, developing fundamental movement and sport specific skills, and providing children the opportunity to engage in regular structured physical activity (Fairclough & Stratton, 2005; Sallis & McKenzie, 1991; Simons-Morton, 1994). Furthermore, PE aims to enable children to lead physically active lifestyles (Sallis & McKenzie, 1991).

In the United States (US), guidelines have been developed to enable PE to promote physical activity to young people (Almond & Harris, 1998). Specifically, it was recommended that schools should offer PE lessons on a daily basis, and in order for PE to meaningfully contribute towards the accumulation of health-enhancing physical activity, children should be sufficiently active for at least 50% of lesson time (USDHHS, 2000). However, in a review of physical activity levels in primary school PE lessons, Fairclough and Stratton (2006) found that, on average, children engaged in MVPA for 37.4% of lesson time. This falls somewhat short of the 50% recommendation. Moreover, since the average duration of the PE lessons reviewed was 33.7 minutes, PE contributed approximately 12 ½ minutes towards recommended daily physical activity levels (Biddle et al., 1998). This finding suggests that if PE was offered on a daily basis, which generally in the UK it is not (Almond & Harris, 1998), PE could contribute around one fifth towards daily activity guidelines (Fairclough & Stratton, 2006).

PE has been the traditional backdrop for school-based interventions, which have been implemented through the formal curriculum with the aiming of increasing children's activity levels. Two large-scale US based interventions that have aimed to increase children's physical activity levels during PE are the Sports Play and Active Recreation for Kids (SPARK; McKenzie et al., 1997b) and the Child and Adolescent Trial for Cardiovascular Health (CATCH; Kelder et al., 2003) programmes. Specifically, SPARK and CATCH involved training elementary (primary) teachers using specially written curricular material to promote high levels of activity during PE, whilst CATCH also aimed to enable children to be sufficiently active for at least 40 % of PE time. Kelder and colleagues (2003) reported that the CATCH programme was effective in increasing and maintaining children's activity levels, with children spending 50 % of their PE lessons engaged in MVPA 5 years after the initial teacher training. Similarly, activity levels were increased after initial training in SPARK, with children gaining an additional 15 minutes of MVPA a week over baseline levels (McKenzie et al., 1997b). However, despite these positive findings, it should be noted that these interventions have been well funded and the true implementation costs of the intervention are unknown (Stone et al., 1998). Furthermore, the additional contribution they have made to daily activity has been relatively small, and the interventions have had limited success in increasing children's out of school physical activity levels (Biddle et al., 2004; Stone et al., 1998).

PE based interventions have demonstrated some promise in increasing children's physical activity levels. However, there are a number of issues that surround PE that warrant attention. Internationally, concern has been expressed that the curricular time allocated by schools for PE is not meeting statutory requirements, with PE making way for supposedly more valuable areas of the curriculum such as numeracy and literacy (Hardman & Marshall, 2000; Shephard, 1997). In the UK alone, Hardman and Marshall (2000) reported that one third of primary schools had reduced PE time provision, with 50% of these schools losing 30 minutes a week, whilst another 20% lost 60 minutes a week. Physical education provision in primary schools is a concern, as only 29% of infant school children and 32% of junior school children receive two or more hours of PE a week in 2002 (Sport England, 2003). This affects the contribution that PE can make towards physical activity guidelines. An additional problem in primary schools is that PE is generally taught by non-specialists (Almond & Harris, 1998; Fairclough, 2003). Nine percent of primary schools have a full-time PE specialist teaching at their schools (Sport England, 2003). The large-scale US-based studies have shown that physical activity levels are higher and therefore contribute more towards activity levels when PE is taught by specialists or specifically trained teachers (McKenzie et al., 1997b; Sallis et al., 1997). These factors contribute towards the concern that PE alone is unlikely to provide sufficient physical activity across the school year to benefit health, particularly as physical activity engagement is only one aim of PE (Almond & Harris, 1998; Biddle et al., 2004; Fairclough, 2003).

In response to these concerns, the UK government released a number of public service agreements, one of which aimed to "enhance the take-up of sporting opportunities by 5-16 year olds by increasing the percentage of school children who spend a minimum of two hours each week on high-quality PE and school sport within and beyond the curriculum from 25% in 2002 to 85% by 2008" (DfES, 2003). The Physical Education, School Sport and Club Links (PESSCL) Strategy contributes to the achievement of this public service agreement through eight programmes of work. These include creating School Sport Coordinator Partnerships, where links are made between schools and the community to increase participation in community sport, provide specialist teaching and coaching, and provide enhance activity opportunities (DfES, 2003). Other programmes include developing school and club links, providing professional development and qualified coaches, and opportunities for swimming (DfES, 2003). Indeed, a major investment has been made in achieving this public service agreement, with over £1 billion being invested in to PE and school sport.

Physical education is one aspect of the school setting that can encourage physical activity in children in relating to the Choosing Health White Paper (DH, 2004b). The effectiveness of the non-curriculum approaches to the provision and promotion of physical activity has also been espoused (Jago & Baranowski, 2004). Such approaches include active transport, after school clubs and playtime (Jago & Baranowski, 2004). In the UK, playtime provides the main opportunity for children to engage in physical activity during school time, and time spent in playtime exceeds that spent in structured PE classes (Kraft, 1989; Sarkin *et al.*, 1997). Playtime is a mandatory part of the school day where children usually spend the majority of their time outside on the playground (Blatchford, 1989; Blatchford et al., 2003). Primary school children will typically experience up to 600 playtimes a year (based on 3 times a day, 5 days a week, 39 weeks a year; Stratton, 1999), leading to children spending more time in unstructured environments compared to structured PE lessons (Kraft, 1989). Specifically, average playtime durations for infant and junior school pupils have been reported to be 91 and 77 minutes respectively per day (Blatchford & Baines, 2006). Therefore, playtime accounts for nearly a quarter of the average primary school day (Blatchford, 1989), and children can spend up to 7 ½ hours in playtime a week (Blatchford & Baines, 2006).

2.3 Physical Activity Levels of Children during School Playtime

Despite accounting for a significant amount of school time (Boulton, 1992), playtime has been referred to as "the forgotten part of the school day" (Blatchford, 1989, p. 4). Children best accumulate physical activity in unstructured environments where they are free to interact with their peers (Pate et al., 1996). Playtime offers children an opportunity to be physically active during the school day, as the unstructured environment lends itself to the highly transitory activity patterns of children (Bailey et al., 1995). However, little empirical research has focused on the physical activity levels of children within the playground and the merit of playtime strategies in this context. Furthermore, studies reporting the contribution of playtime towards recommended physical activity levels are sparse.

To identify empirical research that has quantified children's physical activity levels during school playtime, a literature search was conducted for studies that were published in the English language between 1970 and November 2006. The search used the key words "playtime", "school recess", "playgrounds" and "physical activity" using the Web of Knowledge and Sports Discus online databases. A manual search of conference proceedings and a reference check of the studies retrieved was also performed. Both cross-sectional and intervention studies were included to establish the physical activity levels of children in different school playtime contexts. Additional inclusion criteria for studies were a) physical activity levels during school playtime evaluated using objective measures and b) participants were between 4-12 years of age. Case reports, dissertations, anecdotal discussions, and abstracts subsequently published were excluded.

Seventeen cross-sectional studies that have investigated the physical activity levels of children aged 4 to 12 years during school playtime were returned by the literature search. Twelve studies used the criterion measure of direct observation, with 4 studies combining this with either heart rate or accelerometry. Twenty-four per cent of the published studies report data collected within the UK. Table 2.1 presents a summary of these studies, and identifies some of the quality issues concerned with the published research.

2.3.1. Gender Differences in Playtime Physical Activity Levels

Ten of the studies reported in Table 2.1 investigated differences between boys and girls' physical activity levels during playtime. Gender differences in physical activity levels during playtime have been found, with boys being consistently and significantly more active than girls (Kraft, 1989; McKenzie et al., 1997a; McKenzie et al., 2000; Sarkin et al., 1997; Zask et al., 2001). Conversely, two Portuguese studies reported that girls were significantly more active than boys (Mota et al., 2005a; Mota & Stratton, 2003), and one study reported no differences between boys and girls' activity during playtime (Rosser Sandt & Frey, 2005).

Table 2.1: Summary of cross-sectional studies investigating children's physical activity during school playtime. Table ordered by sample size.

Author(s)	Sample	Country	PA Assessment	Design	Main Results	Quality Issues
Stratton & Mota (2000)	18 girls Junior children	UK & Portugal	DO (CARS) & HR	1 girl observed per playtime per country 5 s HR intervals	Portuguese girls spent more time in stationary & hard/fast activity than UK girls Low correlations between HR & DO	Small sample size Only morning playtime monitored Sensitivity of measures
Mota et al (2005a)	10 boys, 12 girls Grades 3 - 4	Portugal	Accelerometer	3 consecutive days 1 minute epoch	Girls PA > boys PA during playtime	Small sample size from one school Recording period may not reflect children's PA
Mota et al (2005b)	10 boys, 12 girls Grades 3 - 4	Portugal	Accelerometer	3 consecutive days 1 minute epoch	Obese PA > Non-obese PA during playtime	Small sample size from one school Sex differences not investigated
Stratton (1999)	14 boys, 13 girls Years 3-6	UK	HR & DO	1 boy & 1 girl measured & observed per playtime Seasonal effects examined	Winter PA > Summer PA Boys winter PA > girls winter PA Boys summer PA ↔ girls summer PA	Small sample size Only morning playtime measured Other variables affecting HR
Rosser Sandt & Frey (2005)	18 boys, 12 girls (15 had ASD) 5-12 yrs old	USA	Accelerometer & DO (BEACHES)	PA monitored on 4 school days and 1 weekend day 1 minute epoch Observed one PE lesson & one playtime	Boys PA ↔ girls PA during playtime ASD PA ↔ Non-ASD PA during playtime Playtime PA > PE PA	Small sample Children with & without ASD not exposed to same playtime conditions
Mota & Stratton (2003)	16 boys, 23 girls 8-9 yrs old	Portugal	HR	PA assessed over 4 weeks	Girls HR > Boys during playtime Girls PA > Boys during playtime	Small sample size Only morning playtime assessed

Table 2.1 continued: Summary of cross-sectional studies investigating children's physical activity during school playtime. Table ordered by sample size

Author(s)	Sample	Country	PA Assessment	Design	Main Results	Quality Issues
Johns & Ha (1999)	40 children 6-8 yrs old	Hong Kong	DO (BEACHES)	4x1 hr & 6x20 min observations per child	23.3%, 40.5% & 28.1% of playtime children were seated, standing & walking respectively	Small sample size Inter-observer results not given PA Sex differences not investigated
Faison-Hodge & Porretta (2004)	38 non-MR & 8 MR children Grades 3-5	USA	DO (SOFIT) & HR	Data collected in four-wk fitness unit Activity recorded 20 s (SOFIT) & 15 s (HR)	Playtime PA > PE PA Non-MR PA ↔ MR PA during playtime	Small sample size Children recruited from one school Small group of children with MR
Sleap & Warburton (1992)	27 girls, 29 boys Years 1-6	UK	DO (CPAF)	Playtime & PE observed during day using CPAF	Playtime PA > PE PA Afternoon playtime PA > Morning and lunchtime PA	No comparisons made across areas Calculation of agreement method not given
Dale et al (2000)	40 boys, 38 girls Grades 3-4	USA	Accelerometer	4 days monitored: 2 days no school activity, 2 days PE & playtime 1 minute epoch	Playtime & PE PA active day > non-active day Outdoor playtime PA > indoor playtime PA	PA threshold values not used to quantify PA duration or intensity Sensitivity of measures
Sarkin et al (1997)	49 boys, 61 girls Grade 5	USA	Accelerometer	PA measured in PE & playtime on 3 separate days Counts per min used	Boys PA > girls PA during playtime Girls PA PE > Girls PA playtime	Moderate sample size PA threshold values not used Children recruited from one school
Sleap & Warburton (1996)	93 boys, 86 girls Years 1-6	UK	DO (CPAF)	Playtime & PE observed during day using CPAF	Playtime PA > PE PA Morning playtime PA: 55.4% Lunchtime PA: 59.8% Afternoon playtime PA: 46.3%	Observations conducted by undergraduate students Calculation of agreement Observed at school on 1 day only

Table 2.1 continued: Summary of cross-sectional studies investigating children's physical activity during school playtime. Table ordered by sample size

Author(s)	Sample	Country	PA Assessment	Design	Main Results	Quality Issues
Hovell et al (1978)	133 boys, 141 girls Grades 3-6	USA	DO	PA observed during am playtime or lunch 50x5 s observations/child	Boys lower-body PA > girls Girls upper-body PA > boys	First study to look at PA in playtime Results based on 5 min observations
McKenzie et al (1997)	155 boys, 132 girls 4-6 yrs-old	USA	DO (BEACHES)	Observations made in preschool & elementary school (2 yr follow-up) in M-A & E-A children	Boys PA > girls E-A PA > M-A PA Elementary PA > preschool PA	Longitudinal study but 16% attrition rate - children assessed twice Playtime duration differed across schools
Kraft (1989)	201 boys, 168 girls Grades K-3	USA	DO	Active & passive behaviour recorded 1 child observed for 5 min (5 s intervals)	Boys PA > girls during playtime Girls sedentary play > boys Physical play = 59% of playtime Vigorous activity = 21% of time	Descriptive - based on 5 minutes of observation Classified active behaviour & extent of social interactions
Zask et al (2001)	18 schools Grades K-6	Australia	DO (CAST)	SOFIT procedure adapted for playtime	Lunch PA > playtime PA Boys PA > girls PA during playtime Small school PA > Large school PA	Schools viewed on 1 day only CAST not widely used in literature Scanning procedure used in school playground
McKenzie et al (2000)	24 schools Grades 6-8	USA	DO (SOPLAY)	3 days observation per school (72 days total)	Boys MVPA > girls MVPA Boys EE > girls EE Boys PA area visits > girls	Large scale study focusing on playtime behaviour SOPLAY focuses on PA of groups > 20% students enrolled observed

Key: ↔ = No significant difference; > = Significantly greater than; DO = Direct observation; PA = physical activity; MVPA = Moderate-to-vigorous physical activity; PE = Physical Education; HR = Heart rate; M-A = Mexican American; E-A = European-American; EE = Energy expenditure; ASD = Autistic spectrum disorders; MR = Mental retardation; CARS = Children's Activity Rating Scale; BEACHES = Behaviours of Eating and Activity for Children's Health Evaluation System; CPAF = Children's Physical Activity Form; SOFIT = System for Observing Fitness Instruction Time; CAST = Children's Activity Scoring Tool; SOPLAY = System for Observing Play and Leisure Activity in Youth.

The reasons underlying gender differences in playtime activity levels have not been established in the literature. However, links have been made to playtime behavioural research where boys and girls' play behaviour and social interactions during playtime have been observed and recorded. Boys tend to play more active and ball games than girls, whereas girls tend to engage in more inactive play and social behaviours such as passive and verbal games, conversation and socialising during playtime (Blatchford et al., 2003). Girls' lower activity levels may also be attributed to the domination of available space by boys playing vigorous ball games (Armitage, 2001; Evans, 1996; Renold, 1997), suggesting that low active playtime behaviours have not necessarily been chosen by girls. Football often dominates over half of the primary school playground yet is played by approximately one quarter of the school population (Armitage, 2001), leading to the remaining children situating themselves around the playground perimeter and engaging in inactive behaviours (Armitage, 2001; Renold, 1997). Interestingly, while the majority of studies detailing gender differences in physical activity are US-based studies, research that details children's play behaviour during playtime are primarily based in UK schools. Playtime occurs in difference contexts globally; therefore explaining gender differences using empirical findings from different countries may not be entirely accurate. There is a dearth of UK-based studies that have investigated children's physical activity levels during playtime, highlighting a need to establish the activity levels of boys and girls during playtime.

2.3.2. Inclusion and Playtime Physical Activity

Since 2001, the British Government has been committed to widening opportunities for children with disabilities to have access to a mainstream education (DfES, 2004). This emphasis on inclusion is further demonstrated by Every Child Matters (House of Commons, 2003), where schools must identify and aim to remove barriers and provide effective learning opportunities and strategies for children with special educational needs (SEN) and disabilities. There are five outcome areas identified by Every Child Matters, which are being healthy, staying safe, enjoying and achieving, making a positive contribution and economic well-being (House of Commons, 2003). The school environment therefore provides an opportunity to investigate the physical activity levels of children with and without disabilities in a safe environment where children can learn a range of skills, which begins to prepare them for adulthood. Consequently, playtime can be considered as an inclusive setting where children with and without disabilities can be physically active in the same environment.

Two small scale US studies using convenience samples have investigated the physical activity levels of children who were non-disabled and children with mild mental retardation (MR; Faison-Hodge & Porretta, 2004) and autistic spectrum disorders (ASD; Rosser Sandt & Frey, 2005). No significant differences in playtime MVPA were found between children with or without disabilities, though children with ASD showed a trend of being less active than their non-ASD peers (Rosser Sandt & Frey, 2005). The results should be interpreted with caution however, as 20% of the children with ASD did not spend their playtime with mainstream children. Faison-Hodge & Porretta (2004) found that children with MR engaged in similar levels of MVPA as non-MR children who were of low cardiorespiratory fitness, though they were less active, albeit non-significantly, than non-MR children who had high levels of cardiorespiratory fitness (Faison-Hodge & Porretta, 2004). Overall, these findings are important in line with recent governmental policy, as UK schools will have children who disabled and non-disabled in the playground environment. The results suggest that children are similarly effective in using playtime to be physically active, though any interventions implemented within this environment should embrace the principle of inclusion and provide activity opportunities for all children.

2.3.3. Playtime and Physical Education Physical Activity

Table 2.1 highlights that one approach to researching playtime physical activity is to compare it to PE physical activity levels (Faison Hodge & Porretta, 2004; Rosser Sandt & Frey, 2005; Sarkin et al., 1997; Sleap & Warburton, 1992, 1996). The majority of the studies indicate that playtime physical activity levels are significantly higher than PE physical activity levels (Faison Hodge & Porretta, 2004; Rosser Sandt & Frey, 2005; Sleap & Warburton, 1992, 1996). This may be attributable to the playtime and PE contexts, as while PE is highly structured and lesson time is divided between management, instructional time, drills, games and free play (McKenzie et al., 1997b), playtime is typically unstructured where children are able to engage in freely chosen activities on a daily basis that are relatively free from adult control (Blatchford, 1999a, 1999b; Faison-Hodge & Porretta, 2004; Pellegrini & Blatchford, 2002). In contrast, Sarkin and colleagues (1997) noted that while boys' activity levels in playtime and PE were not significantly different, girls were more physically active during PE than playtime. Moreover, boys and girls engaged in similar levels of physical activity during PE. This study suggested that the structure of the PE environment enabled girls to be as physically active as boys, and more active during PE than playtime (Sarkin et al., 1997).

It is notable that, with the exception of the non-ASD children (Rosser Sandt & Frey, 2005), PE physical activity levels in these studies were substantially below the 50% threshold suggested in order to PE to meaningfully contribute towards the accumulation of health-enhancing physical activity (USDHHS, 2000). In comparison, playtime physical activity levels were close to (Sleap & Warburton, 1992; 1996) or exceeded (Faison Hodge & Porretta, 2004; Rosser Sandt & Frey, 2005) the 50% threshold for playtime. This was extrapolated from the USDHHS PE threshold and proffered as an efficiency target for playtime physical activity (Stratton & Mullan, 2005), though empirical testing of this threshold is required to ascertain whether it is a suitable target for children to achieve during playtime. Overall, the results suggest that children are spontaneously active in unstructured playtime environments, though physical activity promotion strategies may be needed to enable children to be more efficient in using playtime to engage in health-enhancing activity. However, the issue of the level of intervention and structure that may be required to promote activity without being detrimental towards children's opportunities for spontaneous activity.

2.3.4. General Playtime Research

A number of variables have been assessed concerning playtime physical activity levels, including differences between seasons (Stratton, 1999), stages of schooling (McKenzie et al., 1997a), children classified as obese and non-obese (Mota et al., 2005b), children of different ethnic origins (McKenzie et al., 1997a), and size of school (Zask et al., 2001). However, these differences have been sparsely examined at best, making if difficult to make reliable conclusions about different groups' activity levels within this context.

Seasonal factors have been found to influence children's habitual physical activity engagement, with youth reported to be more active in the summer months compared to the winter months (Hagger et al., 1997; Loucaides et al., 2003). Contrasting results have been found for playtime however, albeit through one study that investigated this area (Stratton, 1999). It was reported in this study that physical activity levels were higher in winter compared to summer (Stratton, 1999). While these seasonal differences in playtime physical activity levels were not significant, the seasonal variation may be attributable to a thermoregulatory need to keep warm during the colder winter weather (Stratton, 1999), as children in the UK do not have the option of playing inside on cold days (Thomson, 2004). This study provides an insight into the potential seasonal effects on playtime activity, yet further studies are needed to determine this issue further.

One longitudinal study that assessed children's physical activity levels when they attended preschool and an elementary school two years later found that while elementary children had a shorter playtime duration than preschool children, they engaged in higher levels of physical activity during playtime (McKenzie at al., 1997a). This may be explained by the activities that children engage in during playtime. Early primary children may use playtime as an opportunity to practice physical skills and to become confident in their movement (Lindon, 2001), while late primary children play games and develop social skills (Pellegrini, 1995). Participation in games may elicit higher activity levels. McKenzie et al (1997a) suggested this finding was related to the size and management of the available play space, noting that preschool environments were more restrictive than elementary school playgrounds. No comparative cross-sectional study in the UK has investigated stage of schooling differences or the effects of age on physical activity levels during playtime, and it requires empirical research attention.

Ethnicity may affect children's playtime physical activity levels. In the only study to address this issue to date, McKenzie et al (1997a) found that European-American children engaged in higher levels of activity than their Mexican-American counterparts. The underlying reasons for this finding have not been established, though McKenzie et al (1997a) suggested that it might be partially explained by the higher prevalence rates of obesity in Mexican-American populations. Mexican-American children may have lower activity levels because barriers to physical activity participation are greater than for European-American children, and feelings of activity enjoyment and self-esteem are lower (Morgan et al., 2003). These enabling and predisposing factors are hypothesised to have strong influences on physical activity levels in children (Welk, 1999).

The influence that size of school has on children's physical activity levels has been examined using a multilevel modelling approach (Zask et al., 2001). School enrolment was found to be a significant explanatory parameter of both MVPA and vigorous physical activity (VPA) during playtime. When this finding was modelled using school sizes of 100, 200 and 500, it was found that as the size of the school increased, both boys and girls' playtime activity decreased (Zask et al., 2001). Potential reasons link to social inclusion, where inclusion could being stronger in smaller schools due to smaller numbers of children being available to play different games.

Furthermore, it may be linked to playground space, as children are less active in restricted environments (Pellegrini & Smith, 1993). Subsequently, children at larger schools may have less space to be active in due to numbers of children on the playground, which may affect their physical activity levels. This perception however infers that the density of children in the playground increased as school size increased. It is possible that the density of children in the playground during playtime rather than the school size may be the underlying issue with Zask et al's (2001) finding. Overall, Zask et al's (2001) study indicates that the school is an important variable to consider in playtime research, and school influences and contexts may have critical effects on children's physical activity levels during playtime.

In summary, these studies reflect the need for playtime-based studies to consider the effects that pupil-level (e.g. BMI, age, ethnicity) and school-level (school size, play duration, equipment) factors may have on children's playtime physical activity levels. In relation to the Youth Physical Activity Promotion Model (Welk, 1999), pupil-level factors could be classed as demographic factors, and school-level factors could be classed as enabling factors (Welk, 1999). Whilst research into these areas is still in its infancy within this context, further investigation of the effects of these variables could aid the identification of specific populations of children who would benefit from inclusive physical activity interventions.

2.3.5. Contribution of Playtime to Physical Activity Recommendations

Recent studies have attempted to evaluate the contribution that playtime makes to current daily physical activity recommendations. This assessment is complicated however as the majority of playtime-based studies have monitored one period, which has often been morning playtime. Furthermore, the playtime periods assessed are generally short in duration, which may provide little scope for effective interventions to be implemented during this time in order to meaningfully contribute towards activity guidelines.

Table 2.2 highlights that playtime can contribute from 4.7% to 100% and 4.5% to 57.3% towards daily physical activity recommendations for boys and girls respectively, using Biddle et al's (1998) recommendations. Using Andersen et al's (2006) recent findings in relation to physical activity and clustered risk, playtime can contribute from 2.3% to 50.2% and 2.2% to 28.6% towards daily physical activity recommendations for boys and girls respectively (Table 2.2). Table 2.3 indicates that when boys and girls' activity are combined together, playtime can contribute from 16.5% to 59.5% towards daily activity using Biddle et al's (1998) recommendation, and 8.3% to 28.3% towards daily activity using Andersen et al's (2006) findings. This suggests that some young people are effective in using their playtime time to engage in physical activity, though there is potential for interventions to be implemented in this context to enhance activity levels further. This is particularly important for children who engage in little or no activity during playtime, as research indicates that they do not increase their activity levels to accommodate for the inactivity outside of school hours (Dale et al., 2000). An important point highlighted in Tables 2.2 and 2.3 is that as playtime duration increases, the contribution of playtime towards children's recommended amounts of daily physical activity guidelines increases. Verstraete et al (2006) have demonstrated that boys achieved recommended daily activity levels through playtime alone when using Biddle et al's (1998) recommendation, though the average playtime duration in their study is up to seven times longer than reported by other studies in Table 2.2. This highlights the importance of schools providing adequate time periods during the school day for children to be active. Furthermore, researchers should consider assessing activity during all playtimes during the school day in order to determine an adequate baseline so that interventions can be comprehensively evaluated.

2.3.6. Cross-Sectional Playtimes Studies Summary

Cross-sectional investigations into playtime physical activity are currently limited by the relatively small sample sizes recruited from a handful of schools, variable methodologies employing a wide range of physical activity monitoring techniques, and cultural differences in playtime between countries. In addition, a number of pupil-level and school-level variables have been inconsistently investigated. The vast majority of studies with larger sample sizes have employed direct observation techniques that either scanned the playground (McKenzie et al., 2000; Zask et al., 2001) or observed children for short periods of time (Hovell et al., 1978; Kraft, 1989), which may not precisely reflect children's playtime physical activity levels as children have not been monitored for the whole of playtime. In addition, a number of studies have reported activity levels using one playtime period (Kraft, 1989; Stratton, 1999; Stratton & Mota, 2000) or a combination of playtime periods on one day (Faison-Hodge & Porretta, 2004). This affects generalisability and comparisons between studies. Moreover, little empirical attention has focused on establishing a suitable physical activity target for playtime. Only one

Table 2.2: Contribution of playtime towards current daily physical activity recommendations (boys and girls)

Author(s)	Country	Play duration (min)	%MVPA		Contribution towards daily guidelines (%)			
			Boys	Girls	Boys[1]	Girls[1]	Boys[2]	Girls[2]
Kraft (1989)	USA	28	45	38	21	17.7	10.5	8.9
McKenzie at al (1997a)	USA	14.1 (E-A)	56.3	50.7	13.2	11.8	6.6	5.9
		14.1 (M-A)	47.1	44.5	11	10.5	5.5	5.3
Stratton (1999)	UK	17.6 (S)	15.8	15.4	4.7	4.5	2.3	2.2
		17.6 (W)	29.1	22.5	8.5	6.5	4.3	3.3
McKenzie et al (2000)	USA	35.5	67.7	51.7	40	30.7	20	15.3
Zask et al (2001)	Australia	46	49.8	39.7	38.2	30.4	19.1	15.2
Scruggs et al (2003)	USA	33	45.1	32	24.8	17.6	12.4	8.8
Mota & Stratton (2003)	Portugal	20	19	34	6.3	11.3	3.1	5.7
Mota et al (2005a)	Portugal	30	31	38	15.5	19	7.8	9.5
Verstraete et al (2006)	Belgium	102	59	33.7	100	57.3	50.2	28.6

[1] Biddle et al's (1998) recommendation of a minimum of 60 minutes of at least moderate intensity physical activity a day. [2] Andersen et al's (2006) threshold of 120 minutes of at least moderate intensity activity a day to prevent clustering of cardiovascular risk factors.

Key to symbols: S = Summer; W = Winter; E-A = European-American; M-A = Mexican-American

Table 2.3: Contribution of playtime towards children's current daily physical activity recommendations

Author(s)	Country	Play duration (min)	%MVPA	Contribution towards daily guidelines (%)	
				Biddle et al[1]	Andersen et al[2]
Sleap & Warburton (1992)	UK	72[3]	47.1	56.5	28.3
Sleap & Warburton (1996)	UK	70[3]	46.7	54.5	27.2
Faison-Hodge & Porretta (2004)	US	15	66	16.5	8.3

[1] Biddle et al's (1998) recommendation of a minimum of 60 minutes of at least moderate intensity physical activity a day.
[2] Andersen et al's (2006) threshold of 120 minutes of at least moderate intensity activity a day to prevent clustering of cardiovascular risk factors.
[3] Morning, lunch and afternoon playtimes combined to give total play duration across school day.

study to date has attempted to determine whether the PE 50% threshold can be extrapolated and used in a playtime context (Stratton & Mullan, 2005). This requires further investigation. Moreover, larger population-based studies using similar methods and monitoring periods on girls and boys in all school years would enable researchers to further understand the overall contribution of playtime to physical activity during the school day. This is of critical importance in the UK, as little empirical evidence documents children's activity levels within this substantial part of the school day.

2.4 School Playtime Interventions

Blatchford (1989) noted that whilst educational policies have focused on curricular areas such as literacy and numeracy, scant attention had been paid to playtime. Individual schools have often initiated playtime changes, with the provision of equipment and marking of playgrounds being two common strategies, though they rarely rigorously evaluate or describe any effects of the changes in the professional or research literature. The literature search conducted (section 2.3) identified nine studies than have used playtime-based interventions with the aim of increasing children's physical activity levels in this context. Table 2.4 identities that a) physical activity has been quantified using a range of measurement techniques, b) interventions have occurred in a number of Western countries, and c) a variety of intervention strategies have been employed. No studies have been conducted using a longitudinal design; therefore the long-term effects and sustainability of the intervention strategies across time have not been investigated. The variation in methodologies used complicates comparisons between studies in the identification of effective intervention approaches within the context of playtime.

2.4.1 Playground Markings Interventions.

Table 2.4 shows that three studies, all conducted in the UK, have employed a multi-colour playground markings intervention in an attempt to increase primary school children's physical activity levels by providing an environment that supports and facilitates physically active behaviours (Wechsler et al., 2000). The playground markings used in the intervention consisted of games (e.g., soccer lines, snakes and ladders), activities (e.g., targets, hopscotch) and objects (e.g., number squares, clock faces) that were painted on the school playground surface to stimulate physically active play behaviours. Stratton (2000) reported an increase in MVPA of 11.1% in the four weeks following an intervention in a single school. This equated to

Table 2.4: Summary of playtime-based intervention studies. Table ordered by publication date.

Author(s)	Sample	Country	PA Assessment	Intervention	Control Group	Follow-up period	Results	Effective? Short Term	Effective? Long Term
Connelly & McKenzie (1995)	56 children Elementary school	USA	Direct observation, self-report, accelerometry	Games implemented by playground supervisors	Yes	No	PA during games playtime significantly higher than standard playtimes ($p<0.05$). No significant differences between boys and girls' self-report PA ($p>0.05$).	Yes	N/A
Ernst & Pangrazi (1999)	287 children (5 schools) 4-6th Grade	USA	Questionnaire	Daily activity break periods	Yes	No	Experimental boys and girls self-report PA increased between pre and mid test ($p<0.01$), and pre and post-test ($p<0.01$). PA decreased between mid and post-test ($p>0.05$)	Yes	N/A
Stratton (2000)	Exp: 18 boys, 18 girls Con: 12 boys, 12 girls Infant school children	UK	Heart rate	Playground markings	Yes	Up to 4 weeks post-painting	Experimental children's MVPA and VPA increased by 11.1% and 4.7% respectively ($p<0.05$). MVPA increased by 18 min a day post intervention.	Yes	N/A
Stratton & Leonard (2002)	Exp: 18 boys, 18 girls Con: 12 boys, 12 girls Infant children	UK	Heart rate	Playground markings	Yes	Up to 4 weeks post-painting	Rate of EE increased 6.1% and total EE increased 35% during intervention ($p<0.05$). Boys total EE 22% higher than girls during intervention.	Yes	N/A

Table 2.4 continued: Summary of playtime-based intervention studies

Author(s)	Sample	Country	PA Assessment	Intervention	Control Group	Follow-up period	Results	Effective? Short Term	Effective? Long Term
Ernst (2003)	6 boys, 6 girls 4-5th Grade	USA	Direct observation	Daily activity break periods	No	No	Children engaged in more physical activity during structured breaks than playtime ($p<0.01$).	Yes	N/A
Scruggs et al (2003)	10 boys 17 girls 5th Grade	USA	Heart rate, pedometers	Fitness breaks over 3 consecutive days	No	No	MVPA, VPA, and steps per minute during fitness breaks higher than playtime ($p<0.001$). Boys VPA higher in playtime and fitness breaks than girls ($p<0.001$).	Yes	N/A
Stratton & Mullan (2005)	Exp: 30 boys, 30 girls (4 primary schools) Con: 30 boys, 30 girls (4 primary schools)	UK	Heart Rate	Playground markings	Yes	Up to 4 weeks post-painting	Experimental children's MVPA and VPA increased by 13.6% ($p<0.001$) and 4.5% respectively ($p<0.05$).	Yes	N/A
Guinhouya et al (2005)	5 boys, 8 girls 8-10 years old	France	Accelerometry	Increased playtime duration (5 min)	No	No	Time spent in MVPA higher in longer playtime periods ($p<0.001$). MVPA increased by 6.5%	Yes	N/A
Verstraete et al (2006)	Exp: 75 boys, 47 girls (4 primary schools) Con: 46 boys, 67 girls (3 primary schools)	Belgium	Accelerometry	Games equipment	Yes	Yes - 3 months	MVPA increased during morning playtime ($p<0.01$). MVPA and VPA increased during lunch playtime ($p<0.01$). Girls MPA increased during morning playtime ($p<0.01$).	N/A	Yes

Key to symbols: Exp = Experimental group; Con = Control group; MVPA = Moderate-to-vigorous physical activity; VPA = Vigorous physical activity; EE = Energy expenditure; PA = Physical activity

Table 2.5: The effects of interventions on playtime's contribution to daily guidelines.

Author(s)	Change in MVPA (%)			Absolute change (min)			Total contribution towards daily guidelines[1] (%)		
	Boys	Girls	Overall	Boys	Girls	Overall	Boys	Girls	Overall
Stratton (2000)	—	—	11.1	—	—	5.9	—	—	24.7
Scruggs et al (2004)	—	—	—	—	—	—	23.5	23.7	23.6
Stratton & Mullan (2005)	4.2	4.6	13.6	0.7	0.9	3.3	17.7	15.8	20.5
Guinhouya et al (2005)	—	—	6.5	—	—	7.2	—	—	45
Verstraete et al (2006)	-7.6 (M) 13 (L)	3.9 (M) 12.6 (L)	-3.2 (M) 12.9 (L)	-1.2 (M) 11.2 (L)	0.6 (M) 10.8 (L)	-0.5 (M) 11.1 (L)	16.7 (M) 100 (L)	10.4 (M) 66 (L)	14.2 (M) 87 (L)

[1] Biddle et al's (1998) recommendation of a minimum of 60 minutes of at least moderate intensity physical activity a day

Key to symbols: Overall = Increase experienced by the experimental group in the study as a whole (boys and girls data combined); — = no data reported; - = negative change; M = morning playtime; L = Lunch playtime an additional 5.9 minutes a day (9.8%) towards optimal daily activity guidelines (Table 2.5), though children were 3.8% short of achieving the suggested 50% playtime physical activity threshold. Significant changes were also recorded for VPA, with increases of 4.7% being reported (Stratton, 2000). This is of note, as VPA promotes muscular strength over and above that expected from participating in moderate intensity physical activity (Biddle et al., 1998). However, the higher physical activity levels of the control group at baseline suggest that other environmental influences such as the availability of equipment can influence playtime activity levels (Stratton, 2000), and differences between schools should be accounted for using relevant analyses.

In a second study that used a larger sample of children from four schools (two experimental, two control), Stratton and Mullan (2005) reported similar increases in MVPA (13.6%) and VPA (4.5%) four weeks post-intervention to the previous study. The experimental children spent over half of playtime engaged in MVPA (50.3%) following the intervention, achieving the 50% playtime threshold. Both boys and girls experienced similar increases in their MVPA and VPA, suggesting that painting playgrounds with multicolour markings was an effective intervention strategy for increasing both boys and girls' physical activity levels during playtime. Moreover, it indicated that the 50% threshold might be an achievable physical activity target following a playground markings intervention. This study used a short-term follow-up period and as a consequence, novelty effects may have accounted for some of the increases seen. Furthermore, there were possible seasonal effects on the control groups' physical activity levels. Stratton and Mullan (2005) acknowledged the need for longer-term studies to investigate the sustainability of a playground markings intervention.

Total energy expenditure (TEE) and rate of energy expenditure (REE) increases of 35% and 6%, respectively, have been reported following a playground markings intervention (Stratton & Leonard, 2002). Boys and girls ages five to seven years experienced similar increases in TEE and REE, which is consistent with the physical activity intervention studies. This may be attributed to the involvement of children and teachers in the design of the play area. Both children and teachers were consulted about their preference for selected markings. This allowed the children and teachers to take ownership of and recognize the activities painted on the school playground (Stratton & Leonard, 2002). Furthermore, the spacing and types of markings across the playground potentially open up the play space to children who may have been pushed to the perimeter by dominant games prior to painting (Stratton & Leonard, 2002).

Children also had the opportunity to choose which games to play during playtime (Stratton, 2000).

Studies investigating the effects of playground markings on physical activity levels have demonstrated positive short-term effects. However, the studies were limited by their short-term follow-up periods. It is possible that novelty effects influenced children's physical activity levels and energy expenditure, as children viewed the redesigned playground as novel and played on the different markings immediately after the intervention. However, it could be hypothesised that once the novelty of the markings wore off, children may have returned to the games and activated they engaged in prior to the intervention. In addition, all these studies have been conducted within the UK, which could affect the generalisability of the intervention strategy to international school playtime contexts. The longer-term effects of these interventions were not investigated. Further research is needed to determine the longer-term effects and sustainability of playground marking interventions on playtime physical activity levels, accounting for the cross-school variation in the management and regulation of school playtime.

2.4.2. Structured Activity Breaks

Structured fitness breaks have been implemented as an alternative environmental intervention to playground markings (Scruggs et al., 2001). The fitness breaks aimed to engage children in significantly more MVPA compared to traditional unstructured playtime periods. The intervention employed a continuous 400-metre obstacle course across 3 sections of a school play area. Fifth-grade children participated in activities such as dance, jump rope, zigzag runs and crawling over objects for 15 minutes (Scruggs et al., 2001). The fitness break was implemented in the last hour of a school day where children had already participated in two regularly scheduled playtimes earlier in the day. In comparison to playtime, the fitness break stimulated higher MVPA, VPA and steps per minute in a small sample of boys and girls. While boys and girls engaged in similar amounts of MVPA during the fitness break, the boys' step count and VPA was higher than the girls' step count and VPA (Scruggs et al., 2001). Interestingly, children spent over 90% of the fitness break engaged in at least moderate intensity physical activity, highlighting the effectiveness of this approach in increasing physical activity. Fitness breaks contributed just over a third towards the accumulation of daily physical activity, with boys and girls experiencing equal benefits (Table 2.5). This study lends support to Sarkin and colleagues' (1997) suggestion that girls may need a structured environment to achieve similar activity levels as boys, particularly as in this study they were less active than boys during playtime (Scruggs et al., 2003). In general, the study indicates that changes to the physical environment can be effective in increasing physical activity during playtime, and structured activity sessions may equalise activity opportunities between boys and girls.

A unique aspect of Scruggs et al.'s (2003) research design was the measurement of enjoyment. While there were no significant differences in boys and girls' enjoyment levels of playtime, girl's enjoyment of the fitness break was significantly lower than the boys and girls' enjoyment of unstructured playtime periods (Scruggs et al., 2003). There was no difference between the enjoyment of playtime or the fitness breaks for boys. Since enjoyment is a central facet to activity participation this project highlights the inherent problem of overemphasis on fitness at the expense of intrinsic factors for girls (Weiss & Ferrer-Caja, 2002). It also indicates that if structured activities are to be used to increase girls' physical activity levels (Sarkin et al., 1997), the content is a critical consideration for continuing participation behaviours. Despite the intervention being effective, it did not influence children's freely chosen leisure activities and unstructured physical activity opportunities. Such an approach may also be time consuming for school staff to organise and implement over time. Additionally, the encouragement and reinforcement from supervising adults for children to participate may have had an effect on the children's engagement in the activities. The sustainability and feasibility of fitness breaks as an intervention over time are not known, as this intervention was implemented over three consecutive school days.

The Promoting Lifetime Activity for Youth (PLAY) intervention was implemented in the US in order to increase physical activity and to help pupils understand the relationship between activity and health (Ernst & Pangrazi, 1999). This study examined the changes in children's self-reported physical activity levels across a 12 week structured program in a large sample of children recruited from 5 schools. The structured, teacher-led activity breaks were effective in increasing children's physical activity, with boys experiencing greater increases than girls, though whether this approached significance is unknown as sex was not an independent variable in the analyses. However, small but non-significant decreases were recorded when the responsibility for being active transferred from the teachers to the pupils, with larger decreases seen in girls. This suggests that teacher participation and guidance plays an important role in the promotion of physical activity during the break periods. The study was limited by the use of self-report to assess physical activity, as it has limited reliability in children under the age of 11

(Baranowski, 1988). The children undergoing the PLAY intervention were aged 9-11 years old. In addition, the long-term effectiveness of the intervention was not reported, and the applicability of such an intervention to the UK, for example, where daily break periods are built into the timetable is questionable.

Structured activity break interventions reported in the literature have been solely conducted in the US. This is an important consideration, as in the US there is no consistency in the way that playtime is implemented (Pellegrini & Bohn, 2005), and structured breaks were identified as an approach to offering daily physical activity opportunities. However, there is an issue concerning whether structured or unstructured playtimes have a greater benefit to primary school-aged children. In structured breaks (e.g. fitness breaks, PLAY), children are expected to be active during this time and activities are teacher-driven. There is little choice available to the children concerning what activities they wish to engage in. In comparison, unstructured playtimes provide physical activity opportunities using playground markings, for example, where markings increase the attraction of being physically active by creating a variety of activity opportunities, but children are still volitional in their activity decisions (Stratton, 2000; Stratton & Mullan, 2005). Research suggests that children best accumulate physical activity in unstructured settings (Pate et al., 1996), and with self-reported physical activity decreasing once the intervention is removed (PLAY; Ernst & Pangrazi, 1999), data suggests that providing a choice of structured activities during unstructured playtimes may provide a good compromise. In summary, playtime interventions should enable children to have a choice between unstructured and structured activities and about what physical activity, play and social behaviours they wish to engage in during this time (Blatchford, 1998).

2.4.3. Games and Games Equipment Interventions

The effects of a games intervention implemented by playground supervisors at one elementary school on students' voluntary playtime physical activity levels has been investigated (Connolly & McKenzie, 1995). The children were significantly more active during the games playtime than traditional playtime, and boys and girls experienced similar increases, which is similar to the playground markings studies (Stratton, 2000; Stratton & Mullan, 2005). In addition, unlike the findings of Scruggs and colleagues (2003), there were no gender differences in enjoyment or physical activity during the intervention. Both sexes reported similar enjoyment levels of the games and standard playtime, contrasting the findings of Scruggs et al. (2003) for the girls.

While this intervention requires high organisation and supervision for it to be effectively implemented during playtime, it may engage school staff with the children in a more proactive manner compared to the traditional supervisory role (Evans, 1996). In general, though information concerning the types of games that were played during the intervention was not provided, the results suggest that a games approach is effective in increasing playtime physical activity levels in the short-term.

The medium-term effect of games equipment on elementary children's playtime physical activity has recently been investigated (Verstraete et al., 2006). Children in the intervention group engaged in significantly more MVPA during morning playtime, and more MVPA and VPA during lunch playtime compared to the control group. However, positive effects of the intervention were only noted during lunch playtime (Table 2.5), where boys gained greater increases in moderate activity compared to girls, and girls gained greater increases in VPA compared to boys. During morning playtime, boys MVPA and VPA levels decreased while girls' VPA also decreased (Verstraete et al., 2006). This may be explained by playtime duration. The organisation of equipment and games in PE lessons can account for up to a quarter of lesson time (McKenzie et al., 1997b). Applying this information to playtime, the longer lunch playtime may allow for the initial organization of the equipment compared to morning playtime, explaining the greater increases observed. Interestingly, boys accumulated their recommended daily physical activity through lunchtime alone following the intervention (Table 2.5), highlighting the effectiveness the intervention had on daily activity. This study builds on previous playtime-based studies by using a large sample size and investigating the effects of the intervention three months post-implementation. However, no immediate follow-up was conducted meaning that short-term changes in physical activity were not reported. This would have been useful to see whether children were more or less likely to use the games equipment across time. Furthermore, caution should be applied when interpreting the effects of the intervention on boys and girls' playtime activity, as 39% of the intervention group and 59% of the control group consisted of girls. Sex differences in playtime physical activity have been previously noted, and the intervention effects observed may be attributable to the unbalanced experimental groups. Lastly, a one-minute monitoring period was used, where bouts of high intensity activity may be masked by periods of rest or low intensity activity (Welk et al., 2000). This is typical of children's physical activity patterns. In general, however, the study suggests that a games equipment intervention is an effective method for increasing playtime physical activity when playtime duration increases.

2.5 Summary

The promotion of physical activity to children in the school environment has shown promise, whether playtime has been supplemented with additional structured activity breaks (Scruggs et al, 2003; Ernst, 2003; Ernst & Pangrazi, 1999), games playtimes (Connelly & McKenzie, 1995), equipment (Verstraete et al., 2006), or through the use of playground markings (Stratton, 2000; Stratton & Leonard, 2002; Stratton & Mullan, 2005). The results from playtime interventions indicate that physical activity levels and energy expenditure increase when environmental modifications and strategies are implemented. Changing the playground environment can create opportunities for physical activity engagement, and provide messages to the recipients about acceptable or unacceptable behaviours within the specific milieu (Cohen et al., 2000; Giles-Corti et al., 2005; Heath, 2003; Sallis & Owen, 1999). Drawing on ecological models of health promotion, playtime interventions enable children to be active by creating space on the playground, providing relevant equipment and improving access to activities within a safe environment (Welk, 1999). Current research has indicated that children enjoy playtime and take advantage of enriched playtime environments that use playground markings, obstacle courses and games and equipment to be physical active in this context. However, studies are limited by the generally small sample sizes selected from a small number of schools, and by the research design, as some studies have not used a control group or a follow-up period either in the short- or long-term. In addition, the long-term sustainability of these approaches is not known, as research has focused on the short- to medium-term benefits of these interventions. There is a need for empirical research employing multidisciplinary methods to establish children's activity levels and play behaviour, with a particular emphasis on determining the longitudinal effects of playtime-based interactions, to further knowledge of physical activity within this school context.

2.6 Aims of Thesis

The promotion of physical activity has been identified as a public health priority. In particular, enabling children to engage in physical activity during childhood may prevent the clustering of cardiovascular disease risk factors (Andersen et al., 2006), and since high levels of physical activity in childhood have been found to significantly predict high levels of physical activity in adulthood, despite low to moderate correlations being found (Telema et al., 2005), childhood activity may reduce the health risks associated with inactivity and benefit health in adult life (Blair & Connelly, 1996; Kohl & Hobbs, 1998). The school has been acknowledged as a logical setting for the promotion of physical activity to children (Cavill et al., 2001; Kohl & Hobbs, 1998; Sallis et al., 1992; Welk, 1999), as the majority of children attend school and a large proportion of the child population can be reached. Indeed, the school has a health education infrastructure that exists through the formal curriculum that educates children about the need for physical activity as well as developing their knowledge of how to be physically active (Killen & Robinson, 1988). It can be argued that the promotion of physical activity through activity interventions has largely been implemented through PE. In two recent reviews, Fairclough and Stratton (2005, 2006) discussed 18 interventions conducted in primary (elementary) school PE settings, and a further 10 that were implemented in middle and high school PE lessons. In comparison, playtime interventions have attracted little empirical attention. Table 2.2 identifies 9 published studies conducted in a playtime context, all of which have employed different methodologies over differing time frames (for example, immediate follow-up, 4-weeks post-intervention). Furthermore, the efficacy of playtime interventions in large samples of children and their sustainability has not been investigated. The purpose of this thesis, therefore, is to investigate the longitudinal effects of a playground markings and physical structures intervention (Zoneparc design, Youth Sport Trust, 2002) on children's physical activity levels during playtime.

As a number of studies have monitored physical activity levels during one playtime, one school day, and a range of seasons, the effects of day-to-day and seasonal variability on playtime physical activity levels (Aim 1) will be investigated. Seasonality has been initially explored by Stratton (1999), though physical activity levels across consecutive days in different seasons have not been reported. Aim 2 is to establish children's physical activity levels in a playtime context and assess its contribution to current physical activity guidelines, establishing the priority groups for interventions through examining differences in physical activity levels in different demographic variables (Welk, 1999). This will contribute to current knowledge base by investigating physical activity levels in a large sample of children using multiple objective measurement techniques. The use of multiple methods will enable comparisons to previous playtime studies that have used both heart rate telemetry and accelerometry, and it will provide an indication of both the cardiovascular strain (heart rate) and mechanical loading (accelerometry) of the intervention on the children. Aim 3 is to investigate the short-term effects (6-weeks) of the intervention on children's physical activity levels during playtime. This is an interesting consideration, as it provides an initial examination in to the effects of the intervention on activity levels, and provides a marker as to whether activity changes from the first follow-up measure to the second follow-up. This aims to build on the research design of Verstraete et al (2006), where the authors looked at the effects of the games equipment intervention on physical activity levels 3-months post-test yet were unable to clarify whether activity had increased or decreased across the study as no initial post-test measure was recorded. This study investigates enabling factors that may influence physical activity levels in a playtime context (Welk, 1999). Aim 4 is to assess the longitudinal effects of a playground markings and physical structures intervention on children's physical activity levels during playtime. This study aims to investigate the sustainability of the intervention on playtime physical activity levels, which is a question that has not been resolved in the literature to date. While the Youth Physical Activity Promotion Model (Welk, 1999) does not provide a framework concerning the sustainability of physical activity promotion strategies over time (Rowe et al., 2003), determining the longitudinal effects of enabling factors such as the playground environment would inform future intervention studies that aim to promote physical activity to children.

Aim 1: To determine the day-to-day and seasonal effects on children's physical activity levels during playtime (Chapter 4)

Aim 2: To quantify the physical activity levels of children during playtime and examine the contribution of playtime to daily physical activity guidelines using multiple methods (Chapter 5)

Aim 3: To evaluate the short-term effects (6-weeks) of a playground markings and physical structures intervention on children's physical activity levels during playtime (Chapter 6)

Aim 4: To assess the longitudinal effects of a playground markings and physical structures intervention on children's physical activity levels during playtime (Chapter 7)

CHAPTER 3
Methodology

3.0 Methodology

3.1 Recruitment of Schools and Participants

The City of Liverpool secured £400,000 from the Sporting Playgrounds Initiative in 2003 to redesign 20 primary school playgrounds. In order for schools to be awarded monies from the Sporting Playgrounds Initiative, they had to fulfil 2 initial criteria. These were:

- Inclusion within a School Sport Partnership and involvement in the School Sport Coordinator (SSCo) programme, and
- Location within Liverpool Sport Action Zone (SAZ) and/or one of the Education Action Zones (EAZ).

The final 20 primary schools were then selected based on socioeconomic status and indices of deprivation. A Needs Analysis conducted in 2000 showed that three wards within the SAZ boundary were in the 50 most deprived wards in England, and one ward had the 3rd highest rate of child poverty in the country (Liverpool SAZ, 2000). Seventy per cent of households did not have a car, and unemployment was 2-3 times the national average (Liverpool SAZ, 2000). Similar findings were reported during the project, with 4 of the 10 wards with the highest levels of child deprivation nationwide being in Liverpool (Noble et al., 2004).

Children in deprived areas are at risk of poor physical health and low educational attainment, as their families lack the resources that enable them to access activities that can benefit health and education (Noble et al., 2004). The Sporting Playgrounds Project in Liverpool aimed to develop the primary schools facilities, as many of the schools had inadequate facilities for sport and PE, and provide accessible physical activity opportunities to a large number of children. Furthermore, the schools suffered from a lack of equipment and storage space, and the cost of using other facilities (e.g. sports centres) restricted children's opportunities to engage in physical activity (Liverpool SAZ, 2000). Changing these enabling factors are important in the promotion of physical activity in youth (Welk, 1999). An overview of the selected experimental schools data and indicators from Ofsted inspections made prior to the start of the study are shown in Table 3.1.

The twenty schools who were selected to receive funding in order to redesign the playground environment based on the Zoneparc model were recruited into the study. A further 15 schools were invited to take part in a study to act as socioeconomic matched controls. Eleven control schools expressed interest in the study, and the principle researcher arranged a

Table 3.1: Summary of indicators from Ofsted reports for schools receiving funding through the Sporting Playgrounds Initiative. No report available[1]

School	Inspection Date	No on Roll	English not first language	Free School Meal Allocation[2]	Special Educational Needs Register	School Rating
1	June 2000	268	8.4%	63%	32%	Good
2	February 2001	126	40%	75%	35%	Effective
3	May 1998	534	10.1%	56%	50%*	Good
4	September 2001	237	1.7%	51%	37%	Improving
5			**No report available[1]**			
6	January 2002	167	4.2%	61%	31%	Improving
7	October 1999	269	13.4%	66.3%	38.7%*	Okay
8	November 2001	171	0%	72%	26.9%*	Good
9	May 1998	289	9%	75%	23.1%*	Developing
10	November 2000	190	33%	80%	46.3%*	Improving
11	March 2002	418	1.4%	32%	15.6%*	Not yet effective
12	November 1997	235	NR	37%	14%*	Good
13	January 2001	414	2%	48%	25%	Effective
14	March 2001	323	2%	42%	21.4%*	Good
15	July 1999	144	NR	77%	100%	Improving
16	December 2002	330	0.9%	31%	15.2%*	Satisfactory
17	June 1998	319	NR	11.9%	19.1%	Good
18	December 2001	415	0.2%	60.7%	37.8%*	Satisfactory
19	December 2003	334	0.6%	60%	28.7%*	Very good school
20	May 2001	197	0%	60.9%	21%*	Effective

Key: * denotes school registered needs; NR = Not reported

[1] No report was available for school 5 prior to the study taking place as the previous school on the site was closed by Ofsted after being identified as a failing school.

[2] Children are eligible for free school meals if their parents are on income related benefits.

meeting with the Head Teacher of each school in order to outline the study's procedures and objectives. All eleven control schools agreed to participate in the project at this stage. Children from participating schools were sent a formal letter outlining the project, its assessment methods, and an attached parental consent form (Appendix 1). Consent was given by the parent/carer for the duration of the study. Children returned the parental consent forms to the schools, which were collected by the researcher. Eighteen children (equal numbers of boys and girls) were then randomly recruited into the study using returned consent forms. Children in primary schools were selected equally from the infant (Year 2) and junior (Years 3-5) departments. Junior school children were selected from Years 3-5. This was to enable comparisons between previous playground studies, and to analyse potential age-related declines in children's physical activity levels (Biddle et al., 2004). Year 6 children were excluded from the physical activity monitoring phase, as they would not be available for the longitudinal component of the study. Children with SEN statements were not excluded, as some school populations had a large percentage of students with statements. Schools were informed of the children selected. During each testing day, the randomly selected children underwent a familiarisation period with the monitoring equipment at the start of the school day. The requirements of the project were explained to the children at this stage, and verbal assent was obtained from the children prior to the fixing of monitoring equipment. All children wore the monitors for the school day, removing them at the conclusion of the last playtime. A member of school staff supervised the fitting and removal of the monitors alongside the principle researcher. The research protocol and design received ethical approval from the Liverpool John Moores University Ethics Committee.

3.2 Research Design and Settings

All visits to schools occurred in school term time, with care taken to avoid times when children would sit their Standard Attainment Tests, or be out of school on external trips. The research project was split into four phases:

1. The exploratory study into seasonal and day-to-day variability effects on physical activity and behaviour during school playtime was conducted over two academic years.
2. Baseline measures.
3. 4-6 weeks post-intervention measures.
4. 6 months post-intervention measures.

Data was collected over three academic years (2002-2003, 2003-2004, 2004-2005). An overview of the design is shown in Figure 3.1.

Each school was visited three times during the course of the main study. Data were collected from all school playtimes on one day when children were allowed on to the playground. Data recorded during wet playtimes were discarded and repeated on a separate day. No schools had playground markings prior to the start of the study. The intervention schools each received new multicolour playground markings and physical structures as part of the Sporting Playgrounds Project (SPP), whilst the control schools received no playground markings through the SPP initiative. Small pieces of sports equipment such as skipping ropes and footballs were available for use in all school playgrounds throughout the duration of the study. Each school employed at least 3 lunchtime supervisors during lunch playtime who had not been trained in the promotion of playground physical activity. Schoolteachers supervised morning and afternoon playtime periods.

3.3. Instruments

In order to demonstrate the effectiveness of interventions on children's physical activity levels, the accurate quantification of physical activity against current recommendations is important (Pate et al., 1995). Brage et al (2005) note that physical activity is difficult to measure precisely, particularly in free-living situations. Monitoring activity in children is compounded further by the sporadic and intermittent nature of the activity behaviour (Bailey et al., 1995; see 2.1.2 for detailed discussion). This creates issues surrounding the monitoring of activity, as the instrumentation used must be sensitive enough to detect and record children's activity patterns and changes in physical activity levels following the intervention (Welk et al., 2000). With young children experiencing difficulty in accurately recalling their physical activity and there being concern about overestimation of activity using self-report measures (Pate et al., 1994; Trost, 2001), the use of objective measures has increased in recent years. Whilst objective measurement instruments have associated limitations (acknowledged below), they record the accumulation of intermittent free play towards activity guidelines (Sirard & Pate, 2001). Furthermore, they provide reliable information on children's physical activity patterns within given days (Trost et al., 2000).

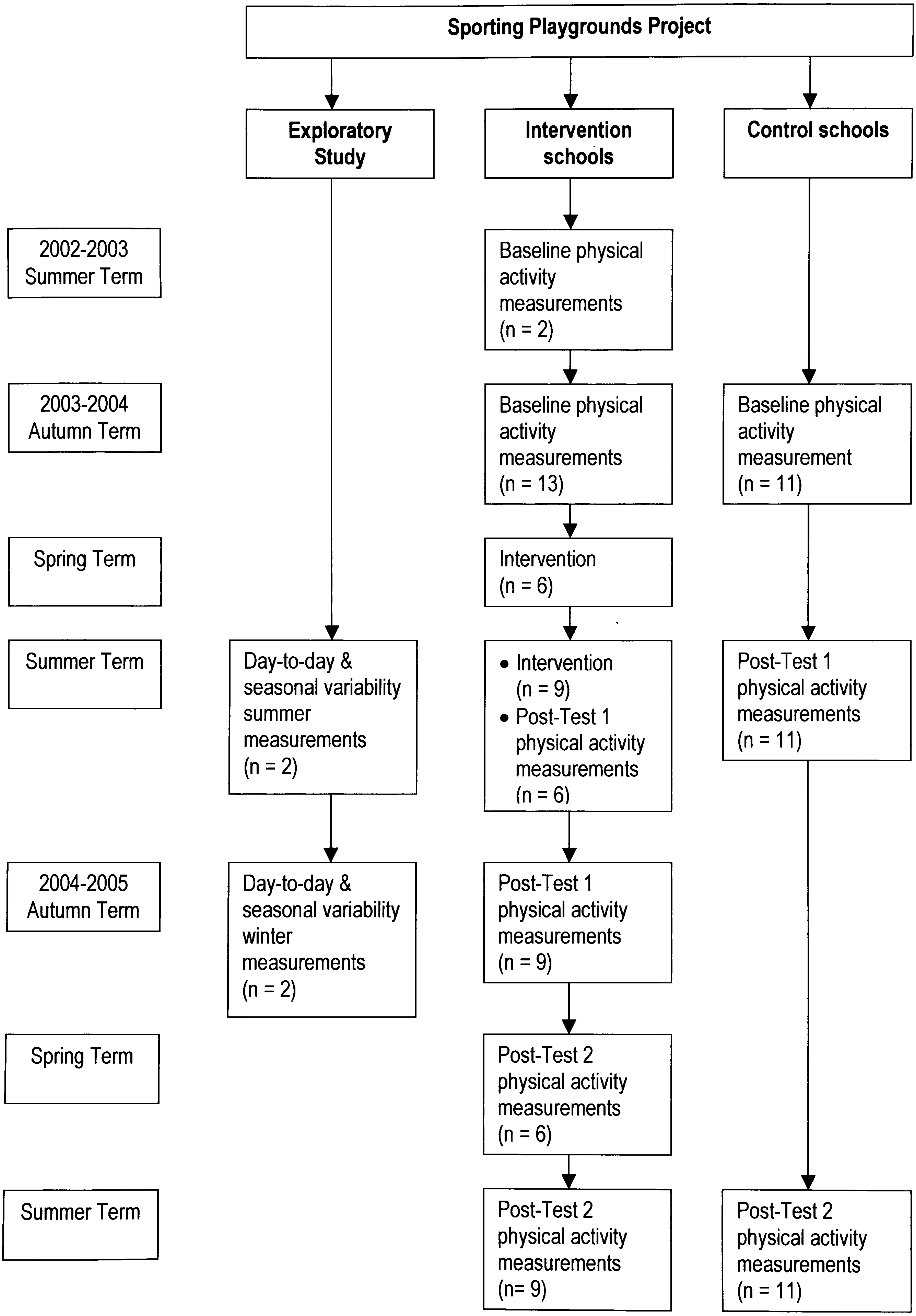


Figure 3.1: Overview of the research design. Numbers of schools involved in each phase of the research are shown.

3.3.1. Accelerometry

Accelerometers measure the frequency, intensity and duration of human movement (Dishman et al., 2001; Mâsse et al., 1999; Rowlands et al., 1999). As acceleration is defined as the rate of change of velocity in a given time, accelerometers assess physical activity through the body's acceleration (Welk, 2002). Accelerometers are relatively unobtrusive, easy to use, can store large amounts of data, and require little participant burden (Coe & Pivarnik, 2001; Dishman et al., 2001; Nilsson et al., 2002; Rowlands, 2001; Sirard & Pate, 2001; Welk & Wood, 2000). However, they are limited by their capacity to assess static physical activity, or activities that require little body movement such as cycling (Dishman et al., 2001). Tri-axial accelerometers have been suggested to be better suited for measuring children's physical activity, as they may be more sensitive to children's activities such as climbing (Eston et al., 1998; Ott et al., 2003). However, since the recordings from the tri- and uni-axial accelerometers are highly correlated ($r = 0.86$; Ott et al., 2003), it is likely that uni-axial accelerometers accurately reflect the frequency, duration and intensity of the majority of children's physical activity.

A number of outcome variables can be obtained from accelerometry output. These include raw counts, prediction of energy expenditure and time spent engaged in physical activity (Welk, 2002). In terms of public health research, the time spent engaged in physical activity is useful as it links to current activity recommendations (Welk et al, 2000). However, this approach is also limited as it uses derived cut points for determining physical activity intensity and duration (Dishman et al., 2001; Welk, 2002). The majority of cut points used in empirical research have been derived using adult populations in laboratory settings (Freedson et al., 1998; Hendelman et al., 2000; Swartz et al., 2000). However, adult cut points may not be accurate in determining the activity levels of children as children's resting metabolic rates decrease across childhood yet cut points are based on adult metabolic rates (Puyua et al., 2002). There is also concern in the variation cut points show in detailing physical activity intensity, particularly at light and moderate intensities (Strath et al., 2003). Only at high intensity activity were no differences observed between different cut points (Strath et al., 2003). Strath and colleagues (2003) stated that the cut points might be too narrow to accurately detail moderate intensity activity. Child specific cut points were described by Puyua et al (2002) who used activity energy expenditure in a small sample of 26 children who undertook a range of active and sedentary behaviours such as jogging, skipping, and playing computer games. However, the children ranged in age from 7 to 16, which could have affected the results due to decreasing metabolic rates. Furthermore, the use of one-minute epochs may have influenced the results as longer measurement periods may obscure short bursts of high intensity physical activity (Nilsson et al., 2002; Welk et al., 2000), which is characteristic of children's physical activity patterns (Bailey et al., 1995).

Children's physical activity is characterised by spontaneous short bursts of high intensity activity interspersed with low or moderate physical activity (Bailey et al., 1995). It has been suggested that shorter epochs could provide a more detailed view of the intensity, duration and an indication of the frequency of the children's physical activity in free-living situations (Nilsson et al., 2002). Nilsson et al (2002) used a 5-second epoch in their study of children's free-living physical activity. Whilst the cut points for physical activity intensity were based on Freedson and co-workers adult derived thresholds, which was a limitation of this study, this study was the first, to the author's knowledge, to use shorter monitoring time frames with children in field settings. Despite its limitations, Nilsson et al's (2002) cut points for 5 second epochs were used in the current study, as they have previously been applied in field settings and been found to provide a detailed picture of children's physical activity patterns. No recommendations from playtime studies have been made concerning physical activity intensities, for previous studies have used raw counts as opposed to cut points (Dale at al., 2000; Mota et al., 2005b).

The children's physical activity levels during playtime were assessed using the ActiGraph (Model 7164, MTI Health Services, Florida, USA). It is a small uni-axial accelerometer (5.1 x 3.8 x 1.5 cm, 42.6g) that measures vertical acceleration and deceleration of human motion between the magnitudes of 0.05-2G. The detected accelerations are filtered, converted to a numerical value and subsequently summed over a specified time interval (epoch), which is defined by the user prior to the commencement of data collection (Tryon & Williams, 1996). The recorded counts for each epoch represent the intensity of the activity undertaken during that time period. At the end of each epoch, the summed value is stored in the memory and the ActiGraph is automatically reset to zero (Tryon & Williams, 1996). All accelerometers were calibrated before use in the study (Actigraph calibrator CAL 71, MTI Health Services, Florida, USA). In this study, a 5 second epoch was used to collect the raw data during playtime. Data were downloaded using a reader interface unit connected to a computer using the ActiSoft Analysis Software Version 3.2 (MTI Health Services, Florida, USA). Data were then analysed using customised macros which determined the amount of time children spent in moderate, high and very high intensities respectively using activity cut-points of 163-479, 480-789, and ≥ 790 counts per five-second epoch during each playtime period (Nilsson et al., 2002). The macro enabled the start and end time for each playtime period to be specified, and was subsequently adjusted for children in each school to account for playtimes starting at different times. The outcome variables extracted from the macro were time spent in MVPA and VPA. MVPA was defined as the summed total time spent in each activity intensity threshold across all playtimes on one school day. VPA was defined as the summed total time spent in high and very high intensity activity. Total relative (percentage) time spent within each activity threshold, that is, MVPA and VPA during daily school playtime were then calculated and used in the subsequent analyses throughout the thesis.

3.3.2. Heart Rate Telemetry

Heart rate is a widely used, objective measurement of the relative stress that physical activity places on an individual's cardiopulmonary system (Armstrong, 1998; Eston et al., 1998; Janz, 2002). This method is not a direct measure of physical activity (Armstrong, 1998). It is reliant on the linear relationship between oxygen uptake and heart rate in order to determine the frequency, intensity and duration of a movement (Armstrong, 1998; Dishman et al., 2001; Eston et al., 1998; Haskell et al., 1993), where the response of the heart to increasing levels of physical activity is directly proportional to the movement intensity and is driven by the rising need for skeletal muscle to receive oxygen (Janz, 2002).

Heart rate telemetry is a relatively inexpensive method of assessing physical activity in small to moderate sized samples (Epstein et al., 2001; Sirard & Pate, 2001). The benefits of heart rate monitoring include its ease of use over extended periods of time (Dishman et al., 2001; Eston et al., 1998; Janz, 2002; Logan et al., 2000), it is socially acceptable (Armstrong, 1998; Dishman et al., 2001), unobtrusive (Armstrong, 1998; Janz, 2002; Vuori, 1998), and requires little participant burden (Sirard & Pate, 2001). Whilst heart rate can be influenced by factors other than body movement, including emotional status such as fear, anger, stress (Epstein et al., 2001; Haskell et al., 1993; Janz, 2002), temperature and climatic conditions (Armstrong, 1998; Janz, 2002), medication (Sirard & Pate, 2001), and the muscle groups performing the activity (Armstrong, 1998), it has been found to be valid and reliable for use in a paediatric population (Logan et al., 2000; Sirard & Pate, 2001).

The Polar Team System (Polar Electro Oy, Kempele, Finland) heart rate monitor was used to measure the children's physiological response to playtime. Heart rate was recorded every 5 seconds, which was short enough to detect random bouts of movement (Eston et al., 1998; Rowlands, 2001). The Polar Precision Performance™ software was used to analyse playtime physical activity, which was expressed as percentage heart rate reserve (HRR). This method provides an estimate of the intensity of physical activity that an individual engages in (Janz, 2002). HRR is defined as the difference between maximal and resting heart rate, and accounts for age and sex differences, as well as changes in children's RHR values (Epstein et al., 2001; Janz, 2002; Stratton, 1996; Trost, 2001). The children's resting heart rate (RHR) was determined by averaging the 5 lowest heart rate values recorded during each daily school visit across the study (Janz, 2002). This definition was used as it is the most common in the literature, and it takes into account the effect that age and fitness can have on children's RHR (Logan et al., 2000). Maximum heart rate was set at 200 beats·min $^{-1}$ (Stratton, 1996). Research has shown that maximal heart rate is stable through childhood and adolescence at a heart rate of approximately 200 beats·min $^{-1}$ (Rowland, 1993). Epstein et al's (2001) review of heart rate studies involving children indicated that maximal heart rates from 11 studies were 199.8 ± 3.0 beats·min $^{-1}$. Physical activity intensity was then determined using HRR threshold values of 50 (HRR_{50}) and 75 (HRR_{75}) per cent to represent moderate-to-vigorous physical activity (MVPA) and vigorous-physical activity (VPA) respectively (Stratton, 1996). HRR_{50} equates to a brisk walk (Armstrong & Welsman, 1997), and HRR_{75} equates to a measure of VPA as it is thought that this intensity increases cardiorespiratory fitness in children (Payne & Morrow, 1993; Stratton, 2000). These threshold values were calculated for every child on each day of measurement using their calculated RHR and maximum heart rate (Stratton, 1996). The percentage absolute time each child spent at or above HRR_{50} and HRR_{75} during playtime for each phase of the research was then calculated by identifying the start and end time of the playtime periods on the individual heart rate curves in the manufacturer's software and used in subsequent analyses.

3.4. Procedures

3.4.1. Anthropometry

Measurements of stature and body mass were taken at each phase of the project using standardised procedures (Norton et al., 1996).

3.4.1.1. Stature

Measurements of stature were recorded using analogue Leicester Height Measure (Seca Ltd., Birmingham, UK). Children were measured without footwear whilst wearing minimal school uniform (trousers/skirt, shirt) prior to the fitting of the physical activity monitoring equipment at the start of the school day. Measurements were recorded to the nearest 0.1 cm.

3.4.1.2. Body Mass

Measurements of body mass were recorded using analogue Seca scales (Seca Ltd., Birmingham, UK). Children were measured without footwear whilst wearing minimal school uniform (trousers/skirt, shirt) prior to the fitting of the physical activity monitoring equipment at the start of the school day. Measurements were recorded to the nearest 0.1 kg.

3.4.1.3. Body Mass Index (BMI)

BMI is a frequently used estimation of overweight and obesity prevalence in child and adult populations (Chinn & Rona, 2001). In order to determine whether the children were normal weight, overweight or obese for their age, the measurements of body mass and stature were used to determine each child's BMI score throughout the duration of the study. BMI was calculated using (weight (kg)/height^2 (m)). Children were classified as normal weight, overweight or obese using Cole et al's (2000) age specific international cut off points.

3.4.2. Physical Activity Assessment

3.4.2.1. Heart Rate Telemetry

Eighteen children per school wore heart rate monitors for one school day at each measurement period. The lightweight heart rate monitors were attached around the children's chest using an adjustable elastic strap (Figure 3.2). Heart rate monitors were fitted to the children at the beginning of the school day following a familiarisation period where children became accustomed to the monitors. During this time children were instructed to seek the researchers for refitting if the monitors became detached. Children were then asked to follow their normal daily routine. The monitors were worn during morning, lunch, and where applicable, afternoon playtime. During this time children were instructed to seek the researchers for refitting if the monitors became detached. Children were then asked to follow their normal daily routine. Monitors were removed at the end of the school day.

Figure 3.2: Positioning of heart rate monitor

Figure 3.3: Positioning of accelerometer

3.4.2.2. Accelerometry

Due to equipment availability, in addition to a heart rate monitor, ten children per school wore an accelerometer for one school day at each measurement period. Accelerometers were fitted to the children's right hip using a tightly fitted elastic belt at the start of the school day following a familiarisation period where children became accustomed to the monitors (Figure 3.3). During this time children were asked to follow their normal daily routine. The monitors were worn during morning, lunch, and where applicable, afternoon playtime. During this time children were instructed to seek the researchers for refitting if the monitors became detached. Children were then asked to follow their normal daily routine. Monitors were removed at the end of the school day and the data immediately downloaded.

3.5. Data Analysis

A range of statistical techniques was used to analyse the data in the following chapters. An overview of the analyses is provided below, whilst specific information concerning the variables analysed are identified in the relevant chapters.

3.5.1. Intraclass Correlation (ICC)

Intraclass correlation (ICC) is a method of determining reliability between two or repeated measures on the same individual (Vincent, 1999). That is, the ICC investigates whether an individual's score is consistent over time (Baranowski & de Moor, 2000). The ICC is sensitive to changes in the mean scores in the data, and the order of change in data (Vincent, 1999). If the order of the subject scores and the mean values obtained on subsequent measures do not significantly change, then the resulting ICC value will be high (Vincent, 1999). High ICCs indicate that there is no significant variability in the measure being analysed (Baranowski & de Moor, 2000). ICC was used to examine the consistency in children's physical activity levels across consecutive days in the exploratory study (Chapter 4). A two-way analysis of variance was used to calculate the ICC, where the criterion score that was used in the analyses was the mean of the repeated days results for each child retained in the analyses (Baumgartner et al., 2003). Trial to trial variance was not considered to due to be measurement error, but to changes in children's physical activity levels on the school playground (Baumgartner et al., 2003). This enabled the author to investigate whether children who, for example, were highly active on one day were also highly active on the following day. This was investigated for both the summer and winter data collected. A reliability value of 0.70 or higher was considered to demonstrate acceptable reliability across the days in this study (Vincent, 1999).

3.5.2. Analysis of Covariance (ANCOVA)

Analysis of covariance (ANCOVA) is a statistical technique that combines an analysis of variance (ANOVA) with regression analysis (Stevens, 1996; Vincent, 1999). It enables researchers to control for potential sources of variation that were not controlled for in the experiment (Stevens, 1996; Tabachnick & Fidell, 2001). Furthermore, ANCOVA can equate groups statistically on factors that are considered to influence the dependent variable (Tabachnick & Fidell, 2001; Vincent, 1999). These factors are termed covariates, and can have "disproportionate effects" (Vincent, 1999, p. 198) on different experimental groups. In an ANCOVA, the independent variables scores are adjusted based on the specified covariates, which remove their influence on the dependent variables (Vincent, 1999). The major question in an ANCOVA is are mean differences among the groups on the adjusted dependent variable likely to have occurred just through chance alone (Tabachnick & Fidell, 2001). ANCOVA assumes that there is a linear relationship between the covariate and the dependent variable, where increases or decreases in one are reflected by increases or decreases in the other.

ANCOVA was used in the exploratory study into seasonal and day-to-day variability effects on physical activity and behaviour during school playtime. The covariate was BMI, for research suggests that children with a higher BMI have lower fitness levels than their normal weight peers (Stratton et al., in press), and are more likely to engage in sedentary behaviours (Taylor et al., 2005). This enabled the analysis of children's physical activity levels across days and seasons when controlling for the effects of their BMI score.

3.6.3. Multi-Level Modelling (MLM)

In the social world, many data have an inherent hierarchical structure than can affect them (Gorard, 2003). For instance, a person's behaviour can be explained by taking into account the context, such as a school or organisation, in which the behaviour occurs (Duncan et al., 1996). The person in this example would form the lowest level of the hierarchical structure, and the organisation would form the second level. Therefore, the individual is nested within the organisation (Maas & Hox, 2004). Other examples of hierarchical structures include longitudinal research, where repeated observations are nested within the individual (Maas & Hox, 2004).

Ecological models highlight the importance of considering how a person's environment can influence behaviour both directly and indirectly (Bauman et al., 2002; King et al., 2002; Sallis & Owen, 2002). Indeed, the characteristics of a built environment, such as a school playground, can affect behaviour (Sallis & Owen, 2002); In relation to children's physical activity during school playtime, their behaviour can be considered to be closely connected to the social context of the school that they attend (Duncan et al., 1996). Children's physical activity levels can be a result of a combination of individual characteristics such as the sex of the child, their playground behaviour, fitness levels and social competencies, and school characteristics such as the equipment provided, supervision, the playground culture, number of pupils attending the school and the physical playground environment. This highlights that children at one school will be exposed to different behavioural influences compared to children at another school (Duncan et al., 1996), as different processes affect different individuals (Wu & Wooldridge, 2005).

The use of multilevel modelling (MLM) is considered to be the most appropriate data analysis technique for nested data (Goldstein, 1995; Plewis & Fielding, 2003). MLM captures the individual variation in behaviour, and the effect of the context in which that behaviour occurs (Bauman et al., 2002; Duncan et al., 1996). Since physical activity levels vary across individuals and contextual effects vary across schools, MLM builds on traditional single level regression analyses by relaxing the assumptions of constant slopes and intercept to model individual regression lines for each school (Mâsse et al., 2002). Furthermore, it can describe the population trends in a response and model variation around a response at different levels (Plewis & Fielding, 2003).

MLM has several advantages over conventional ANOVAs, which are often used to investigate differences between groups in empirical research. An assumption of ANOVA is independence of observations (Harrison, 2003; Vincent, 1999). However, in longitudinal research, observations are generally not independent as the measurements are nested within subjects and are correlated (Quené & van den Bergh, 2004). No assumptions concerning sphericity are required to conduct MLM. A second advantage is that when three or more measurements have been taken from an individual, MLM is robust against missing data (Mâsse et al, 2002; Harrison, 2003; Quené & van den Bergh, 2004). MLM can estimate intervention effects over time whilst making use data from children with incomplete follow-up (Quené & van den Bergh, 2004). This is extremely beneficial in studies using relatively small samples (Harrison, 2003). This is compared to repeated measures ANOVA, where if a participant misses an observation or measurement, all data from that participant have to de discarded. MLM therefore allows the analysis of incomplete data sets (Quené & van den Bergh, 2004).

One of the main problems concerning MLM pertains to power and sample size calculations (Mâsse et al, 2002). MLM power calculations are complicated by variance across groups, and the presence of intraclass correlations (Mâsse et al, 2002). However, using MLM can benefit power over single level analyses such as ANOVA as it accounts for the individual differences that occur (Harrison, 2003). A second problem relates to the complexity of MLM and its ease of use (Gorard, 2003; Quené & van den Bergh, 2004). Gorard (2003) is critical about MLM in that it is not easily accessible and understood to a wider audience, and the results obtained are difficult to compare across studies in disciplines, which do not widely use MLM to analyse data. The primary use of MLM in sports science has been concentrated in physiological studies that examined the effects of age, maturation and gender, for example, on oxygen uptake (Armstrong & Welsman, 2001). The use of MLM to examine physical activity levels has not, to the author's knowledge, been widely used.

Despite these issues, MLM is a suitable analysis technique for analysing nested data (Goldstein, 1995; Plewis & Fielding, 2003). To investigate the effects of the intervention on children's playtime physical activity, this thesis will use association models to determine the association between the main independent variable, that is the intervention effect, and children's physical activity levels (Twisk, 2006). In association models, the intervention effect needs to be evaluated as accurately as possible, therefore the effect should be corrected for potential confounders (Twisk, 2006). It is possible to investigate the covariance between the school intercepts and slopes on the intervention term. This enables the analysis of how the intercepts and slopes differ from each other on the outcome variable (Twisk, 2006). Furthermore, potential effect modification should be evaluated. This is where interactions between the covariates and the intervention term are constructed to identify whether the intervention effect is different for different subgroups (Twisk, 2006). The effect of pupil-level and school-level covariates, covariance, and the interaction of the covariates with the intervention term will be investigated in the main study.

CHAPTER 4

Day-to-Day and Seasonal Effects on Physical Activity Levels during Playtime

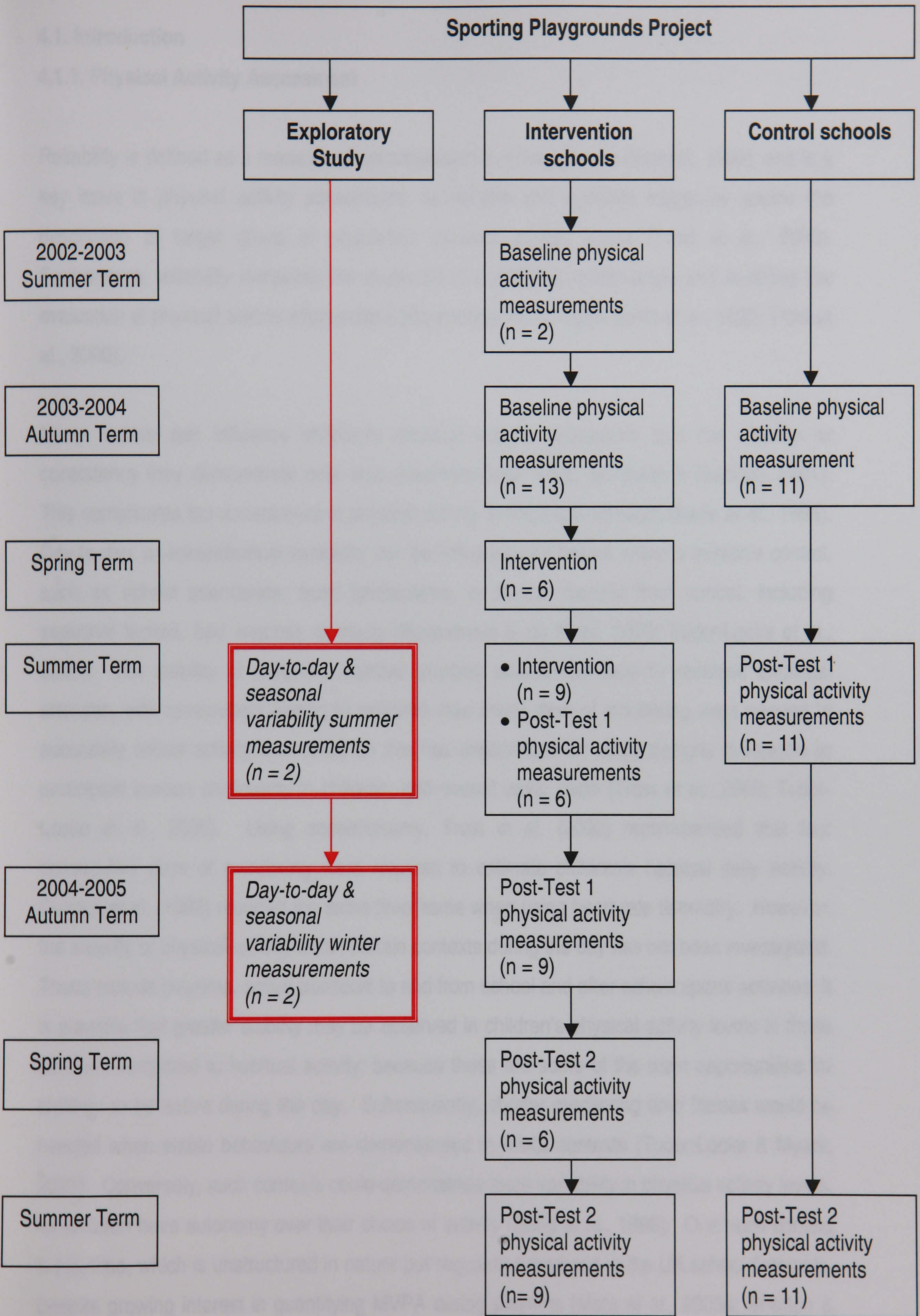


Figure 4.1: Stage of research design. Numbers of schools involved in each phase of the research are shown.

4.1. Introduction

4.1.1. Physical Activity Assessment

Reliability is defined as a measure of consistency in a measurement (Vincent, 1999), and is a key issue in physical activity assessment, as reliable and accurate measures enable the description of target group or population physical activity levels (Trost et al., 2000). Furthermore, reliability increases the likelihood of identifying relationships and enabling the evaluation of physical activity interventions (Baranowski et al., 1999; Sallis et al., 1992; Trost et al., 2000).

Many factors can influence children's physical activity behaviours and the stability or consistency they demonstrate over time (Benhiam-Deal, 2005; Boreham & Riddoch, 2001). This complicates the assessment of physical activity in empirical research (Sallis et al., 1995). Day-to-day, or intraindividual variability can be influenced by factors within a person's control, such as school attendance, sport participation, or factors beyond their control, including seasonal factors, bad weather, or injury (Baranowski & de Moor, 2000; Tudor-Locke et al., 2005). The stability of children's habitual physical activity has recently received empirical attention, with researchers aiming to establish how many days of monitoring were needed to accurately reflect activity over time, as this has implications on study designs in relation to participant burden particularly in children, and overall study costs (Trost et al., 2000; Tudor-Locke et al., 2005). Using accelerometry, Trost et al. (2000) recommended that four consecutive days of monitoring were required to estimate children's habitual daily activity. DuRant et al. (1992) reported the same time frame when using heart rate telemetry. However, the stability of physical activity within certain contexts during the day has not been investigated. These include playtime, active transport to and from school and after school sports activities. It is possible that greater stability may be observed in children's physical activity levels in these contexts compared to habitual activity, because these are some of the main opportunities for children to be active during the day. Subsequently, shorter monitoring time frames would be needed when stable behaviours are demonstrated in these contexts (Tudor-Locke & Myers, 2001). Conversely, such contexts could demonstrate more variability in physical activity levels, for children have autonomy over their choice of activity (Sallis et al., 1995). One such context is playtime, which is unstructured in nature but regularly scheduled in the UK school timetable. Despite growing interest in quantifying MVPA during playtime (Mota et al., 2005a; Stratton & Mullan, 2005), issues surround the measurement of activity and warrant further study. These include: a) how does children's playtime activity vary day-to-day; b) does children's playtime activity vary across seasons; and c) how many days of monitoring are representative of typical playtime physical activity levels?

4.1.2. Day-to Day Variability

A number of factors can influence the variability in children's physical activity levels during playtime. These factors include the equipment provided (Zask et al., 2001), the management of the playground (Evans, 1996), playtime duration (Zask et al., 2001), the organisation of games and activities by school staff, physical activity prompts (McKenzie et al., 1997a), numbers in the playground due to school size (Zask et al., 2001), dominant activities such as football in the playground (Boyle et al., 2003), activity choices (Lever, 1976; Pellegrini et al., 2004), play space and surface available (Boyle et al., 2003; Evans, 1996; Stratton, 1999), the size of the children's social group (Beth-Halachmy, 1980), and the length of confinement prior to playtime (Pellegrini & Davies, 1993). These support Sallis et al. (1995) and their notion that variability in physical activity can be attributed largely to transient environmental and social factors. However, these factors may not be as transient as they appear, for playtime occurs at the same time each day for the same duration, children have the opportunity to plan what activities they wish to engage in (Blatchford, 1998), and the playground hierarchy often dictates what games can be played in which space and with whom during playtime (Blatchford, 1998).

There is no consensus about how long physical activity should be recorded during playtime in order to accurately document playtime activity and behaviour. Previous investigations that have examined activity during playtime have used a variety of measurements periods, such as one playtime (McKenzie et al., 1997a; Stratton, 1999; Stratton & Mota, 2000), one day (Stratton, 2000; Stratton & Leonard, 2002; Stratton & Mullan, 2005) and three days (Mota et al., 2005a). This has limited the comparisons that can be made between the findings in regard to playtime activity levels. Studies that aim to establish whether one day or multiple days of monitoring are needed in order to accurately document playtime physical activity levels may help to inform future studies and enable more detailed comparisons between them.

4.1.3. Seasonal Variability

Seasonal factors have been found to influence children's physical activity participation. Researchers that have assessed habitual physical activity have found that activity levels vary according to season, with children reported to be more active in the summer months compared to the winter months (Hagger et al., 1997; Loucaides et al., 2003; Shephard et al., 1980), though physical activity has largely been assessed through self-report. Baranowski and colleagues (1993) however reported that children's outdoors physical activity was lower during the summer than the winter months, indicating that location can also impact on children's activity. Reasons for seasonal differences in habitual physical activity levels have been attributed to limited daylight hours, which do not affect playtime, and restrictions that adverse weather place on outdoor physical activity during the winter months (Hagger et al., 1997; Loucaides et al., 2003). Temperature and humidity may influence outdoor activity in the summer months, though this may not be as influential in the UK compared to warmer countries (Baranowski et al., 1993).

The impact of seasonality on playtime physical activity however has contrasted with the majority of results from habitual activity studies (Stratton, 1999). Using heart rate telemetry to quantify physical activity levels, children were more active in the winter months (January - February) compared to summer months (June – July; Stratton, 1999), though these differences were not significant. Although the opportunity to go outside during playtime is more likely to be cancelled during the winter than summer due to inclement weather, higher activity levels during winter might be associated with a thermoregulatory need to keep warm (Stratton, 1999). Furthermore, children may be taking advantage of playtime to engage in physical activity due to limited opportunities after school with regard to daylight hours. Interestingly, direct observation of the children's activity during playtime indicated that there were no differences in the children's choice of activity, suggesting that behaviour was consistent over time (Stratton, 1999). This contrasts with the findings of behavioural studies, which have indicated that as the school year progresses, the nature and frequency of children's play behaviours and choice of activities change (Pellegrini et al., 2004). Whilst Stratton's (1999) study was limited in that is used a small sample size from one school, and monitored morning playtime only, it indicates that further studies are needed to develop understanding of the impact of season on children's playtime physical activity and play behaviours.

4.1.4. Aims and Objectives

There has been limited empirical attention that has focused on physical activity levels within the primary school playground, and the day-to-day and seasonal variability of children's physical activity during playtime has not been reported. Therefore, the purpose of this study was to investigate whether children's physical activity during playtime differed across consecutive schools days in the summer and winter school terms (Aim 1, page 48).

4.2. Method

4.2.1. Subjects

Fifteen boys and 19 girls (aged 6-10 years; mean age = 8.3 ± 1.1 years) randomly selected from 2 primary schools in the North West of England returned signed parental informed consent to participate in the study. The schools were located in the same geographical area of high social and economic deprivation in a large urban city (Noble et al., 2004). The study was conducted over two consecutive academic years, with physical activity being measured in the summer term of the first academic year and the winter term of the second academic year.

4.2.2. Study Overview

All children participating in the study followed their normal daily school routine. Physical activity was monitored using heart rate telemetry during morning and lunch playtimes for 10 days, 5 consecutive days in the summer term and 5 consecutive days in the winter term. Neither school had an afternoon playtime. The mean daily playtime time available for the children to engage in physical activity in the playground was 86 ± 11.8 minutes in the summer and 80 ± 15.3 minutes in the winter. The average temperature during playtime in the summer was 19°C, whilst for winter it was 10°C. Small pieces of sports equipment such as skipping ropes and footballs were available for use in both school playgrounds throughout the duration of the study. Each school employed at least 2 lunchtime supervisors during lunch playtime who had not been trained in the promotion of playground physical activity. Schoolteachers supervised the morning playtime. The research protocol received ethical approval from the University Ethics Committee.

Seventeen children per school were recruited into the study using returned parental consent forms. The children's physical activity during school playtime was monitored on five consecutive school days (Monday to Friday) in the summer term (June 2004) and the winter term (November 2004). Measurements of body mass (to the nearest 0.1 kg) and stature (to the nearest 0.1 cm) were recorded using Seca scales (Seca Ltd., Birmingham, UK) and the Leicester Height Measure (Seca Ltd., Birmingham, UK) on the first day of testing in each school in the summer and winter terms prior to fitting the heart rate monitors. The subsequent procedures followed the method described in Chapter 3.

4.2.3. Data Analysis

Due to student absence in the summer term, and weather disruption in the winter term, three complete consecutive days (Monday to Wednesday) were obtained and used for analysis. Heart rate data were downloaded using the Polar Team System Interface and analysed as described in Chapter 3 using the Polar Precision Performance™ 3.0 Software (Polar Electro Oy, Kempele, Finland). Of the thirty-four children monitored in this study, 20 of the sampled children (10 boys, 10 girls) provided complete data sets (Monday to Wednesday in both terms) and were retained for analysis. Four children's data were lost due to incomplete heart rate curves being obtained (3 boys, 1 girl), and two children had left the schools in the winter term (1 boy, 1 girl). Eight children's data were lost due to absenteeism from school on one or more of the testing days retained for the analyses (1 boy, 7 girls).

All data were analysed using the Statistical Package for the Social Sciences (SPSS) version 10. The dependant variables were percentage of time spent in MVPA and VPA. The independent variables were season (summer, winter) and day (Monday, Tuesday, Wednesday). As the study primarily considers seasonality and day-to-day variability, and because of the small sample size used, boys and girls data were combined to increase statistical power (Stratton, 2000). Means and standard deviations were calculated to describe the physiological characteristics of the children, and differences between children with complete data and those with incomplete data were explored using one-way ANOVAs. Intraclass correlations (ICC) were used to indicate whether children's physical activity was consistent over time; that is, highly active children on one day are highly active on another day. Values above .70 were considered as demonstrating acceptable reliability (Vincent, 1999). A 3 x 2 (day x season) repeated measures analysis of covariance (RM ANCOVA) was used in order to analyse day and seasonal differences on the dependent variables. BMI was used as a covariate to account for changes in children's stature and body mass across the duration of the study. The alpha level was set at $p < 0.05$.

4.3. Results

The mean (± SD) values for the descriptive data are shown in Table 4.1.

Moderate-to-Vigorous Physical Activity (MVPA).

ICC: In summer, the ICC ranged from 0.71 to 0.85 for two days, and the value for three days was 0.83. In winter, the ICC ranged from 0.53 to 0.81 for two days, and the value for three days was 0.71.

RM ANCOVA: RM ANCOVA revealed that there were no main effects for day, $F(2, 14) = 0.52$; $p > 0.05$, and season, $F(2, 14) = 0.20$; $p > 0.05$. There was a trend for physical activity levels to be higher in winter than summer, though this trend was not significant (Table 2). The day x season interaction was not significant ($p > 0.05$).

Vigorous Physical Activity (VPA).

ICC: In summer, the ICC ranged from 0.42 to 0.57 for two days, and the value for three days was 0.59. In winter, the ICC ranged from 0.51 to 0.84 for two days, and the value for three days was 0.79.

RM ANCOVA: RM ANCOVA revealed that there were no main effects for day, $F(2, 14) = 0.04$; $p > 0.05$, and season, $F(2, 14) = 0.02$; $p > 0.05$. There was a trend for children to be more vigorously active in winter than summer, though this trend was not significant (Table 4.2). The day x season interaction was not significant ($p > 0.05$).

4.4. Discussion

The purpose of this study was to investigate the variability of children's physical activity during playtime across consecutive school days during the summer and winter terms. A second aim was to examine how many days of monitoring are needed to determine children's physical activity levels during playtime.

Table 4.1: Descriptives (mean ± SD) of complete and incomplete data

		Age (years)	Body Mass (kg)	Stature (m)	Body Mass Index ($kg{\bullet}m^{-2}$)	MVPA (% playtime)	VPA (% playtime)
Summer	Complete Data (n = 20)	7.8 ± 1.0	28.6 ± 4.9	1.32 ± 0.07	16.3 ± 2.0	24.5 ± 13.5	6.4 ± 5.7
	Incomplete Data (n = 14)	7.4 ± 1.2	30.1 ± 5.5	1.32 ± 0.08	17.3 ± 2.9	23.5 ± 11.8	6.0 ± 6.2
Winter	Complete Data (n = 20)	8.4 ± 1.1	33.2 ± 6.4	1.34 ± 0.07	18.3 ± 2.6	25.6 ± 14.6	9.1 ± 9.4
	Incomplete Data (n = 14)	8.1 ± 1.1	31.4 ± 5.5	1.34 ± 0.08	17.7 ± 3.1	19.5 ± 13.7	6.2 ± 6.9

No significant differences between complete and incomplete data sets on all variables $p > 0.05$

Table 4.2: Percentage of time spent in MVPA and VPA during playtime according to season and day (mean ± SD)

Season	Day	MVPA	VPA
Summer	1	22.5 ± 15.1	6.7 ± 6.6
	2	28.6 ± 17.9	8.1 ± 10.6
	3	22.6 ± 13.7	4.4 ± 4.8
Winter	1	25.6 ± 16.1	9.9 ± 12.1
	2	26.3 ± 21.2	8.1 ± 11.3
	3	25.1 ± 17.6	9.4 ± 9.6

No significant differences between days or seasons $p > 0.05$

4.4.1. Day-to-Day Variability

The results of the study suggest that there is variability in children's MVPA during daily school playtime. The RM ANCOVA revealed no significant differences between daily physical activity in both the summer and winter terms. Variability in MVPA is present during playtime, indicated by the standard deviations in relation to mean playtime MVPA, as children are free to choose the activities they wish to engage in within the confines of the playground (Blatchford, 1989; Mota et al., 2005a). Despite this, observations in the present study revealed that children engaged in similar activities in each playtime period. During playtime, boys tended to play football in the school playground, with different year groups organising separate games. Girls generally engaged in skipping games, and conversations around the perimeter of the playground. Furthermore, children tended to play with the same social group on a daily basis, supporting Lever's (1976) observations. Throughout the duration of the study, physical environment of the playground remained unchanged and the same equipment was provided daily. This could have reduced some of the variability in physical activity behaviour as children had similar physical activity opportunities across playtime. The present study suggests that children's MVPA is generally stable across days of measurement during school playtime.

Greater daily variability was seen for VPA, particularly in the summer term compared to the winter term. However, the RM ANCOVA revealed no significant main effects or interactions for VPA. The results suggest that children's engagement in VPA is characterised by greater day-to-day variability than MVPA, and this could be linked to their physical activity patterns and the nature of traditional playtime games. Children's physical activity is spontaneous, transitory and intermittent (Bailey et al., 1995). Short bursts of high activity are followed with longer periods of low to moderate activity (Bailey et al., 1995). Traditional playtime activities such as skipping, chasing games and ball games often involve short bursts of high activity interspersed with longer periods of low to moderate activity due to turn taking or resting periods (Pellegrini, 1995). It is possible that these characteristics of physical activity patterns and games influence the amount of VPA engaged in to a greater extent than MVPA, leading to greater variability. In addition, the greater variability in VPA during the summer could be linked to the children's thermoregulation, with children taking longer rest periods between vigorous bursts of physical activity. Furthermore, the length of confinement before playtime could have influenced the variability. Pellegrini and Davies (1993) found that the longer boys were kept seated in class, the higher their VPA was at the start of playtime. Longer confinement for girls led to an increase in sedentary behaviour for girls, though the reasons for this finding were not known (Pellegrini & Smith, 1993). Whilst the timetable in both schools did not change, meaning that the length of confinement was consistent across the study, this is an important consideration for future studies which may need to examine how such factors influence the children's physical activity during playtime across days and seasons. The present study suggests that to measure VPA alone during playtime, more than one day's monitoring is required, particularly in summer, to accurately describe children's typical playtime VPA.

The monitoring length used may explain some of the individual variability found in the present study. Children's physical activity during playtime was recorded at 5-second intervals, which was deemed short enough to capture the sporadic nature of children's activity patterns. Habitual studies traditionally use 1-minute epochs, and as these accumulate children's activity they can mask periods of moderate to high intensity when recorded with periods of low intensity activity (Nilsson et al., 2002; Rowlands, 2001). In addition, 1-minute epochs may be less sensitive to the intermittent and transient nature of children's physical activity. The results suggest that whilst a number of factors can lead to variability in daily physical activity, children's physical activity patterns on a day-to-day basis are similar within a playtime context.

4.4.2. Seasonal Variability

There was a trend for both MVPA and VPA to be higher in winter than summer in the present study, though this trend was not significant. This trend is consistent with Stratton's (1999) findings, where children were more active during playtime in the winter compared to the summer, though again these differences were not significant. Whilst the underlying reasons for the differences in physical activity across the seasons are not widely established, the seasonal variations in habitual activity have been attributed to the effect of inclement weather in winter months (Hagger et al., 1997), and more daylight hours in the summer months (Loucaides et al., 2003). Playtime seasonal variation has been associated with children's thermoregulatory need to keep warm during the colder winter weather (Stratton, 1999). In the majority of UK primary schools, children are expected to play outside on the playground during playtime, the exception being when it is raining (Evans, 1996). Many children do not have the choice of staying inside when, for example, the weather is cold (Thomson, 2004). Therefore, the trend for higher physical activity levels may be linked to the temperature on the playground during playtime (Stratton, 1999). In light of the non-significant differences however in children's physical activity levels across the seasons, this study suggests that physical activity is similar across seasons in playtime. However, as this study has been conducted in one area in the UK, it might not be generalisable to different areas or countries. Future studies are required using larger sample sizes and a range of objective measures, including accelerometry, in different nations to examine seasonality effects further.

Reliability in a measure enables the evaluation of physical activity intervention studies (Baranowski et al., 1999; Sallis et al., 1992; Trost et al., 2000). The results indicated that there was approximately 2-3% variability between the seasons on each recorded day for MVPA, which equated to a time difference of approximately 1 minute. For VPA, the variability observed was approximately 5%, which equated to a time difference of 3 minutes. With regards to the evaluation of the effects of interventions, research that reports increases greater than 2-3% for MVPA and 5% for VPA could arguably be due to the effect of the intervention rather than the influence of factors such as seasons. This provides an indication of the impact of an intervention over and above other potential sources of variability.

4.4.3. Numbers of Days Needed

Sallis et al. (1995) note that the assessment of physical activity is complicated by the variability of an individual's physical activity behaviour, and that the majority of variance is likely to be accounted for by transient environmental factors. Researchers who have aimed to investigate children's habitual physical activity have generally concluded that multiple days of monitoring are needed to reliably estimate physical activity behaviour (Sallis et al., 1995). The number of days of monitoring that are required to represent typical playtime physical activity levels has not, to the best of the author's knowledge, been investigated. The preliminary results indicate that one day of physical activity monitoring during all playtime periods (morning and lunch) could be representative of their daily playtime MVPA in both summer and winter terms, though further research is needed to examine this issue in more detail. This somewhat lends support to the notion that shorter time frames for monitoring are needed when stable behaviours are demonstrated (Tudor-Locke & Myers, 2001). For VPA alone however, the results suggest that more than one day of monitoring is required, though further investigation is needed to establish how many days are needed for acceptable reliability. Throughout the duration of the study, the playground environment was consistent in its structure, for the same equipment and supervision was provided at the same time on a daily basis. This could have affected the impact of playtime as a context on children's day-to-day physical activity. Additionally, the children tended to engage in similar activities at each playtime period with their peers, with their stable behaviour potentially explaining the non-significant differences found in the data. These observations support the findings of Stratton's (1999) study. Overall, monitoring children on one day may be representative of their MVPA during school playtime.

4.4.4. Study Limitations

Whilst the current study attempted to investigate the day-to-day and seasonal variability on children's physical activity levels during playtime, a number of limitations require attention. The study used a small sample size from only two primary schools, and there was a high dropout rate, which can partially be explained by the stringent nature of the data analysis. In order to increase statistical power gender differences were not investigated. Due to reported differences in boys and girls choice of activity during playtime (Evans, 1996; Blatchford et al., 2003), further studies should investigate the day-to-day variability of boys and girls playtime physical activity using a larger sample size in order to facilitate generalisability to a wider population, although such research designs are time intensive and can be difficult to conduct as they can impact on the participating schools day-to-day routine.

The study is also limited by the use of heart rate monitoring as an objective measure of playtime physical activity. Heart rate measures the stress that physical activity places on a child's cardiopulmonary system (Janz, 2002), but it is not a direct measure of physical activity

(Armstrong, 1998). Children's recorded heart rates can be affected by level of fitness, temperature and psychological and environmental stress (Armstrong, 1998; Janz, 2002; Sirard & Pate, 2001), and children can react to wearing the monitor and change their physical activity behaviour. Future studies should replicate this study using other objective measures such as accelerometry or pedometers, which are not affected by other factors than children's movement patterns. However, it should be acknowledged that heart rate reserve was calculated each day to take into account fluctuations in resting heart rate values. Additionally, children underwent familiarisation with the heart rate monitors to limit problems with reactivity. Variability may also be accounted for by measurement error, although previous studies indicate that this is small compared to heart rate recorded using ECG (Janz, 2002). Despite the limitations of heart rate monitoring, it is an objective measure that is reliable and valid for paediatric physical activity assessment.

4.5. Conclusions and Summary

The aim of this study was to determine the day-to-day and seasonal variability on children's playtime physical activity. The results of the study indicate that there was no significant variation in day-to-day or seasonal playtime MVPA & VPA, suggesting that the playtime environment provides similar physical activity opportunities across week days and seasons, and that children utilise playtime to engage in similar levels of physical activity across the days and seasons. In conclusion, studies may not need to correct for day-to-day and seasonal effects on children's physical activity during school playtime. Furthermore, assessing children's physical activity levels during playtime on one day may be representative of typical moderate-to-vigorous playtime activity in larger empirical studies.

CHAPTER 5

Physical Activity Levels of Primary School Children during Playtime

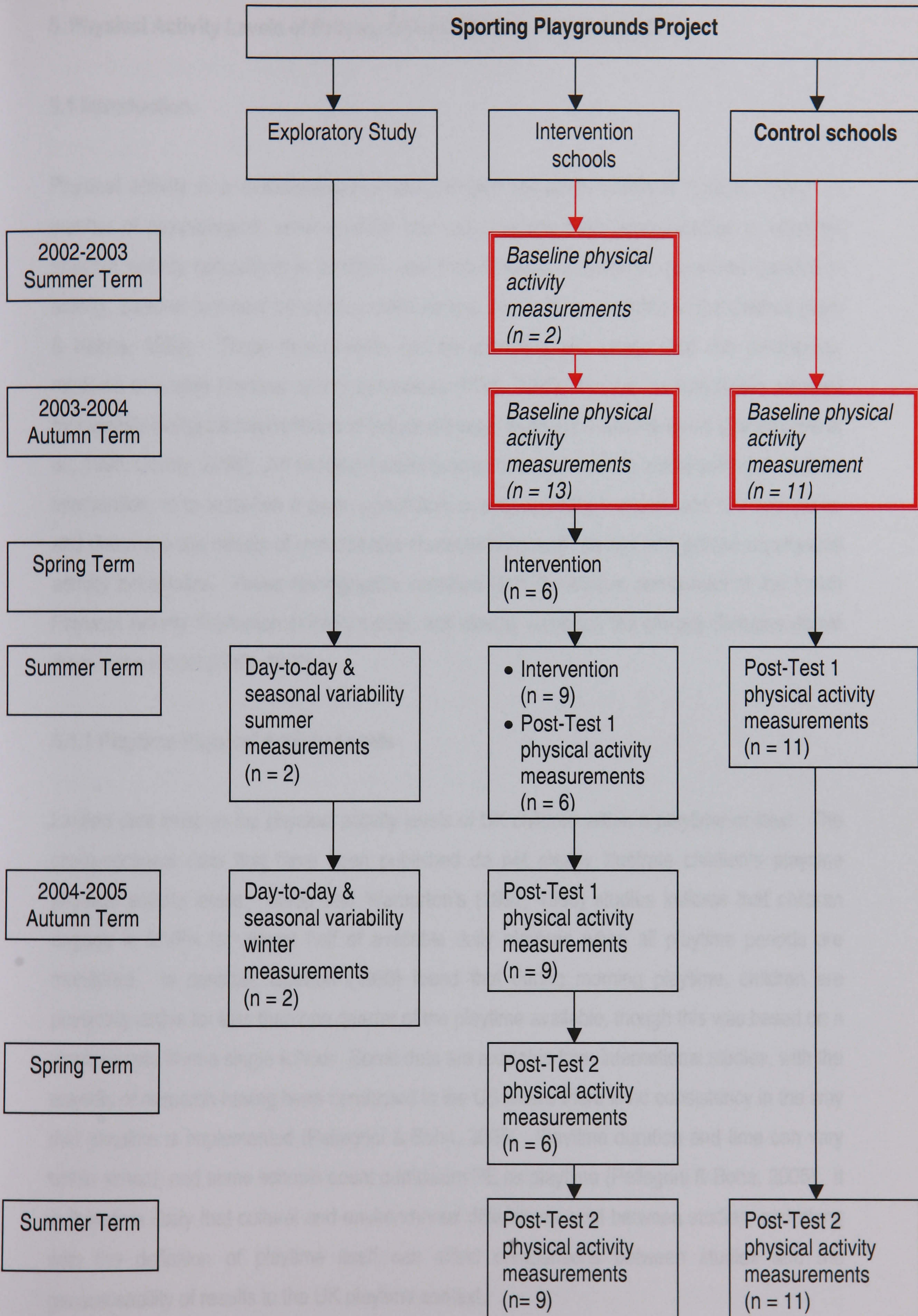


Figure 5.1: Stage of research design. Numbers of schools involved in each phase of the research are shown.

5. Physical Activity Levels of Primary School Children during Playtime

5.1 Introduction

Physical activity is a multidimensional and complex behaviour (Sallis & Patrick, 1994). A number of psychological, environmental and social factors have been reported to influence physical activity behaviours in children, and these include maturation, perceived barriers to activity, parental and peer behaviours, self-efficacy, and facilities available to the children (Kohl & Hobbs, 1998). These determinants can be classified into factors that can predispose, reinforce or enable physical activity behaviours (Welk, 1999), and can be specifically targeted by carefully designed interventions to induce changes in physical activity levels (Baranowski et al., 1998; Gorely, 2005). An important consideration however, prior to implementing an activity intervention, is to establish a given population or subpopulation's needs and characteristics, and determine the effects of unmodifiable characteristics such as age and gender on physical activity behaviours. These demographic variables form the bottom component of the Youth Physical Activity Promotion (YPAP) model, and directly influence the primary domains above them in the model (Welk, 1999).

5.1.1 Playtime Physical Activity Levels

Limited data exist on the physical activity levels of UK children within a playtime context. The cross-sectional data that have been published do not clearly illustrate children's playtime physical activity levels. Sleap and Warburton's (1992, 1996) studies indicate that children engage in MVPA for almost half of available daily playtime when all playtime periods are monitored. In contrast, Stratton (1999) found that during morning playtime, children are physically active for less than one quarter of the playtime available, though this was based on a small sample from a single school. Some data are available from international studies, with the majority of research having been conducted in the US where there is no consistency in the way that playtime is implemented (Pellegrini & Bohn, 2005). Playtime duration and time can vary within school, and some schools count curriculum PE as playtime (Pellegrini & Bohn, 2005). It is therefore likely that cultural and environmental differences exist between studies, and along with the definition of playtime itself can affect comparisons between studies and the generalisability of results to the UK playtime context.

A range of objective methods have been used to quantify playtime physical activity, and these vary with sample size. Studies using large sample sizes have used direct observation where scanning procedures (Zask et al., 2001), momentary time sampling (McKenzie et al., 1997a; McKenzie et al., 2000) and short observation periods (Kraft, 1989) have been used to detail physical activity. Smaller scale studies have used activity monitors to record physical activity, particularly accelerometers, though these have often used one-minute recording periods (Mota et al., 2005a; Mota et al., 2005b; Rosser Sandt & Frey,2005). This affects the quantification of playtime physical activity, as children's activity is characterised by short bursts of intermittent, spontaneous, high intensity activity and longer monitoring periods or scanning procedures may mask children's true activity patterns (Nilsson et al., 2002). Few studies have used combined measures to quantify physical activity, and no studies have combined heart rate and accelerometry, which may improve the accuracy of assessment of children's activity (Sirard & Pate, 2001).

Presently in the school environment, physical activity guidelines exist for physical education (PE) but not for playtime. In order for PE to meaningfully contribute towards the accumulation of physical activity, it has been recommended that children are active for at least 50 per cent of class time, and schools should offer PE lessons on a daily basis (USDHHS, 2000). Since playtime is regularly scheduled on a daily basis in the UK school timetable (Blatchford & Sumpner, 1998; Stratton, 1999), Stratton and Mullan (2005) extrapolated the USDHHS (2000) PE criterion to playtime, suggesting that children should be physically active for 50% of playtime. However, empirical testing of this threshold is required to ascertain whether it is a suitable target for children to achieve during school playtime.

5.1.2 Gender and Age Effects on Playtime Physical Activity

Gender has been found to be an important biological determinant of children's habitual physical activity, with boys engaging in more physical activity than girls (Sallis et al., 2000). Similar findings have been reported in playtime studies, with 70% of the studies reporting that boys are more active than girls (Table 2.1). The differences in activity levels range from 0.4% to 25.3% (Table 2.2), which equated to boys accumulating 0.2% to 42.7% (Biddle et al., 1998) or 0.1% to 21.6% (Andersen et al., 2006) more physical activity towards daily recommendations than girls. However, only one UK study has investigated gender differences in activity levels during playtime, and while boys were more active than girls, the differences were not significant

(Stratton, 1999). There is an unmistakable need to investigate and quantify the physical activity levels of boys and girls in a UK playtime context.

No cross-sectional UK studies have examined age group or stage of schooling differences in playtime physical activity. While the population age range varies across playtime studies, the results do not provide a consistent pattern of playtime activity with respect to age. Direct comparisons between stages of schooling have only been specifically examined in one longitudinal study, where children were less active in preschool compared to elementary school (McKenzie et al., 1997a). Examining baseline data reported in an intervention study revealed no significant differences in infant and junior school children's playtime activity prior to a playground markings intervention, though this comparison was not a stated aim of the study nor subsequently discussed (Stratton & Mullan, 2005). The determinants literature suggests that a negative association exists between age and habitual physical activity, despite the fact that this relationship was inconsistently reported, in children aged 4-12 years (Sallis et al., 2000). While little data exists concerning age differences in physical activity levels during playtime, playtime behavioural research has indicated that older junior boys dominate available playground space with vigorous ball games (Boyle et al., 2003), which may restrict younger children's opportunities to engage in activity for children are less active in restricted environments (Pellegrini & Smith, 1993). Taken together, these findings suggest that the age of the children being investigated requires consideration, and there is a need for data examining the effect of age group on playtime physical activity.

5.1.3 Aims and Objectives

The aim of the current study was to quantify the physical activity levels of children during school playtime and to assess gender and age group differences on MVPA and VPA (Aim 2, page 48). A secondary aim was to determine the extent to which playtime could contribute towards the current daily physical activity recommendations and to ascertain whether the target of 50 per cent of playtime engaged in at least moderate activity is an appropriate health promotion criterion for schools to adopt. It is hypothesised that boys would engage in more physical activity during school playtime than girls (H1), and infant children would be significantly more active than junior children (H2).

5.2 Method

5.2.1. Subjects

Five hundred and thirty-five children (270 boys, 265 girls) randomly selected from 31 primary schools situated in one large urban city in the North West of England returned signed parental informed consent to participate in the study. One hundred and forty-seven children were classified as infant school children (75 boys, 72 girls, mean age = 6.3 ± 0.6 years), and 388 children were classified as junior school children (195 boys, 193 girls, mean age = 8.7 ± 1.1 years). The baseline data collection was conducted between June 2003 and January 2004. Seasonality was not controlled for as the study in Chapter 4, which was conducted geographically close to the current schools, found no significant differences in children's playtime physical activity levels between seasons.

5.2.2. Study Overview

Eighteen children from each school had their physical activity levels during school playtime measured on one school day. Children were randomly allocated to wear either one (heart rate) or two (heart rate, accelerometer) physical activity monitors during playtime. Randomisation was stratified by gender. All children (n = 535) wore a heart rate monitor, whilst 347 children (169 boys, 178 girls; 65% of sample) also wore a uni-axial accelerometer. Physical activity was monitored during morning, lunch and, where applicable, afternoon playtime on one school day. Children from 16 schools had two playtimes (morning and lunch), while children from 15 schools had three playtimes. The mean daily playtime available for children to engage in physical activity on the playground was 83 (± 16.2) minutes. Playtime duration was measured from the time the school bell rang to start playtime to the time it rang to conclude playtime. Small pieces of sports equipment such as skipping ropes and footballs were available for use in the school playgrounds. No schools participating in the study had playground markings prior to the study commencing. Each school employed at least 2 lunchtime supervisors during lunch playtime who had not been trained in the promotion of playground physical activity. Schoolteachers supervised the morning playtime. The research protocol received ethical approval from the Liverpool John Moores University Ethics Committee. The subsequent procedures followed and the raw data handling adhere to the method detailed in Chapter 3.

5.2.3. Data Analyses

Of the initial 535 children monitored using heart rate telemetry, complete data sets were obtained for 450 children (223 boys, 227 girls) and used in subsequent analyses. Two hundred and eighty-five (148 boys, 137 girls) complete accelerometry data sets were also obtained and used in the analyses. Electronic interference and technical difficulties involving downloading data accounted for the missing data.

Heart rate and accelerometry data were downloaded and analysed as described in Chapter 3. All data were analysed using the Statistical Package for the Social Sciences (SPSS) version 12. The dependent variables were percentage of time spent in MVPA and VPA quantified using heart rate and accelerometry during total daily playtime. The independent variables used to group the data were gender (boy, girl) and age (infant, junior). Descriptive data for age, body mass, stature and body mass index (BMI) were also calculated. Independent t-tests were conducted to examine gender and age group differences on these data. In addition, initial exploratory analyses were conducted on the data to establish whether any differences existed between the percentage MVPA and VPA accumulated across two (morning and lunch) or three (morning, lunchtime and afternoon) playtimes. The main analysis consisted of a 2 x 2 (gender x age group) analysis of covariance (ANCOVA) in order to analyse gender and age group differences on the dependent variables. Separate analyses were conducted for MVPA and VPA using each measurement method. Play duration and BMI were used as the covariates in the analyses. The alpha level was set at $p < 0.05$.

5.3 Results

5.3.1 Descriptive Analyses

The mean (± SD) values for the children's anthropometric characteristics are shown in Table 5.1

5.3.2. Exploratory Analyses

Number of Daily Playtimes: Independent t-tests revealed no significant differences between the children's percentage $MVPA_{HR}$, $t_{(1, 490)} = 0.42$; $p > 0.05$, VPA_{HR}, $t_{(1, 490)} = 0.12$; $p > 0.05$, $MVPA_{ACC}$, $t_{(1, 315)} = -0.11$; $p > 0.05$, and VPA_{ACC}, $t_{(1, 315)} = -0.35$; $p > 0.05$, whether they participated in two or three playtimes. The MVPA and VPA heart rate and accelerometry data from the differing number of playtimes were subsequently collapsed into physical activity engagement across the total daily playtime available, and the number of playtimes was not used as a factor in the ensuing analyses.

Table 5.1: Anthropometric characteristics of whole sample (n = 535; mean ± SD)

	Infants		Juniors	
	Boys (n = 75)	**Girls (n = 72)**	**Boys (n = 195)**	**Girls (n = 193)**
Age	6.3 ± 0.6	6.3 ± 0.7	8.9 ± 1.4	8.8 ± 1.2
Body Mass (kg)	25.6 ± 5.4	24.1 ± 5.9	33.6 ± 8.5	32.9 ± 9.1
Stature (m)	1.23 ± 0.06*	1.20 ± 0.07*	1.36 ± 0.08	1.35 ± 0.09
BMI (kgm^{-2})	16.9 ± 2.7	16.6 ± 2.5	17.9 ± 3.1	17.9 ± 3.3

* Significant t-test gender difference: infant boys > infant girls
Note: Significant differences between infant and junior children on age, body mass, stature and BMI: juniors > infants

5.3.3. Main Analyses

5.3.3.1 Heart Rate

MVPA: Boys and girls engaged in $MVPA_{HR}$ for 33.8 (± 16.6) and 26.7 (± 16.6) per cent of playtime respectively (Figure 5.2). The ANCOVA revealed a significant main effect for gender ($F_{1, 449} = 14.34$, $p < 0.001$) but not for age group. The gender by age group interaction was not significant ($p > 0.05$). The results indicated that boys engaged in 28 minutes of $MVPA_{HR}$ during playtime compared to 22 minutes for girls.

VPA: Boys and girls engaged in VPA_{HR} for 12.1 (± 11.6) and 8.8 (± 10.8) per cent of playtime respectively (Figure 5.4). The ANCOVA revealed a significant main effect for gender ($F_{1, 449}$ = 10.51, $p < 0.001$) but not for age group. The gender by age group interaction was not significant ($p > 0.05$). The results indicated that boys engaged in 10 minutes of VPA_{HR} during playtime compared to 7 minutes for girls.

5.3.3.2 Accelerometry

MVPA: Boys and girls engaged in $MVPA_{ACC}$ for 32.6 (± 12.9) and 25.7 (± 10.3) per cent of playtime respectively (Figure 5.3). The ANCOVA revealed a significant main effect for gender but not for age group. The gender by age group interaction was not significant ($p > 0.05$). The results indicated that boys engaged in 27 minutes of $MVPA_{ACC}$ during playtime compared to 21 ¼ minutes for girls.

VPA: Boys and girls engaged in VPA_{ACC} for 6.3 (± 5.5) and 5.1 (± 4.8) per cent of playtime respectively. The main effects for gender and age group were not significant ($p > 0.05$). The ANCOVA revealed that the gender x age group interaction was approaching significance ($F_{1, 285} = 3.35$, $p < 0.1$). Independent t-test post-hoc tests revealed that junior boys (6.6%) engage in significantly more VPA_{ACC} during playtime than junior girls (4.6%; $p < 0.01$). No differences were observed between the remaining groups (Figure 5.5). Overall, the results indicated that boys engaged in 5 ¼ minutes of VPA_{ACC} during playtime compared to 4 ¼ minutes for girls.

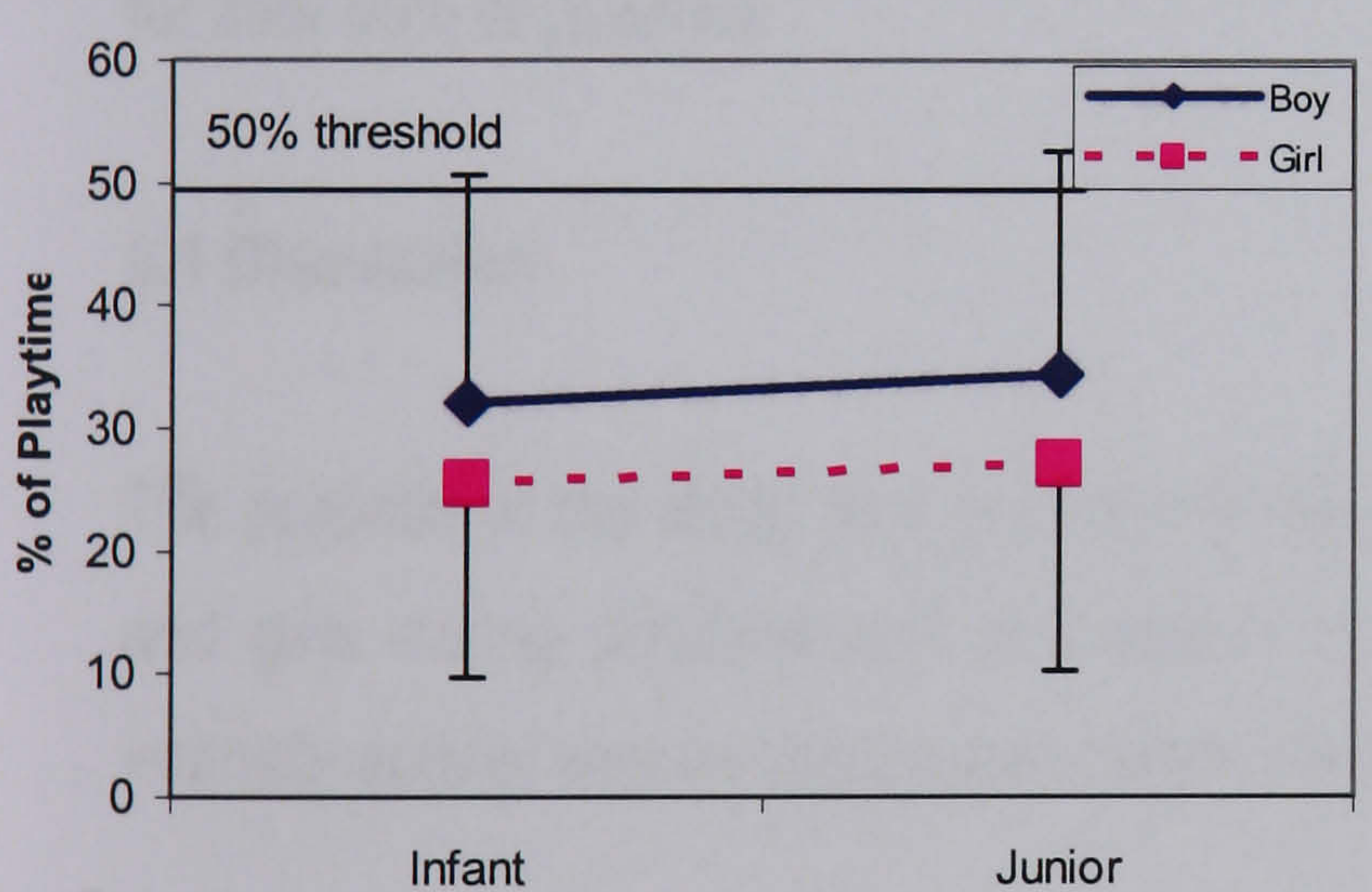


Figure 5.2: Infant and junior boys and girls MVPA during school playtime using heart rate raw scores (mean ± SD). The 50 per cent threshold value is marked on the graph.

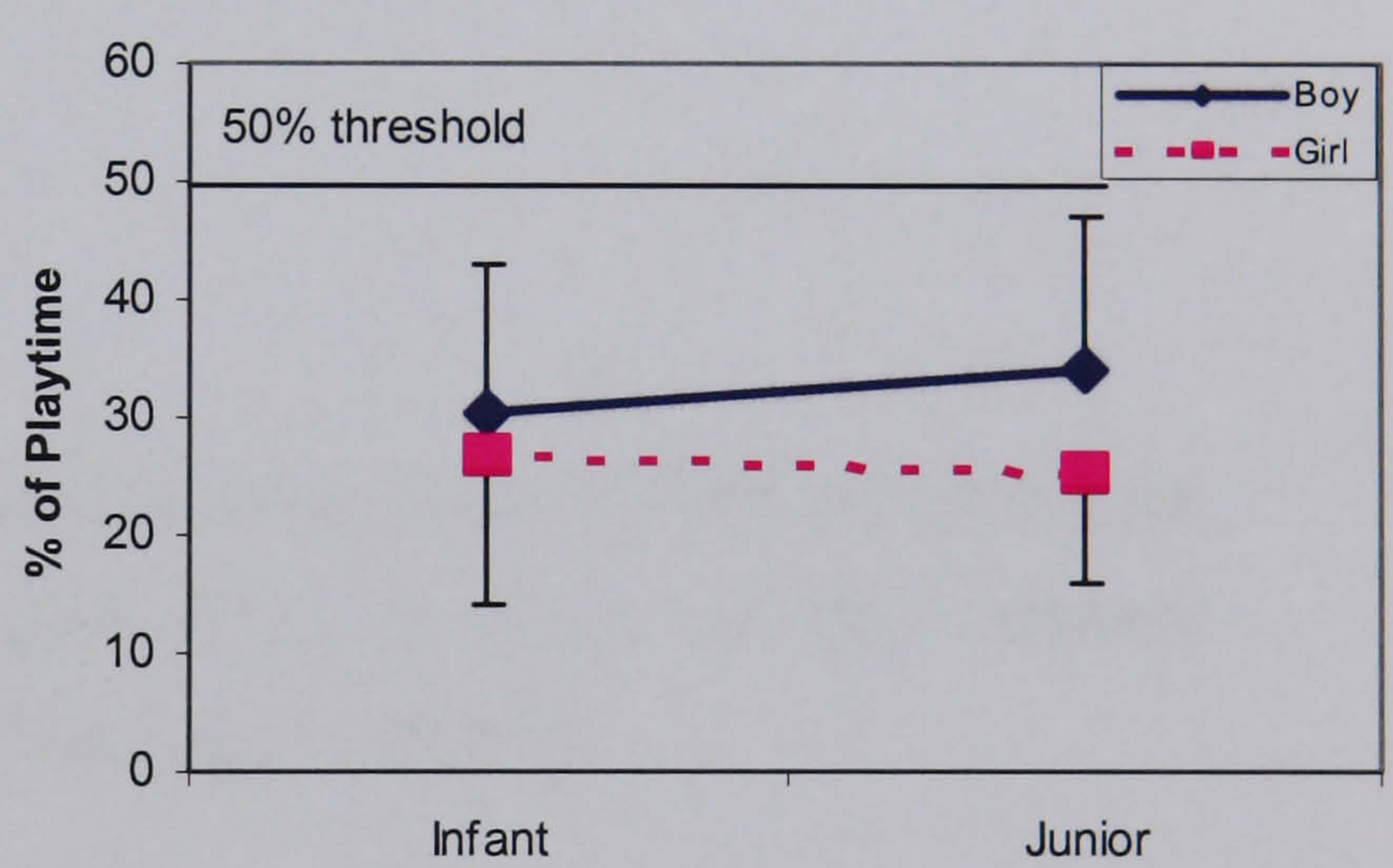


Figure 5.3: Infant and junior boys and girls MVPA during school playtime using accelerometry raw scores (mean ± SD). The 50 per cent threshold value is marked on the graph.

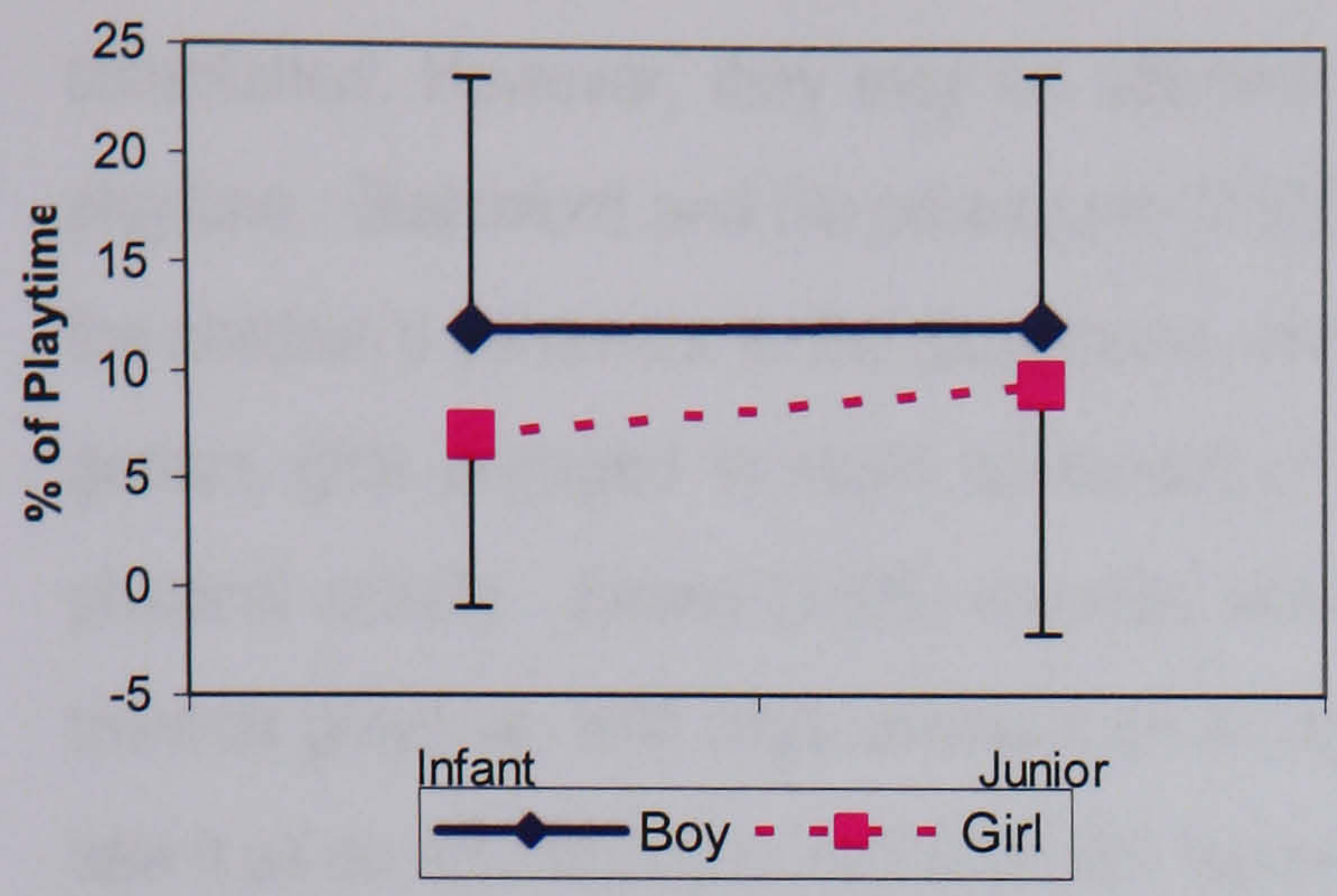


Figure 5.4: Infant and junior boys and girls VPA during school playtime using heart rate raw scores (mean ± SD).

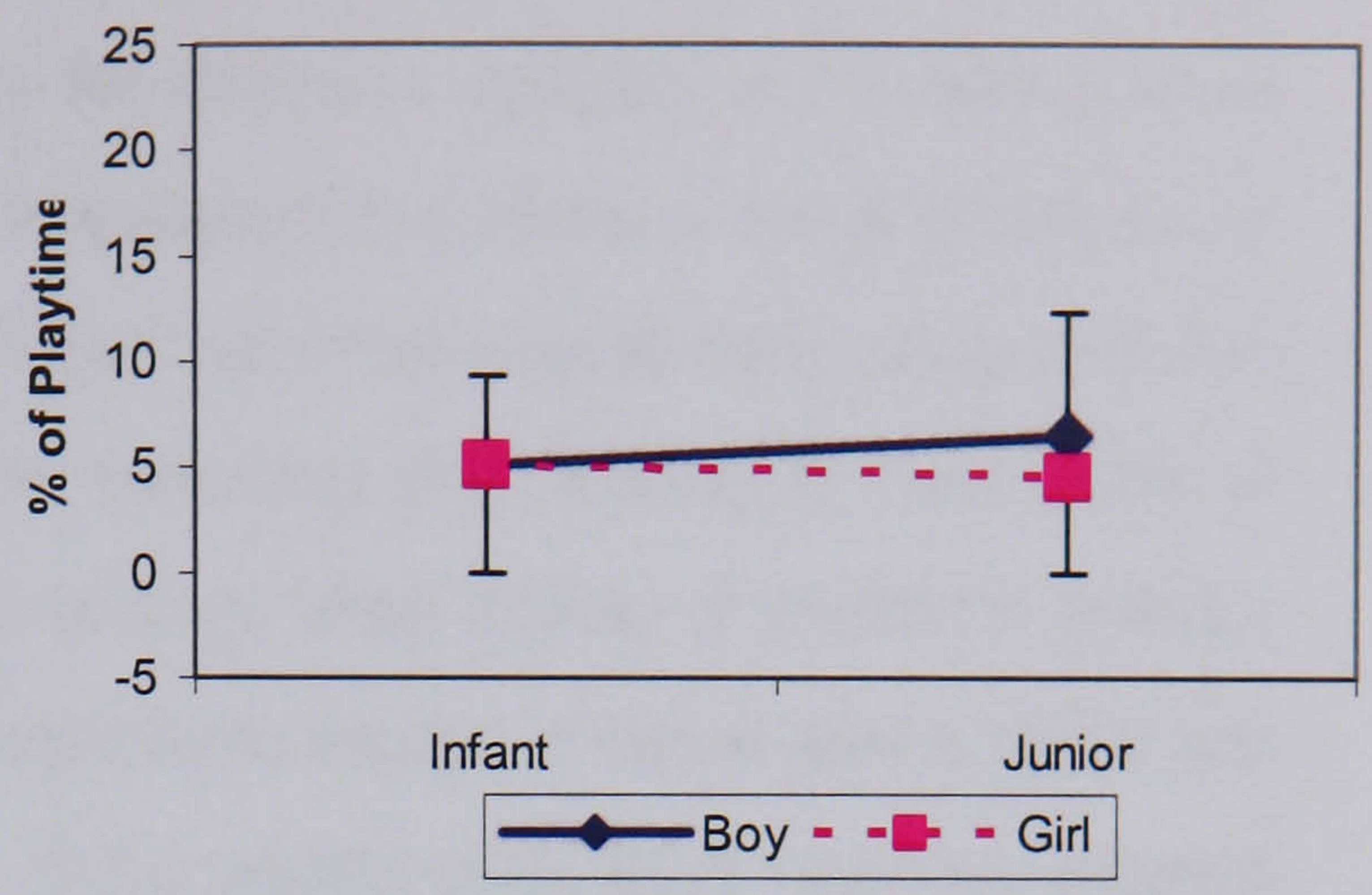


Figure 5.5: Infant and junior boys and girls VPA during school playtime using accelerometry raw scores (mean ± SD).

5.3.3.1 50% Physical Activity Threshold.

Forty-nine boys (9.2%) and 21 girls (3.9%) met the 50% MVPA during playtime threshold when their physical activity was quantified using heart rate. The accelerometry results revealed that 19 boys (5.5%) and 3 girls (0.9%) were engaged in at least moderate intensity physical activity for over 50% of playtime.

5.4 Discussion

The purpose of the study was to examine the physical activity levels of infant and junior boys and girls during playtime and to establish whether 50% of playtime in at least moderate intensity activity was an appropriate health promotion target for schools.

5.4.1 Gender Differences

Significant gender differences were observed in this study, with boys engaging in significantly more MVPA and VPA than girls. These findings are consistent with previous studies (Kraft, 1989; McKenzie et al., 1997a; McKenzie et al., 2000; Sarkin et al., 1997; Scruggs et al., 2003), though the margin of difference (6.9 - 7.1% for MVPA) is greater than has been previously reported by UK playtime studies (Stratton, 1999; Stratton & Mullan, 2005). In addition, this finding is consistent with the determinants literature, which has identified gender as being a strong biological correlate of physical activity in children (Sallis et al., 2000).

The reasons behind the gender differences in the levels of physical activity are not widely established. However, they may be affected by the children's attitudes and beliefs towards playtime. Blatchford and his colleagues (2003) investigated the effects of social influences on the children's behaviour in the playground, and found that whilst boys tended to play more ball games, girls engaged in more conversation and sedentary play, leading to lower levels of physical activity. Evans (1996) reported similar findings when looking at children's attitudes towards playtime, with boys seeing it as an opportunity to engage in active games whilst girls saw it as an opportunity to socialise with friends. In the present study, boys may have engaged in higher levels of physical activity as they saw it as an opportunity to play competitive games, which dominate the school playground (Renold, 1997). In such circumstances, the girls tend to situate themselves around the perimeter of this area, engaging in more sedentary behaviours as the space for physical activity is limited (Renold, 1997). This in turn could explain, in part, the lower physical activity levels of the girls. Overall, these data suggest that boys are more efficient in using the playtime context to engage in health-promoting physical activity, and primary school girls of all ages are an important target group for playtime interventions. Playtime may need to be restructured so that girls and boys receive equal opportunities to be physically active (Sarkin et al., 1997).

5.4.2 Age Group Differences

There are no directly comparable cross-sectional data concerning age group differences in playtime physical activity to this study in the literature. Children have been found to be more active in elementary school compared to preschool (McKenzie et al., 1997a), though comparisons are restricted as the present study used a different age range. The infant children in this study, who were the same age as the elementary children in McKenzie and co-workers study, were less active, indicating that cultural differences may explain differences in playtime physical activity.

Some data concerning age differences in playtime activity in a UK context have been reported in an intervention paper, where no differences were found between infant and junior school children's playtime activity at baseline (Stratton & Mullan, 2005). This study is consistent with this finding, and suggests that the physical activity levels of children during primary school playtime are relatively similar across time, and that they do not decrease as a result of their stage of schooling. The underlying reasons for this finding are not known, though it is possible that the schools afforded the same opportunities for infant children as their older counterparts to be active during school playtime. It is a concern, however, that infant girls maintain similar activity levels as the junior girls, and that their activity levels are lower than the boys at both stages of schooling. With regards to the accelerometer findings, where junior girls engaged in significantly less MVPA than the junior boys, the results indicate that initiatives are need to promote activity to girls, but in particular to junior girls. Furthermore, encouraging girls to be active during their infant years may motivate them to engage in higher activity levels in the junior phase of schooling. Interestingly, though the differences were not significant, junior boys activity showed a trend of being higher than the infant boys' activity (Figures 5.2 & 5.3). Playtime behavioural research has noted that older junior boys tend to dominate available playground space with vigorous ball games (Boyle et al., 2003), which may restrict activity opportunities for younger boys (Renold, 1997). The results of this study lend some support to this notion. It is recommended that future studies incorporate direct observation in to the research design to ascertain whether the playtime behavioural research explains the findings of the present investigation. In addition, further research is needed to establish if this trend is consistent in UK playgrounds, as this information may impact on the intervention strategy employed, if any, to increase children's physical activity levels during playtime.

5.4.3 Playtime Physical Activity Levels

The data suggested that the physical activity levels of children were low compared to previous studies that have quantified physical activity during playtime both cross-sectionally (Sleap & Warburton, 1992, 1996) and prior to intervention (Stratton, 2000; Stratton & Mullan, 2005). While this study focused on physical activity of at least moderate intensity, the results indicate that sedentary and light intensity activity levels were most prevalent in the playground, accounting for the largest proportion of playtime activity. However, it was encouraging that boys engaged in 27-28 minutes of MVPA during playtime, depending on the method of activity measurement, which is just short of the minimum physical activity recommendation of 30 minutes of MVPA for children (Biddle et al., 1998). The girls were approximately two-thirds of the way to meeting this minimum recommendation. These data indicate that playtime provided a salient opportunity for children to achieve minimum daily physical activity guidelines. Furthermore, they suggest that playtime represents a significant context for the promotion of physical activity to school age children.

It has recently been stated that physical activity recommendations should be higher than current published international guidelines to prevent the clustering of cardiovascular disease risk factors (Andersen et al., 2006). Specifically, Andersen and colleagues (2006) indicate that children aged 9 years old should engage in one hundred and twenty minutes of at least moderate intensity activity a day. Using the recommendation of both Andersen et al. (2006) and Biddle et al. (1998) respectively, boys can accumulate between 22 to 45% of their total daily physical activity during playtime, while girls can accumulate between 17 to 35%. Boys can therefore achieve approximately a quarter to a half of their total daily physical activity in this situation whilst girls can achieve approximately a sixth to a third of their total daily physical activity, depending on the threshold value used. These results suggest that playtime offers children an opportunity to engage in physical activity during the school day, though the significance of playtime is different depending on which target is used.

Using PE guidelines for physical activity (USDHSS, 2000), Stratton and Mullan (2005) hypothesised that children should engage in MVPA for 50% of playtime. Previous playtime studies have provided conflicting results concerning the efficacy of this threshold. Several US based playtime studies that have used direct observation (McKenzie et al., 1997a; McKenzie et al., 2000) and heart rate (Faison-Hodge & Porretta, 2004) to quantify playtime physical activity levels have suggested that children are physically active in excess of 50% of playtime. However, the majority of playtime studies that have used a range of physical activity measures have indicated that, on average, children do not engage in MVPA for 50% of playtime (Kraft, 1989; Stratton, 1999; Zask et al., 2001). It is possible that some of the differences in physical activity levels may be attributable to the method of measuring physical activity. While more children who were monitored using heart rate met the proposed threshold in the present study compared to accelerometry, the results suggest that it may be an unrealistic target for UK children to meet during school playtime.

In light of this, an alternative suggestion based on current minimum activity UK recommendations (Biddle et al., 1998) is proposed. A threshold value of 40 per cent of at least moderate intensity activity may be more achievable during total school playtime, as this is equivalent to children engaging in MVPA for 33 minutes of playtime a day. Using the heart rate results firstly, 87 boys (16.3%) and 57 girls (10.7%) achieved the 40% threshold, while 44 boys (12.7%) and 14 girls (4%) achieved this value when activity was quantified using accelerometry. This highlights that some primary-school aged children can achieve minimum activity guidelines through playtime alone, potentially benefiting health both in childhood and in later life. It should be noted that VPA is a component of MVPA, which raises the issue of what proportion of this suggested 40% threshold should be VPA. This is an interesting line of investigation for future research, as VPA is negatively related to body fatness (Ruiz et al., 2006), and minutes of daily VPA have been linked to obesity status (Dencker et al., 2006). Using the baseline data (Figures 5.2 - 5.5) and the findings of previous playtime studies (Stratton, 1999; Stratton & Mullan, 2005), it could be speculated that approximately a quarter of this threshold should be VPA to benefit bone health (McKay et al., 2005) and cardiorespiratory fitness (Payne & Morrow, 1993; Stratton, 2000). In general, 40% of playtime engaged in physical activity may prove to be a fitting marker for physical activity during playtime, and could represent a suitable threshold to use as an indicator of the effectiveness of playtime interventions.

5.4.4 Limitations

A number of limitations exist that warrant attention. The variability of children's physical activity during playtime has been examined using heart rate telemetry but not using accelerometry (Chapter 4). The results of the study are based on one day's monitoring at each school, therefore the accelerometer results may have to be viewed with some caution. However, accelerometry is becoming a criterion standard in field based physical activity assessment (Sirard & Pate, 2001), as accelerometers have high objectivity and validity, and are not influenced by factors other than body movement (Sirard & Pate, 2001; Welk, 2002), which is a limitation of heart rate telemetry (Armstrong, 1998; Janz, 2002). Furthermore, the mean data obtained from the two activity monitors were comparable, particularly for MVPA, suggesting that activity patterns of children were reflected in this setting by the objective measures used.

A second limitation of the study is that the availability of equipment in the playground or the levels of supervision provided by the schools were not controlled in this study. Zask et al. (2001) found that equipment availability or teacher supervision were not significant predictors of children's MVPA during playtime, though the availability of balls did significantly predict VPA engagement. Balls were freely available across all schools in this study for children to use, and informal observations indicated that boys tended to use this equipment more than girls, which may explain some of the differences seen. Zask et al. (2001) reported that teacher supervision did not predict MVPA, though McKenzie et al. (1997a) found that children complied with and maintained their physical activity participation following adult encouragement to be active during playtime. This indicates that future studies are needed to further determine the effects of equipment availability and adult supervision on activity levels during playtime.

5.5 Conclusions

In relation to the first aim, boys engaged in significantly more MVPA and VPA during playtime than girls, supporting the first hypothesis (H1). This suggests that strategic interventions are needed in order to provide equal opportunities for boys and girls to be physically active during the school day. The differences between age groups were not significant, which does not support the second hypothesis (H2). Indeed, the data suggested the opposite of this hypothesis for boys, as there was a trend for boys to become more active between infant and junior school. Little difference was observed between infant and junior girls' playtime physical activity. With respect to the second aim, it was found that physical activity could contribute up to a half of the recommended daily physical activity for boys, and over a third for girls. The study found that a small percentage of children achieved the 50% threshold value suggested by Stratton and Mullan (2005), which equated to 41 ½ minutes of physical activity during playtime. As a consequence, an alternative threshold was suggested. The data indicated that a threshold value of 40% for playtime physical activity might represent a more realistic health-promoting target for schools to adopt, as meeting this value enables children to accumulate the minimum recommendation of daily physical activity through playtime alone (Biddle et al., 1998). Moreover, since playtime offers children their main opportunity to be active during the school day (Sarkin et al., 1997), schools can play a significant role in promoting the activity levels of children by adopting measures to achieve this threshold. In conclusion, playtime provides children with daily opportunities to be physically active, though interventions are needed, particularly for junior girls, to induce higher activity levels within this context.

CHAPTER 6

Short-Term Effects (6-weeks) of a Playground Markings and Physical Structures Intervention on Physical Activity Levels during Playtime

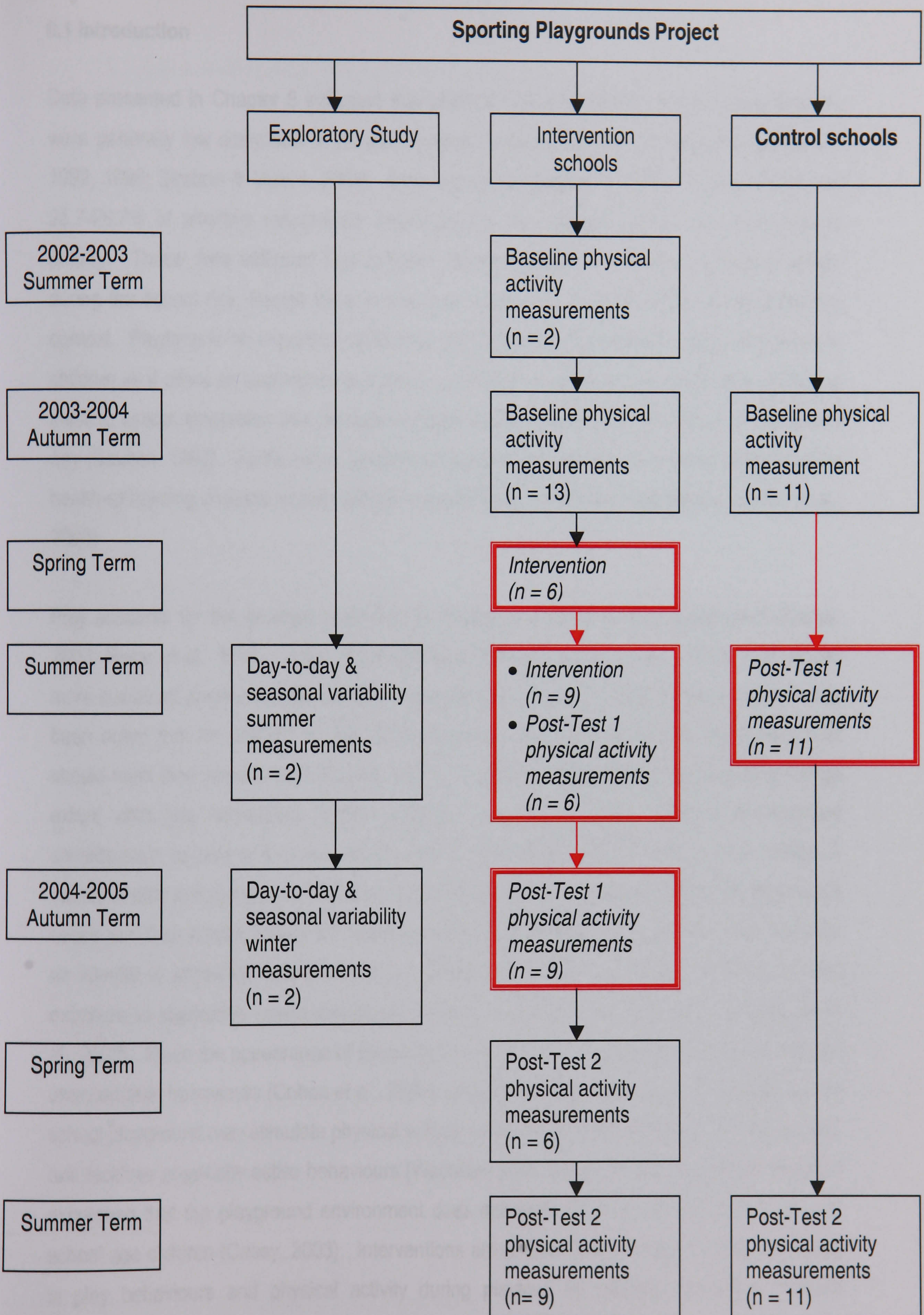


Figure 6.1: Stage of research design. Numbers of schools involved in each phase of the research are shown.

6.1 Introduction

Data presented in Chapter 5 indicated that children's physical activity levels during playtime were generally low compared to previous studies conducted in the UK (Sleap & Warburton, 1992, 1996; Stratton & Mullan, 2005). Boys and girls engaged in MVPA for 32.6-33.8% and 25.7-26.7% of playtime respectively depending on the method used to measure physical activity. These data indicated that children utilised playtime to engage in physical activity during the school day, though there is scope for increasing physical activity levels within this context. Playtime is an important context for the promotion of physically active behaviours to children as it offers an opportunity to increase children's physical activity levels without altering existing school timetables and because it accounts for a substantial proportion of the school day (Boulton, 1992). Furthermore, playtime presents an opportunity for children to accumulate health-enhancing physical activity without compromising academic performance (Strong et al., 2005).

Play accounts for the greatest proportion of children's physical activity engagement (Casey, 2003; Rippe et al., 1993). While the contribution of play to daily physical activity may require more sustained involvement than traditionalist definitions of play (Coalter & Taylor, 2001), it has been noted that for children to play spontaneously in the playground then the environment should meet their requirements (Casey, 2003). In addition, the environment dictates to a large extent what play behaviours children engage in (Armitage, 2001), which is an important consideration as play is the most natural way for children to be active (Rippe et al., 1993). A variety of play and activity opportunities should be provided relative to children's developmental needs and their health, fitness and behavioural benefits (Strong et al., 2005) in order to retain an interest in physically active behaviours (Welk et al., 2000). Ecological models posit that exposure to supportive environments can enhance physical activity behaviour (Giles-Corti et al., 2005). Since the appearance of the environment provides messages about acceptable and unacceptable behaviours (Cohen et al., 2000), providing space, equipment and facilities on the school playground may stimulate physical activity levels by providing environments that support and facilitate physically active behaviours (Wechsler et al., 2000). However, concern has been expressed that the playground environment does not meet the play or educational needs of school age children (Casey, 2003). Interventions are needed to encourage children to engage in play behaviours and physical activity during playtime by creating stimulating physical environments at school.

6.1.1 Physical Activity Levels following Playtime Interventions

The school playground environment, in which children spend the majority of their playtime, provides subtle messages to children about how particular places can be used and for whom they are intended (Titman, 1994). There is potential for playgrounds to be modified to provide equitable and regular activity opportunities to stimulate healthy activity and play behaviours in children of all ages (Casey, 2003; Giles-Corti & Donovan, 2002; Rippe et al., 1993). Individual schools are often motivated to initiate changes to playtime, the physical playground environment and playtime policy for a variety of reasons (Casey, 2003). These include improving behaviour, supporting the curriculum, safety reasons, better play facilities and increasing physical activity levels (Blatchford & Sumpner, 1998; Casey, 2003), though these changes are rarely rigorously evaluated. It is only recently that the effects of playtime-based interventions occurring in the playground on children's physical activity have been reported in the empirical literature (Table 2.4).

Positive effects of playtime based intervention strategies on children's physical activity levels have been reported when environmental modifications and strategies have been implemented. Several researchers have found significant short-term increases in children's physical activity levels and energy expenditure following playground markings interventions (Stratton, 2000; Stratton & Leonard, 2002; Stratton & Mullan, 2005). Other playtime-based interventions including fitness breaks (Scruggs et al., 2003), equipment provision (Verstraete et al., 2006), and a games intervention (Connolly & McKenzie, 1995) have reported significant increases in physical activity levels. Despite these positive findings, there is a need for playtime interventions to be conducted on larger numbers of objectively monitored children, as the majority of playtime studies are limited by small sample sizes. Examining the effects of playtime duration, age and gender on the intervention effect should also be considered, as these child and school-level variables have been shown to influence activity levels (Chapter 2). In addition, there is a need for playtime intervention studies to incorporate a control group and utilise a follow-up period to assess the impact of the intervention over time. Over half of the studies reported in Table 2.4 lack at least one of these in their research design. There is a need for playtime intervention research to incorporate both a control group and a follow-up period as these could have important implications in the interpretation of intervention studies results and consequently in the promotion of health-enhancing physical activity to primary school children whilst providing more generalisable data (Stratton & Mullan, 2005).

6.1.3. Purpose of Study

The main purpose of the current study was to investigate the short-term effects of the sporting playground intervention on children's MVPA and VPA during school playtime (Aim 3, page 48). A secondary aim of the study was to evaluate the potential influence of pupil-level and school-level covariates on the intervention effect.

6.2. Method

6.2.1. Subjects

Two hundred and thirty-two boys and 238 girls (aged 5-10 years) randomly selected from 26 primary schools from one large city in the North West of England returned signed written parental informed consent to participate in the study. Fifteen schools (130 boys, 126 girls) underwent the playground markings and physical structures intervention, while 11 schools (102 boys, 112 girls) served as socioeconomic matched control schools.

6.2.2 Intervention

Twenty intervention schools each received £20,000 to redesign the playground environment based on the sporting playground Zoneparc design [Figure 1.1]. The Zoneparc design has been described in Chapter 1. Of the initial 20 schools, 5 five schools did not receive the completed playgrounds within the timeframe of the project and were not included in the longitudinal phase of the research. Eleven schools served as socio-economic matched controls, and did not receive any playground markings through the national initiative. Small pieces of sports equipment (e.g. footballs, skipping ropes) were available for use in all school playgrounds throughout the duration of the study. Schoolteachers supervised morning and afternoon playtime, whilst specially employed lunchtime assistant's supervised lunchtime.

6.2.3 Study Overview

Children recruited into the study were randomly allocated to wear either one or two physical activity monitors. Randomisation was stratified by gender. All children wore a heart rate monitor (Polar Team System; n = 470), whilst 298 children (149 boys, 149 girls) additionally wore a uni-axial accelerometer (Actigraph, Model 7164). More children wore heart rate monitors compared to accelerometers due to equipment availability. Baseline measures were collected between July 2003 and March 2004. Follow-up intervention phase data were collected 6-weeks following the redesigning of the intervention schools' playgrounds, which occurred between March 2004 and July 2004. Control data were collected during these two measurement periods. All children wore the monitors on one school day at each measurement point. Seasonality was not controlled for due to data collected on a subgroup of schools indicated that there were no significant day to day or seasonal differences in playtime physical activity levels (Chapter 4). Anthropometric data were collected at each phase of the study using standardised procedures. The subsequent procedures followed the method described in Chapter 3.

6.2.4 Data Analysis

Heart rate and accelerometry data were downloaded and analysed as described in Chapter 3. Of the initial 470 children monitored using heart rate telemetry, complete data sets were obtained for 363 children (184 experimental, 179 control) and used in subsequent analyses. Thirty-eight children's data (20 boys, 18 girls) was lost due to monitor malfunction during the data collections. Thirty-one children were absent from school at the 6-week follow-up measurement (16 boys, 15 girls), and 38 children (20 boys, 18 girls) had left the schools being monitored. Two hundred and forty-three (107 intervention, 136 control) complete accelerometry data sets were also obtained and used in the analyses. Twenty children's data (9 boys, 11 girls) were lost due to monitor malfunction. Thirteen children were absent from school at the 6-week follow-up measurement (7 boys, 6 girls), and 22 children (11 boys, 11 girls) had left the schools being monitored.

Exploratory independent t-tests were conducted to examine differences in heart rate baseline physical activity levels for children wearing one or two physical activity monitors, and to examine gender and intervention group differences in baseline variables (age, stature, body mass and BMI). In addition, due to the attrition rate, independent t-tests were used to explore potential differences in children's playtime physical activity levels at baseline between children retained in the study and those with incomplete data for both heart rate telemetry and accelerometry. Descriptive data were analysed using the Statistical Package for the Social Sciences version 12 (SPSS Inc., Chicago, IL, USA).

6.2.4.1 Multilevel Modelling.

The main analysis used in this study to estimate the effect of the intervention on children's playtime physical activity was multilevel modelling (MLM). In this study, a two-level data structure was used where children were defined as the first level unit and schools as the second level unit (Twisk, 2006). The data were analysed using MLwiN 1.10 software (Institute of Education, University of London, UK). The percentage of MVPA and VPA engaged in during playtime 6-weeks following the intervention from both heart rate telemetry and accelerometry were the outcome variables, with baseline values for playtime physical activity (percentage), BMI (kgm^{-2}), age (years) and daily playtime duration (minutes; continuous variables) and gender (dichotomous variable) being used as covariates. Two analyses were conducted for the outcome variables on the 6-week follow-up measurement. The first analysis determined the difference between the intervention and the control group on children's playtime physical activity levels on the follow-up measure whilst controlling for differences in baseline physical activity levels ('crude' analysis), whilst the second determined this effect when the covariates were added to the model ('adjusted' analysis; Twisk, 2006). In addition, potential effect modification was assessed for all covariates in order to investigate whether the intervention effect is different for different subgroups. The effect of covariance was between the school intercepts and slopes was investigated using a covariance matrix, and assessed for significance by comparing the –2 log likelihood for each model on a Chi-square distribution with 2 degrees of freedom (Twisk, 2006). Subgroup analyses were conducted where significant effect modification was revealed. Separate analyses were conducted for MVPA and VPA using both monitoring methods. Regression coefficients in the model were assessed for significance using the Wald statistic (Twisk, 2006). The Wald statistic is calculated using the following equation:

$$\text{Wald statistic} = (\text{Regression Coefficient}/\text{Standard Error})^2$$

Statistical significance was set at $p < 0.05$, with the exception being interaction terms where it was $p < 0.10$ (Twisk, 2006). Wald tests are set at a higher significance level for interaction terms due to interactions having less power (Twisk, 2006).

6.3 Results

6.3.1 Descriptive Analyses

The mean (± SD) values for the children's anthropometric characteristics at baseline and 6-weeks post-test are shown in Table 6.1. Independent t-tests revealed that the experimental boys were significantly older than the control boys at baseline. There were no other significant gender or group differences on the remaining variables at baseline ($p > 0.05$). Independent t-tests revealed that the experimental boys were significantly older, had a higher body mass and higher stature than the control boys, while the experimental girls were significantly older and had a higher stature than the control girls at 6-weeks post-intervention ($p < 0.01$).

Table 6.1: Anthropometric characteristics of intervention and control children at baseline (number of boys = 232, number of girls = 238) and 6-weeks post-intervention (number of boys = 196, number of girls = 205; mean ± SD)

		Baseline		6-weeks	
	Gender	**Exp**	**Con**	**Exp**	**Con**
Age	Boy	8.4 ± 1.9*	7.9 ± 1.4*	9.1 ± 1.7*	8.3 ± 1.5*
	Girl	8.1 ± 1.7	8.1 ± 1.5	9.0 ± 1.5#	8.4 ± 1.6#
BM (kg)	Boy	31.9 ± 7.8	30.2 ± 8.6	33.7 ± 7.9*	30.9 ± 9.0*
	Girl	30.6 ± 8.4	30.3 ± 9.7	33.1 ± 8.8	30.8 ± 9.0
Stature (m)	Boy	1.33 ± 0.08	1.31 ± 0.09	1.36 ± 0.08*	1.33 ± 0.09*
	Girl	1.31 ± 0.09	1.29 ± 0.11	1.36 ± 0.09#	1.31 ± 0.11#
BMI (kgm^{-2})	Boy	17.8 ± 2.8	17.3 ± 2.9	18.2 ± 3.2	17.9 ± 3.1
	Girl	17.4 ± 2.9	17.7 ± 3.3	17.7 ± 3.0	17.8 ± 3.3

* Significant t-test inter-group result: experimental boys > control boys, $p < 0.01$

Significant t-test inter group result: experimental girls > control girls, $p < 0.01$

Key: BM = Body mass; BMI = Body mass index; Exp = Experimental (intervention) group; Con = Control group

6.3.2 Exploratory Analyses

The mean and *SD* values for children's physical activity levels during school playtime at baseline are shown in Table 6.2 for children who were retained and those who dropped out. Independent t-tests revealed a significant difference between complete and incomplete measures in baseline VPA when assessed using heart rate for girls ($p < 0.05$). Girls who had incomplete measures were less active than girls with complete measures. No significant differences were found between baseline playtime physical activity for boys and girls when quantified using either heart rate or accelerometry ($p > 0.05$). In addition, there were no significant differences between children who were retained and those who dropped out on age, body mass, stature and body mass index ($p > 0.05$).

Table 6.2: Descriptive baseline physical activity data (mean ± *SD*) for complete and incomplete data.

		Baseline MVPA (% playtime)		Baseline VPA (% playtime)	
		HR	ACC	HR	ACC
Complete	**Boys**	31.3 ± 18.7	32.2 ± 12.6	11.4 ± 11.8	5.8 ± 5.2
	Girls	25.1 ± 15.6	25.2 ± 10.6	8.2 ± 7.9*	4.9 ± 4.8
Incomplete	**Boys**	35.6 ± 14.9	32.7 ± 12	12.4 ± 8.3	5.4 ± 4.4
	Girls	19.9 ± 16.9	20.5 ± 8.8	4.5 ± 5.8*	3.5 ± 2.8

Note: HR data: Complete: boys = 176, girls = 187; Incomplete: boys = 56, girls = 51. ACC data: Complete: boys = 122, girls = 121; Incomplete: boys = 27, girls = 28.

Key: HR = Heart rate; ACC = Accelerometry; MVPA = Moderate-to-vigorous physical activity; VPA = Vigorous physical activity. * $p < 0.05$

6.3.3 Main Analyses

The results of the multilevel modelling analysis for MVPA and VPA assessed using heart rate and accelerometry are presented in Table 6.3. The random structure used in the models considered variation between the schools in their intercepts (level 2), and was used throughout the analyses. There was no significant effect of covariance on the model and it was not included in the association models.

6.3.3.1 Heart Rate

The crude analysis revealed a positive but statistically non-significant effect for the intervention. Children in the experimental group engaged in 4.32% (CI: -1.66 to 10.30) and 2.3% (CI: -0.52, 5.12) more $MVPA_{HR}$ and VPA_{HR} during playtime than the control group respectively. When the correction for potential confounders was performed (adjusted analysis), the $MVPA_{HR}$ regression coefficient decreased while the VPA_{HR} regression coefficient increased, though both intervention terms remained non-significant.

Table 6.3: Results of multilevel model analysis on the playground intervention on children's playtime physical activity levels (% playtime)

Outcome Measure	Crude Model[1]		Adjusted Model[2]	
	β (95% CI)	p	β (95% CI)	p
Heart Rate				
MVPA	4.32 (-1.66, 10.30)	0.16	4.05 (-1.70, 9.79)	0.17
VPA	2.3 (-0.52, 5.12)	0.11	2.49 (-0.32, 5.29)	0.08
Accelerometry				
MVPA	5.95 (0.14, 11.77)	<0.05*	4.5 (-1.05, 10.05)	0.11
VPA	1.7 (0.01, 3.39)	<0.05*	1.3 (-0.24, 2.84)	0.10

Note: The reference category for the intervention effect is control school. A positive beta coefficient (β) indicates a positive intervention effect on the physical activity levels of intervention children compared to control children during playtime at 6-weeks post-intervention. The β value reflects the percentage increase in activity levels during playtime of the intervention group compared to the control group. [1]Corrected for baseline physical activity. [2]Corrected for gender, BMI, age and playtime duration. CI = Confidence interval; MVPA = Moderate-to-vigorous physical activity; VPA = Vigorous physical activity.
* $p < 0.05$

Several significant interactions were revealed by the analyses. An inverse interaction was found between the intervention and baseline $MVPA_{HR}$ and VPA_{HR} ($p = 0.02$ and $p = 0.01$, respectively), indicating that the intervention effect is stronger for children who were less active at baseline. A positive interaction was found between the intervention and daily playtime duration for $MVPA_{HR}$ and VPA_{HR} ($p = 0.03$ and $p = 0.06$ respectively), indicating that the more absolute playtime there is available on a daily basis, the stronger the intervention effect is. In addition, a positive interaction was found between the intervention and gender for VPA_{HR} ($p = 0.05$). Subgroup analyses revealed that the intervention effect on VPA_{HR} during playtime was significantly stronger for girls than boys at 6-weeks post-intervention. Girls experienced greater increases in their VPA_{HR} engagement during playtime than boys (Table 6.4). The intervention effect for boys was not significant. All other interactions showed *p*-values > 0.10.

Table 6.4: Intervention effect on boys and girls VPA_{HR} levels during playtime

	β	95% CI	*p*
Boys			
Crude model[1]	-0.20	-3.84 to 3.43	0.91
Adjusted model[2]	0.20	-3.53 to 3.92	0.92
Girls			
Crude model[1]	4.22	0.71 to 7.71	0.02*
Adjusted model[2]	4.52	0.97 to 8.06	0.01*

Note: The β value reflects the percentage increase in activity levels during playtime of boys and girls in the intervention group compared to the control group.

[1]Corrected for baseline physical activity

[2]Corrected for BMI, age and play duration

* $p < 0.05$

6.3.3.2 Accelerometry

The crude analysis revealed a statistically significant effect for the intervention, with the intervention group engaging in 5.95% (CI: 0.14 to 11.77) and 1.7% (CI: 0.01 to 3.39) more $MVPA_{ACC}$ and VPA_{ACC} during playtime than the control group respectively. When the correction for potential confounders was performed (adjusted analysis), the regression coefficient for the intervention term was reduced and rendered non-significant for both $MVPA_{ACC}$ and VPA_{ACC}.

A number of significant interactions were revealed by the analyses. An inverse interaction was found between the intervention and age for both $MVPA_{ACC}$ and VPA_{ACC} ($p = 0.01$ and $p = 0.09$, respectively), indicating that the intervention effect is stronger for the younger children. In addition, a positive interaction was found between the intervention and daily playtime duration for $MVPA_{ACC}$ ($p = 0.07$), indicating that the more absolute daily playtime there is available, the stronger the intervention effect is. Subgroup analyses were conducted on VPA_{ACC} to investigate the effect of the intervention on boys and girls (Table 6.5). The results revealed that girls experienced greater increases in their VPA_{ACC} engagement during playtime than boys, though the increases were not significant. All other interactions (with baseline physical activity and BMI) showed *p*-values > 0.10.

Table 6.5: Intervention effect on boys and girls VPA_{ACC} levels during playtime

	β	95% CI	*p*
Boys			
Crude model[1]	1.37	-0.69 to 3.44	0.19
Adjusted model[2]	0.91	-1.06 to 2.89	0.37
Girls			
Crude model[1]	1.61	-0.53 to 3.75	0.08
Adjusted model[2]	1.73	-0.35 to 3.80	0.10

Note: The β value reflects the percentage increase in activity levels during playtime of boys and girls in the intervention group compared to the control group.

[1]Corrected for baseline physical activity

[2]Corrected for BMI, age and play duration

6.4 Discussion

The purpose of this study was to evaluate the short-term effects of a playground markings and physical structures intervention on children's physical activity levels during playtime using heart rate telemetry and accelerometry. A secondary aim of the study was to investigate the influence of pupil-level and school-level covariates on this effect. This study is unique in that MLM was used to analyse the results, as no playtime-based intervention studies have used this technique to analyse hierarchical data to date.

6.4.1. Intervention Effects on Physical Activity Levels during Playtime

The results revealed a positive yet non-significant intervention effect on children's playtime MVPA and VPA assessed using both heart rate and accelerometry. The absence of a significant intervention effect on children's playtime physical activity levels contrasts the findings of preceding empirical playtime-based studies, which have demonstrated significant increases in activity levels (Ernst & Pangrazi, 1999; Scruggs et al., 2003; Stratton, 2000; Stratton & Mullan, 2005; Verstraete et al., 2006). Furthermore, the results of the present study suggest that children in the intervention group engaged in approximately 4 - 4.5% and 1.3 - 2.5% more MVPA and VPA respectively during playtime than children in the control group. These increases are generally smaller than the short-term effects reported following playground markings (Stratton, 2000; Stratton & Mullan, 2005) and games equipment interventions on children's playtime MVPA and VPA (Verstraete et al., 2006).

In the present study, the accelerometry crude model analyses for MVPA and VPA indicated a significant positive effect of the intervention on activity levels when only baseline physical activity was controlled for. However, once potential pupil-level and school-level confounding variables were corrected for, small decreases were observed in the intervention regression coefficient. This rendered the intervention effect for both MVPA and VPA non-significant. These results highlight the influence of the assessed covariates on children's playtime physical activity levels. Furthermore, it suggests that both individual and group-level variables affect children's physical activity during playtime (Pellegrini & Smith, 1993; Zask et al., 2001). Pellegrini and Smith (1993) reviewed the effects of individual and group-level variables on children's behaviour during playtime, concluding that factors such as age, gender, and play duration interact with each other and relate to playground activity and behaviour. The findings from this study support this notion, and indicate that whilst the environmental intervention raised physical activity levels, the process of increasing activity during playtime is complex when additional variables are considered.

Zask et al. (2001) utilized multilevel modelling in a cross-sectional study to assess whether contextual variables including equipment availability, teacher behaviour and playground management were significant predictors of children's playtime physical activity. They found that the assessed contextual variables were not significant predictors of playtime MVPA. Significant predictors of MVPA were gender, playtime period and school size, where boys were more active than girls, lunchtime activity levels were higher than morning playtime, and children in small schools were more active than children in large schools (Zask et al., 2001). Similar findings were reported for VPA, though the ball to child ratio was also a significant predictor (Zask et al., 2001). Since the intervention in the present study only changed the physical playground environment, it is possible that the non-significant effects reported could be related to the social environment and contextual variables within the playgrounds assessed. The availability of equipment, for example, was not controlled for and children may have engaged in similar activities during baseline and post-test assessments regardless of the new structure of playground, as the same physical activity choices and equipment were available to them. Furthermore, the division of the playground into three colour coded areas may have encouraged children to participate in a wider range of activities, but all of these may not have necessarily promoted MVPA and VPA (e.g. sedentary choices such as over-sized board games in the yellow zone). Future studies should aim to combine objective physical activity monitoring with observational procedures, so that the effectiveness of the intervention on both activity and social behaviours may be assessed in more detail.

6.4.2. Pupil Level Influences on Intervention Effect

The Youth Physical Activity Promotion Model (Figure 1.2) highlights how individual characteristics can influence physical activity behaviour, and recognises the influence of both individual and environmental factors on activity engagement (Welk, 1999). Individual influences in combination with social and environmental factors can facilitate or inhibit individual behaviour through a reciprocal relationship (Cohen et al., 2000; King et al., 2002; Sallis & Owen, 1999; Spence & Lee, 2003). Previous playtime studies have evaluated the short-term effects of factors that enable children to be active, including playground markings and equipment, as well as reinforcing factors such as organised games and primarily teacher-led structured activity breaks (Ernst & Pangrazi, 1999). While some empirical research has compared intervention effects between boys and girls' activity or between children at different stages of schooling, to the best of the authors knowledge, no playtime intervention studies designs have considered the effect of the intervention effect or the differences in the intervention effect when individual and school-levels variables have been controlled for.

In this study, potential effect modification was assessed for all covariates in order to investigate whether the intervention effect is different for different subgroups (Twisk, 2006). The results revealed significant interaction terms for age, baseline physical activity and gender with the intervention effect. The intervention effect was stronger on younger children's MVPA and VPA compared to older children when assessed using accelerometry, while girls VPA increased significantly compared to boys when quantified using heart rate. These findings may both be related to the social context of the school playground. Behavioural studies, both cross-sectional and longitudinal, have suggested that as children grow older, the size of their social group increases (Blatchford, 1998; Blatchford et al., 2003). In addition, boy's networks are significantly larger than girls, and they are more likely to play with same-aged peers (Blatchford et al., 2003). With older boys often dominating the available play space for active games such as football (Armitage, 2001; Boyle et al., 2003), younger children and older girls are often found on the margins of the playground (Armitage, 2001; Renold, 1997). The environmental intervention in this present study provided both playground markings and physical structures, which increased the choice of activities during playtime for boys and girls alike, and as competitive ball games (such as football) were restricted to one area, these children were no longer marginalised on the playground (Armitage, 2001; Boyle et al., 2003). Pellegrini and Smith (1993) noted that children were more active in spacious environments compared to restricted environments. Their study found that younger children had more space and physical activity opportunities when football became less dominant, potentially explaining why the effect on younger children's MVPA and VPA and girls' VPA was stronger than older children and boys' VPA. Further studies employing systematic observation of play behaviour are required to verify these initial findings.

From a public health perspective, it is positive that the playground intervention effect was stronger for children who engaged in less MVPA and VPA at baseline. Low active children have been found to remain less active than their more active peers when activity was tracked in early childhood (Pate et al., 1996), and physical activity behaviours adopted in childhood appear to track, albeit weakly, into adolescence (Malina, 1996). In addition, Telema and colleagues (2005) reported that physical activity in childhood and adolescence significantly predicts activity participation in adulthood. Given that both activity and inactivity appear to track across time (Malina, 1996; Pate et al., 1996; Telema et al., 2005; van Mechelen & Kemper, 1995), the results of the present study suggest that changing the playground environment to include playground markings and physical structures may be a suitable intervention for promoting physical activity levels in low active children. It is possible that the intervention provided low active children with a greater range of activity opportunities, which increased their access to facilities and potentially decreased their perceived barriers to activity engagement as a number of activities were offered in the specific zones within well resourced playgrounds. These determinants have been identified as having consistent relationships with physical activity (Sallis et al., 2000). It should be noted that this finding was only found for HR monitoring. Thus our data suggests that the strain placed on the cardiorespiratory system increased, whilst mechanical stress may not have been greatly influenced. Future playtime studies should implement direct observation to discern what activities these children engaged in both at baseline and follow-up to clarify these findings. Moreover, the maintenance of physical activity behaviours is an important component of activity tracking across time (Malina, 1996; Telema et al., 2005), therefore longitudinal studies are required to discern whether playground interventions continue to stimulate children who were low active at baseline.

6.4.3. School Level Influences on Intervention

A significant interaction for MVPA between the intervention effect and playtime duration was found, with longer playtime length increasing children's MVPA engagement. Previous studies have reported conflicting findings concerning physical activity engagement with regards to playtime length. McKenzie et al. (1997a) reported that as playtime progressed at elementary schools, children became significantly less active. In contrast, the study by Zask et al. (2001) highlighted that the length of playtime contributed to playtime physical activity engagement, with activity levels as a proportion of playtime being higher during the longer lunchtime compared to morning playtime. It was suggested that higher activity during lunchtime might reflect that the children had more time available to become engaged in games and other activities (Zask et al., 2001). The present study lends support to this latter suggestion, as higher physical activity levels were associated with longer playtime duration, suggesting that the intervention was more effective when playtime was longer.

The effects of playtime duration have been examined in previous intervention studies. One study that investigated the effects of a games equipment intervention on activity levels revealed greater increases in activity engagement during lunchtime compared to morning playtime, while boys' activity actually decreased following the intervention during morning playtime (Verstraete et al., 2006). A second study that investigated the effect of playtime length on physical activity levels by increasing play duration by 5 minutes found that children engaged in more absolute MVPA during the longer playtimes, though interestingly there was little percentage change in activity levels following the intervention (Guinhouya et al., 2005). The findings from these and the present study indicate that longer playtime periods enable children to engage in more MVPA and VPA following the intervention. However, it is not known whether children engaged in more short bouts of MVPA and VPA, a characteristic of their physical activity patterns (Bailey et al., 1995; Baquet et al., in press), or engaged in more sustained bouts of physical activity. Research into physical activity patterns has suggested that the majority of bouts of activity are short in duration. Baquet and co-workers reported that approximately 75% of bouts of MVPA and VPA were under 4 seconds in duration, whilst Bailey et al. (1995) reported that 95% of high intensity activity was less than 15 seconds on duration. Future research should investigate this issue in combination with direct observation to assess which playground markings or physical structures encourage bouts of activity or sustained activity. This would enable researchers to determine which aspects of the playground are most effective in promoting or sustaining physical activity in the playground environment.

The effect of playtime duration on physical activity levels may be explained in a number of ways. Firstly, the children may have had more time to take advantage of the increased activity opportunities during playtime, and become habituated to the activity opportunities on offer in the redesigned playgrounds (Pellegrini & Smith, 1993; Zask et al., 2001). Secondly, approximately one quarter of PE lessons can be accounted for by the organization of teams, activities and games rules (McKenzie et al., 1997b). Consequently, longer playtime duration may allow time for the initial organisation of games and activities while reducing the impact these social interactions could have on activity levels. A pressing concern in the literature has been the erosion of playtime available, with reductions being reported both in the UK and in the United States (Blatchford & Baines, 2006; Blatchford & Sumpner, 1998; Pellegrini & Bohn, 2005). This study suggests that longer playtime durations are needed for children to effectively use the playground interventions to be physically active in this context.

6.4.4. Study Limitations

This study attempted to determine the effects of the sporting playgrounds markings and physical structures intervention 6-weeks using a multilevel modelling approach. However, a number of limitations exist that warrant attention. The use of heart rate telemetry to quantify physical activity levels is a limitation, as heart rate is not a direct measure of physical activity and can be affected by factors such as fitness and emotional states (Epstein et al., 2001; Janz, 2002). Nevertheless, heart rate is a widely used objective measure that has been found to be valid and reliable for use in paediatric populations (Janz, 2002), and comparable data to accelerometry were recorded in the study. In addition, no significant differences were observed in physical activity values between days and seasons, with similar standard deviations reported, suggesting that recorded activity was not greatly affected by external variables (Chapter 4). Secondly, the drop out at the follow-up test following the intervention, which was equally attributable to children either leaving the monitored school, being absent on the testing day, or experiencing monitoring problems, limited the study. All experimental and control schools were situated in areas of high economic and social deprivation, which was a factor in the schools having a highly transient population across the academic year. However, it should be noted that the baseline physical activity levels of the children retained in the project and those who dropped out were not significantly different for both heart rate and accelerometry, with the only significantly difference being observed for girls' VPA_{HR}.

The study is also limited, as it did not control the amount of equipment that was available to children in each school, and it did not monitor the method of supervision provided by the adult staff during playtime. Both these factors may have effects on the physical activity levels of children during the intervention. In addition, while school was included in the multilevel modelling as a level and the effect of school on the outcome measures were controlled for, the number of children on the playground relative to its size during playtime was not controlled for. It is possible that the schools, which had a large number of pupils in the playground in relation to its size, may have affected physical activity levels, as children have been found to be more active in spacious environments (Pellegrini & Smith, 1993). It is recommended that future studies should combine physical activity measurements, for example accelerometry with direct observation, as the social context of the playground is an important influencing factor on children's playtime physical activity and play behaviour (Pellegrini & Smith, 1993). In addition, assessing the number of children on the playground in relation to its size may be an essential factor to consider and control for in playtime research. It is important to determine the effects of playtime interventions on physical activity levels, but this study suggests that there is a need for observational data to explain what other factors may have influenced the findings.

6.5 Conclusions

The present study contributed to the dearth of empirical literature investigating the short-term effects of a school-based intervention on children's playtime physical activity levels by using multiple objective measures to quantify physical activity levels in a large sample of children. The study suggested that the effect of the intervention was not significant when potential confounders were added to the analysis. It is possible that future playtime interventions should consider a combination of initiatives targeting both individual factors and group factors to develop the utility of playtime as a health promotion context. In this study, significant interaction terms indicated that the effects of the intervention were greater for younger children, children who were less active at baseline, and children with longer playtime duration. From an ecological perspective, the results suggest that children who have a broader range of activity opportunities during playtime do not necessarily make the most of these opportunities to engage in health enhancing physical activity, though environmental effects may be subtle and only manifest themselves over time (Spence & Lee, 2003; Welk, 1999). However, the non-significant but positive increases indicate that some effect was present, and that access to these opportunities is more preferable than having no opportunities for PA engagement during playtime (Welk, 1999). There is a need to evaluate the longer-term effects of environmental interventions on physical activity levels during playtimes.

CHAPTER 7

Evaluating the Long-Term Effects of a Playground Markings and Physical Structures Intervention on Children's Playtime Physical Activity Levels

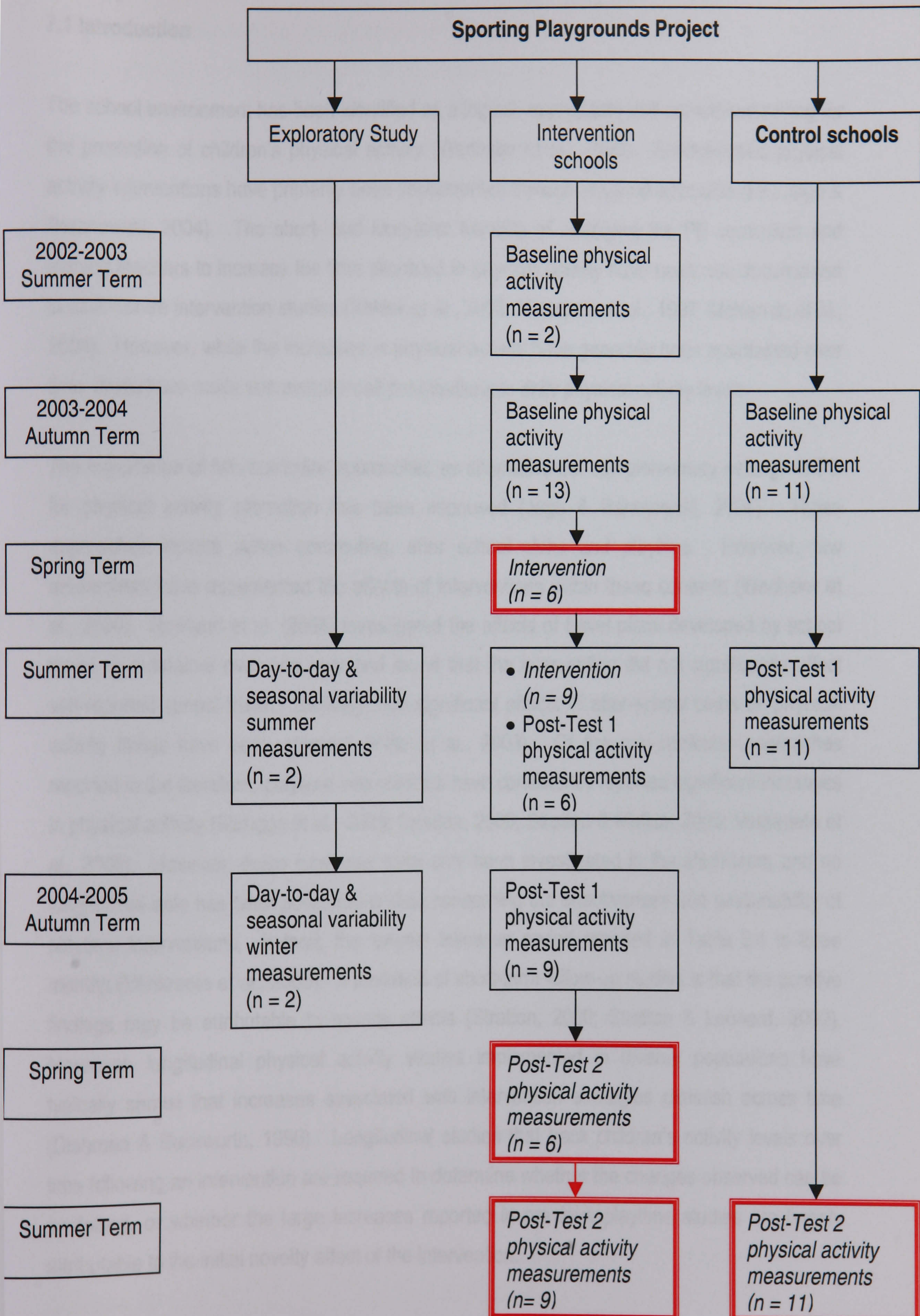


Figure 7.1: Stage of research design. Numbers of schools involved in each phase of the research are shown.

7.1 Introduction

The school environment has been identified as a logical, appropriate and convenient setting for the promotion of children's physical activity (Wechsler et al., 2000). School-based physical activity interventions have primarily been implemented through physical education (PE; Jago & Baranowski, 2004). The short- and long-term benefits of modifying the PE curriculum and training teachers to increase the time allocated to physical activity have been well documented in multi-centre intervention studies (Kelder et al., 2003; McKenzie et al., 1997; McKenzie et al., 2004). However, while the increases in physical activity have generally been maintained over time, these have made somewhat small contributions to daily physical activity levels.

The importance of non-curricular approaches as alternative but complementary settings to PE for physical activity promotion has been espoused (Jago & Baranowski, 2004). These approaches include active commuting, after school clubs and playtime. However, few researchers have documented the effects of interventions within these contexts (Wechsler et al., 2000). Rowland et al. (2003) investigated the effects of travel plans developed by school travel co-ordinators over one year and found that the intervention did not significantly affect self-reported school travel. Similarly, non-significant effects of after-school clubs on physical activity levels have been reported (Pate et al., 2003). Of the non-curricular approaches reported in the literature, playtime interventions have consistently reported significant increases in physical activity (Scruggs et al., 2003; Stratton, 2000; Stratton & Mullan, 2005; Verstraete et al., 2006). However, these increases have only been investigated in the short-term, and no longitudinal data has been published to date concerning the effectiveness and sustainability of playtime interventions. Indeed, the longest follow-up period reported in Table 2.4 is three months (Verstraete et al., 2006). A limitation of short-term follow-up studies is that the positive findings may be attributable to novelty effects (Stratton, 2000; Stratton & Leonard, 2002). Moreover, longitudinal physical activity studies implemented in diverse populations have typically shown that increases associated with intervention strategies diminish across time (Dishman & Buckworth, 1996). Longitudinal studies that track children's activity levels over time following an intervention are required to determine whether the changes observed can be sustained, or whether the large increases reported in previous playtime studies are largely attributable to the initial novelty effect of the intervention.

In the US, PE interventions are strongly recommended by the US Task Force as a school-based context for increasing children's physical activity (Heath, 2003; Kahn et al., 2002). In the UK, Choosing Health (DH, 2004b) also highlights PE as an important context for children to be active, and includes the public service agreement of two hours of high quality PE and school sport a week in its action plan. However, similar recommendations have not been provided for playtime, despite Choosing Health (DH, 2004b) stating the importance of increasing informal opportunities, such as play, for children to be active. This may be attributable to the lack of empirical data concerning the effectiveness and sustainability over time. Moreover, PE in comparison to playtime offers a broader taught approach that can promote young people's physical, social, psychological and moral development beyond the PE lesson itself (Fairclough & Stratton, 2006). Medium to long-term data on the effect of interventions on the promotion of children's physical activity during primary school playtime are required. Such data will enable health promoters to quantify the sustainability of positive behaviour change in a commonly occurring ubiquitous context. Due to the repeatability of school playgrounds as a physical activity promoting context positive results may have a direct influence over current public health policy

Playground interventions have been developed in recent years largely on the premise that as they are largely peer-controlled, they represent a sustainable physical activity context (Casey, 2003). Physical structures and resources such as equipment are available (Cohen et al., 2000; Wechsler et al., 2000), which can influence a child's decision about activity engagement (King et al., 2002). In contrast, concern has been expressed that the interventionist approach may have limited effects on physical activity and play behaviour (Blatchford, 1998; Casey, 2003), and that we are moving towards a play to order approach for children (Thomson, 2005). In addition, the use of prescriptive spaces that are designed for specific activities has been chastised as adult attempts to contain and control children's play at school rather than allowing children to freely choose activities, which places strain on the space of the playground (Thomson, 2005). Imposing new structures and restrictions on playground may not be maintained for long, as they do not originate from the existing playground culture, and the playground could revert back to its former structure; this structure being an established hierarchy of power based around age (Blatchford, 1998). There is therefore a need to determine whether playground interventions have a sustained impact on physical activity levels over time.

7.1.2. Purpose of Study

The main purpose of the present study was to investigate the longitudinal effects of a playground markings and physical structures intervention on children's playtime moderate-to-vigorous (MVPA) and vigorous physical activity (VPA) engagement during playtime over time (Aim 4, page 48), and to evaluate the potential influence of covariates on the intervention effect.

7.2. Method

7.2.1 Subjects

Two hundred and thirty-two boys and 238 girls randomly selected from 26 primary schools from one large city in the North West of England returned signed written parental informed consent to participate in the study. Fifteen schools (130 boys, 126 girls) underwent the intervention, while 11 (102 boys, 112 girls) served as socioeconomic matched controls. The playground markings and physical structures intervention has been previously described in Chapters 1 and 6.

7.2.2 Study Overview

All children wore a heart rate monitor (Polar Team System; n = 470), whilst 298 children (149 boys, 149 girls) additionally wore a uni-axial accelerometer (Actigraph, Model 7164). All children wore the monitors on one school day at each measurement point. Baseline measures were collected between July 2003 and March 2004. Follow-up intervention phase data were collected 6-weeks and 6-months following the redesigning of the intervention schools' playgrounds, which occurred between March 2004 and July 2004. Control data were collected during these three measurement periods. Anthropometric data were collected at each phase of the study using standardised procedures. The subsequent procedures followed the method described in Chapter 3.

7.2.3 Data Analysis

Heart rate and accelerometry data were downloaded and analysed as described in Chapter 3. At follow-up 1 (6-weeks), heart rate and accelerometry data were collected from 80% and 87%

of the available sample in this phase of the project respectively. Children who did not withdraw from the study but who did not record data due to school absence or monitoring problems were recorded as missing data at that point. At follow-up 2 (6-months), heart rate and accelerometry data were collected from 84% and 92% of the available sample respectively. Despite some missing data, all longitudinal data collected from the children were used in subsequent analyses. Multilevel modelling is robust against missing data points and can estimate intervention effects over time whilst making use data from children with incomplete follow-up (Quené & van den Bergh, 2004).

Exploratory independent t-tests were conducted to examine gender and intervention group differences in baseline variables (age, stature, body mass and BMI). In addition, paired t-tests were conducted to examine changes in experimental and control children's age, stature, body mass and BMI between baseline and 6-weeks, and 6-weeks and 6-months post-intervention. Descriptive data were analysed using the Statistical Package for the Social Sciences version 12 (SPSS Inc., Chicago, IL, USA).

7.2.3.1 Multilevel Modelling

A three-level multilevel data structure was used to determine the effects of the playground intervention across time. The three levels of analysis were the timing of the follow-up measurement (level 1), pupil (level 2) and school (level 3). Multilevel data were analysed using MLwiN 1.10 software (Institute of Education, University of London, UK). The two measurements of MVPA and VPA assessed using HR and accelerometry following the intervention were defined as the outcome variables. Baseline values for MVPA, VPA, BMI, age and playtime duration (continuous variables) and gender (dichotomous variable) were used as covariates within the analyses. Since follow-up measures were conducted at irregularly spaced intervals, time (dichotomous variable) was included in the analyses to account for this. Two analyses were conducted on MVPA and VPA for each physical activity measurement method to examine the effect of the intervention over time. The first analysis determined the effect of the intervention over time whilst controlling for baseline physical activity and time ('crude' analysis), whilst the second determined the intervention effect when the covariates were added to the model ('adjusted' analysis; Twisk, 2006). The effect of covariance was between the school intercepts and slopes was investigated using a covariance matrix, and assessed for significance by comparing the –2 log likelihood for each model on a Chi-square distribution with

2 degrees of freedom (Twisk, 2006). Potential effect modification was assessed by constructing interaction terms between the intervention group and all covariates. Separate analyses were conducted for MVPA and VPA measured using each method. Regression coefficients in the model were assessed for significance using the Wald statistic (Twisk, 2006). Statistical significance was set at $p < 0.05$, with the exception being interaction terms where it was $p < 0.10$ (Twisk, 2006).

7.3 Results

7.3.1 Descriptive Analyses

The anthropometric characteristics of the children in the sample are described in Table 7.1. Independent t-tests revealed that the experimental boys were significantly older than the control boys at baseline. There were no other significant gender or group differences on the remaining variables at baseline ($p > 0.05$). Independent t-tests revealed that the experimental boys were significantly older, had a higher body mass and higher stature than the control boys, while the experimental girls were significantly older and had a higher stature than the control girls at 6-weeks post-intervention. At 6-months post-intervention, the experimental boys were significantly older, and had a higher body mass and stature than the control boys. In addition, the experimental girls had higher stature and body mass than the control girls at 6-months post-test. Paired t-tests revealed significant increases changes in age, body mass, stature and BMI between baseline and 6-weeks for intervention and control boys and girls ($p < 0.01$), with the exception of BMI in control girls ($p > 0.05$). Significant increases were observed in age, body mass and stature between 6-weeks and 6-months in control and experimental boys and girls ($p < 0.01$). No significant changes were observed in BMI between 6-weeks and 6-months ($p > 0.05$).

7.3.2 Main Analyses

The descriptive (mean ± SD) anthropometric characteristics of the children at baseline are displayed in Table 7.2. Intervention boys were older than control boys at baseline ($p < 0.05$). No other significant differences were found between the groups, and between boys and girls, for the remaining variables ($p > 0.05$). Table 7.3 shows the effect of the intervention on both MVPA and VPA across time assessed using HR and accelerometry. The random structure used in the models considered variation between the schools in their intercepts (level 2), and was used throughout the analyses. There was no significant effect of covariance on the model and it was not included in the association models.

7.3.2.1 Heart Rate.

A statistically positive intervention effect across time was found for both $MVPA_{HR}$ ($p < 0.05$) and VPA_{HR} ($p < 0.05$; Table 7.1). Intervention school children engaged in 4% and 2.4% more $MVPA_{HR}$ and VPA_{HR} respectively during playtime than control school children over time (adjusted scores). Figures 7.2 and 7.3 descriptively show that the control children's $MVPA_{HR}$ and VPA_{HR} during playtime remained relatively stable across time, while the intervention children's activity was increased and sustained across time (raw scores). A positive interaction term was found between the intervention and daily playtime duration for both $MVPA_{HR}$ and VPA_{HR} ($p < 0.05$), indicating that the intervention effect was stronger with increasing playtime duration. In addition, inverse interaction terms were found between the intervention and baseline $MVPA_{HR}$ and VPA_{HR} ($p < 0.05$ and 0.10 respectively), indicating that the intervention effect was stronger for children who were less active at baseline. All other interaction terms (with time, gender, age and BMI) showed p-values > 0.10.

7.3.2.2 Accelerometry.

A statistically positive intervention effect across time was found for both $MVPA_{ACC}$ ($p < 0.05$) and VPA_{ACC} ($p < 0.05$; Table 7.1). Intervention school children engaged in 4.5% and 2.3% more $MVPA_{ACC}$ and VPA_{ACC} respectively during playtime than control school children over time (adjusted scores). Figures 7.4 and 7.5 show descriptively that the control children's $MVPA_{ACC}$ and VPA_{ACC} during playtime decreased slightly across time across time, while the intervention children's $MVPA_{ACC}$ increased then decreased, while children's VPA_{ACC} continued to increase over time (raw scores). An inverse interaction between intervention and age was found for $MVPA_{ACC}$ ($p < 0.05$), indicating that the intervention effect was stronger for the younger children. In addition, a positive interaction was found between the intervention and daily playtime duration for $MVPA_{ACC}$ ($p < 0.10$), indicating that the intervention effect was stronger with increasing playtime duration. A positive interaction was found between the intervention and time for VPA_{ACC} ($p < 0.05$), suggesting that the intervention effect strengthened longitudinally across time. All other interaction terms showed p-values > 0.10.

Table 7.1: Anthropometric characteristics of intervention and control children at baseline, 6-weeks and 6-months post-intervention (mean ± SD)

		Baseline		6-weeks		6-months	
	Gender	Exp	Con	Exp	Con	Exp	Con
		(n = 256)	(n = 214)	(n = 185)	(n = 178)	(n = 205)	(n = 100)
Age	Boy	8.4 ± 1.9**	7.9 ± 1.4**	9.1 ± 1.7*	8.3 ± 1.5*	9.7 ± 1.8**	8.9 ± 1.5**
	Girl	8.1 ± 1.7	8.1 ± 1.5	9.0 ± 1.5##	8.4 ± 1.6##	9.6 ± 1.6	9.0 ± 1.4
Body Mass (kg)	Boy	31.9 ± 7.8	30.2 ± 8.6	33.7 ± 7.9**	30.9 ± 9.0**	35.2 ± 8.8*	32 ± 10.5*
	Girl	30.6 ± 8.4	30.3 ± 9.7	33.1 ± 8.8	30.8 ± 9.0	34.4 ± 9.0##	31.9 ± 8.2##
Stature (m)	Boy	1.33 ± 0.08	1.31 ± 0.09	1.36 ± 0.08**	1.33 ± 0.09**	1.38 ± 0.08**	1.35 ± 0.11**
	Girl	1.31 ± 0.09	1.29 ± 0.11	1.36 ± 0.09##	1.31 ± 0.11##	1.38 ± 0.09##	1.33 ± 0.10##
BMI (kgm^{-2})	Boy	17.8 ± 2.8	17.3 ± 2.9	18.2 ± 3.2	17.9 ± 3.1	18.3 ± 3.3	17.9 ± 3.5
	Girl	17.4 ± 2.9	17.7 ± 3.3	17.7 ± 3.0	17.8 ± 3.3	17.9 ± 3.0	17.8 ± 3.5

Significant t-test inter-group result: experimental boys > control boys, $p < 0.01$**, $p < 0.05$*

Significant t-test inter group result: experimental girls > control girls, $p < 0.01$##

Key: Exp = Experimental (intervention) group; Con = Control group

Table 7.2: Uncorrected means ± SD for physical activity levels during playtime (% playtime) assessed using heart rate and accelerometry at baseline, and 6-weeks and 6-months post-intervention for children in the intervention and control schools.

		Baseline		6-weeks[a]		6-months[b]	
PA Measure	**Gender**	**Exp**	**Con**	**Exp**	**Con**	**Exp**	**Con**
MVPA							
HR	Boy	29.3 ± 17.2#	37.1 ± 18.5#	35.4 ± 18.7	36.7 ± 18.4	37.9 ± 20.3	36.6 ± 19.3
	Girl	23.5 ± 16.6	27.3 ± 15.3	29.1 ± 19.1*	25.1 ± 16.5*	28.4 ± 16.7	24.2 ± 15
ACC	Boy	30.8 ± 11.7	33.7 ± 13.2	38.1 ± 15.3	34.6 ± 12.9	37.1 ± 14.5	32.2 ± 12.1
	Girl	21.9 ± 9.9#	27 ± 10.4#	28.2 ± 12.8	23 ± 9.7	26.8 ± 11.8	22.1 ± 7.7
VPA							
HR	Boy	9.6 ± 10.2#	13.5 ± 12.6#	11.6 ± 10.8	13.6 ± 13.5	14.2 ± 14.2	13.9 ± 12.7
	Girl	6.9 ± 7.6	8 ± 7.1	10.4 ± 12.2	6.7 ± 8.1	8.9 ± 9.4	6.8 ± 8.4
ACC	Boy	4.5 ± 4.1#	7 ± 5.7#	10.2 ± 6.9	9.1 ± 6.6	10.7 ± 8.3	8.1 ± 6.3
	Girl	2.9 ± 3.6#	6.5 ± 4.9#	5.9 ± 5.3	5.3 ± 3.4	5.8 ± 5.2	4.9 ± 3.3

[a] Sample size at 6-weeks: HR Boys = 220 (114 Exp, 106 Con), Girls = 222 (116 Exp, 106 Con); ACC Boys = 140 (67 Exp, 73 Con), Girls = 136 (62 Exp, 74 Con)

[b] Sample size at 6-months: HR Boys = 172 (110 Exp, 62 Con), Girls = 174 (111 Exp, 63 Con); ACC Boys = 108 (64 Exp, 44 Con), Girls = 105 (61 Exp, 44 Con)

Significant inter-group difference: control > experimental group, $p < 0.05$; * Significant inter-group difference: control < experimental group, $p < 0.05$

Key: Exp = Experimental (intervention) group; Con = Control group; MVPA = Moderate-to-vigorous physical activity; VPA = Vigorous physical activity; HR = Heart rate; ACC = Accelerometry

Table 7.3: Results of longitudinal multilevel model analyses on the playground intervention on children's playtime physical activity levels over 2 follow-ups.

Outcome Measure	Crude Model[1] β (95% CI)	Crude Model[1] p	Adjusted Model[2] β (95% CI)	Adjusted Model[2] p
Heart Rate				
MVPA	4.52 (0.19, 8.85)	0.04*	4.03 (0.15, 7.91)	0.04*
VPA	2.36 (-0.11, 4.83)	0.06	2.43 (0.06, 4.80)	0.04*
Accelerometry				
MVPA	5.68 (1.41, 9.96)	<0.01**	4.53 (0.59, 8.47)	0.03*
VPA	2.47 (0.75, 4.19)	<0.01**	2.32 (0.71, 3.93)	<0.01**

Note: Reference category for intervention effect is control school. Regression coefficients (β) reflect the average differences in physical activity levels during playtime assessed using heart rate and telemetry over the two follow-up measurements (6-weeks and 6-months post-intervention) from baseline. A positive β value indicates a positive intervention effect on the physical activity levels of intervention children compared to control children during playtime over time (6-weeks and 6-months post-intervention). The β value reflects the percentage increase in activity levels during playtime of the intervention group compared to the control group. [1]Crude model: Adjusted for baseline value of physical activity measure and time. Since follow-up measures were conducted at irregularly spaced intervals, time was included in the crude model to account for this. [2] Adjusted model: Model further additionally adjusted for gender, and baseline BMI, age and playtime duration. CI = Confidence intervals. MVPA = Moderate-to-vigorous physical activity. VPA = Vigorous physical activity. * $P < 0.05$, ** $P < 0.01$.

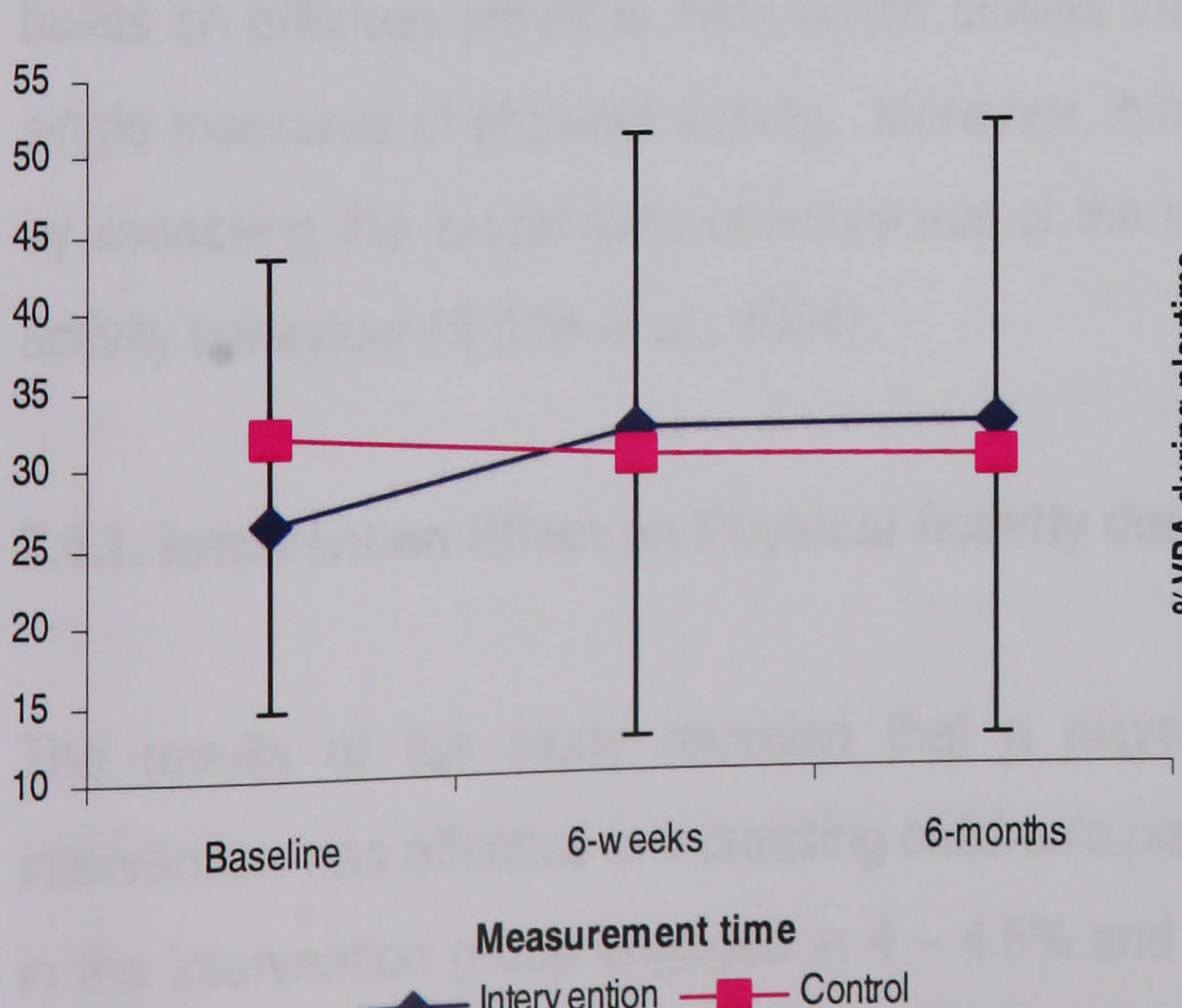


Figure 7.2: Participation in MVPA assessed using heart rate during playtime for the intervention and control groups across the study (raw scores).

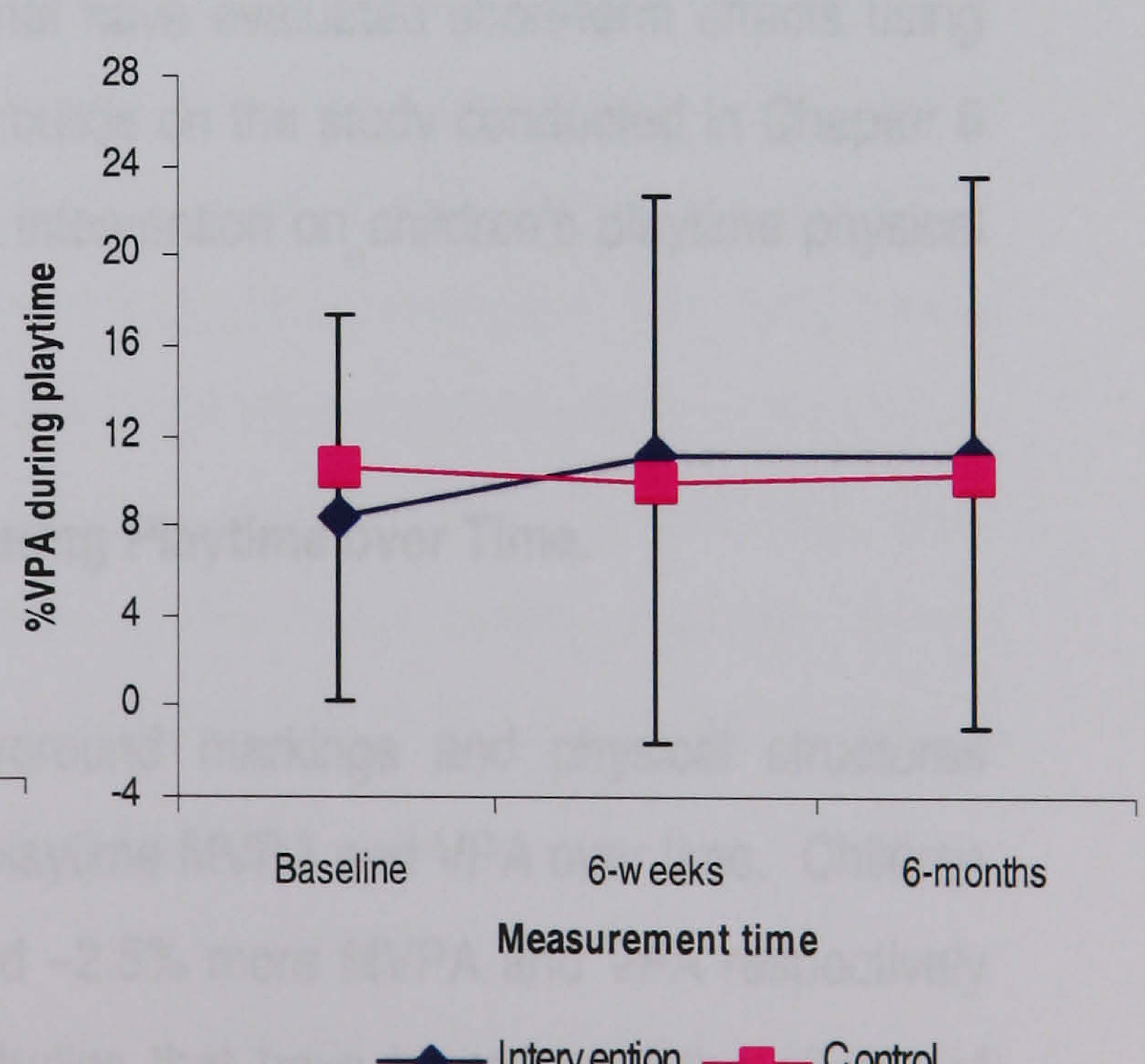


Figure 7.3: Participation in VPA assessed using heart rate during playtime for the intervention and control groups across the study (raw scores).

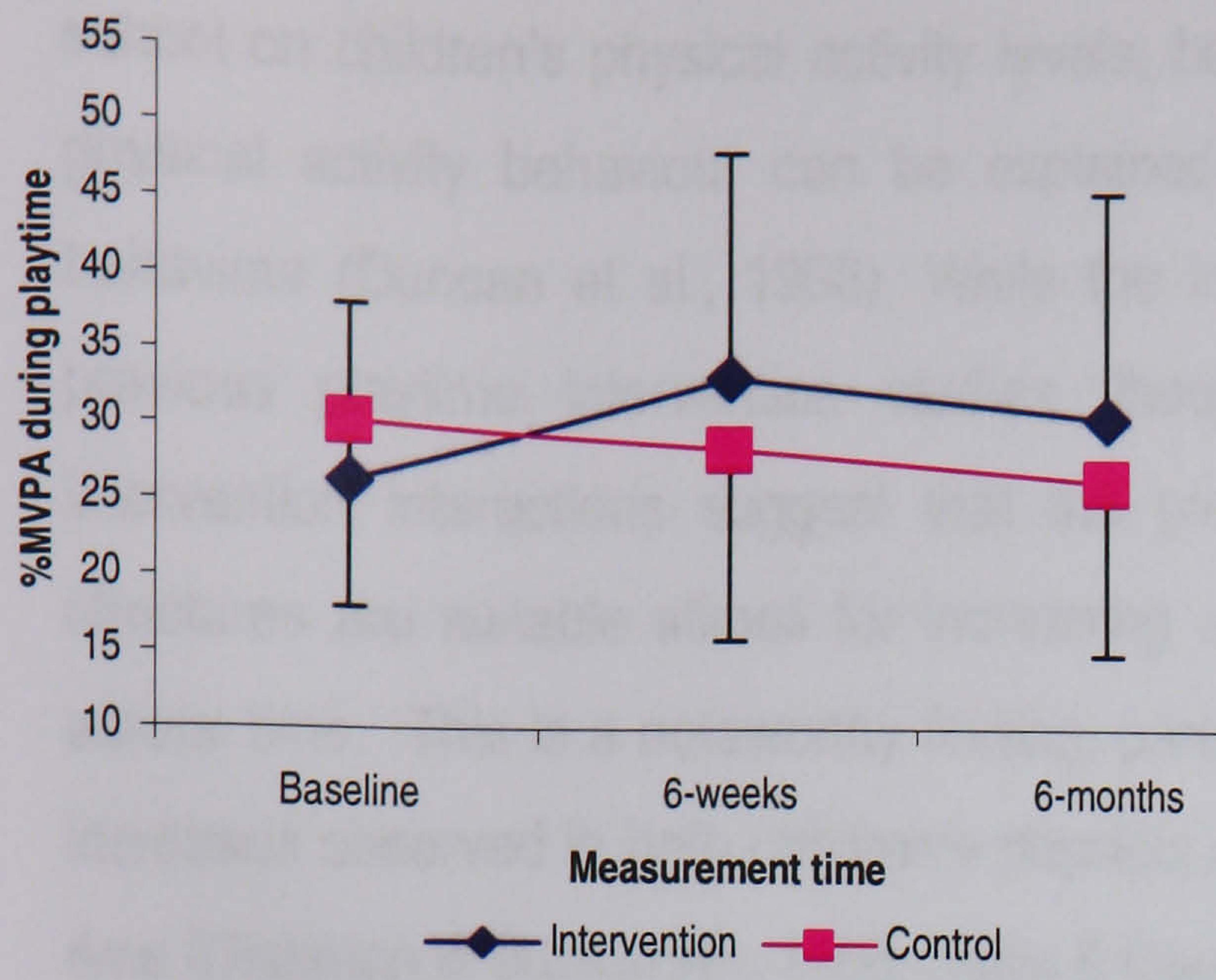


Figure 7.4: Participation in MVPA assessed using accelerometry playtime for the intervention and control groups across the study (raw scores).

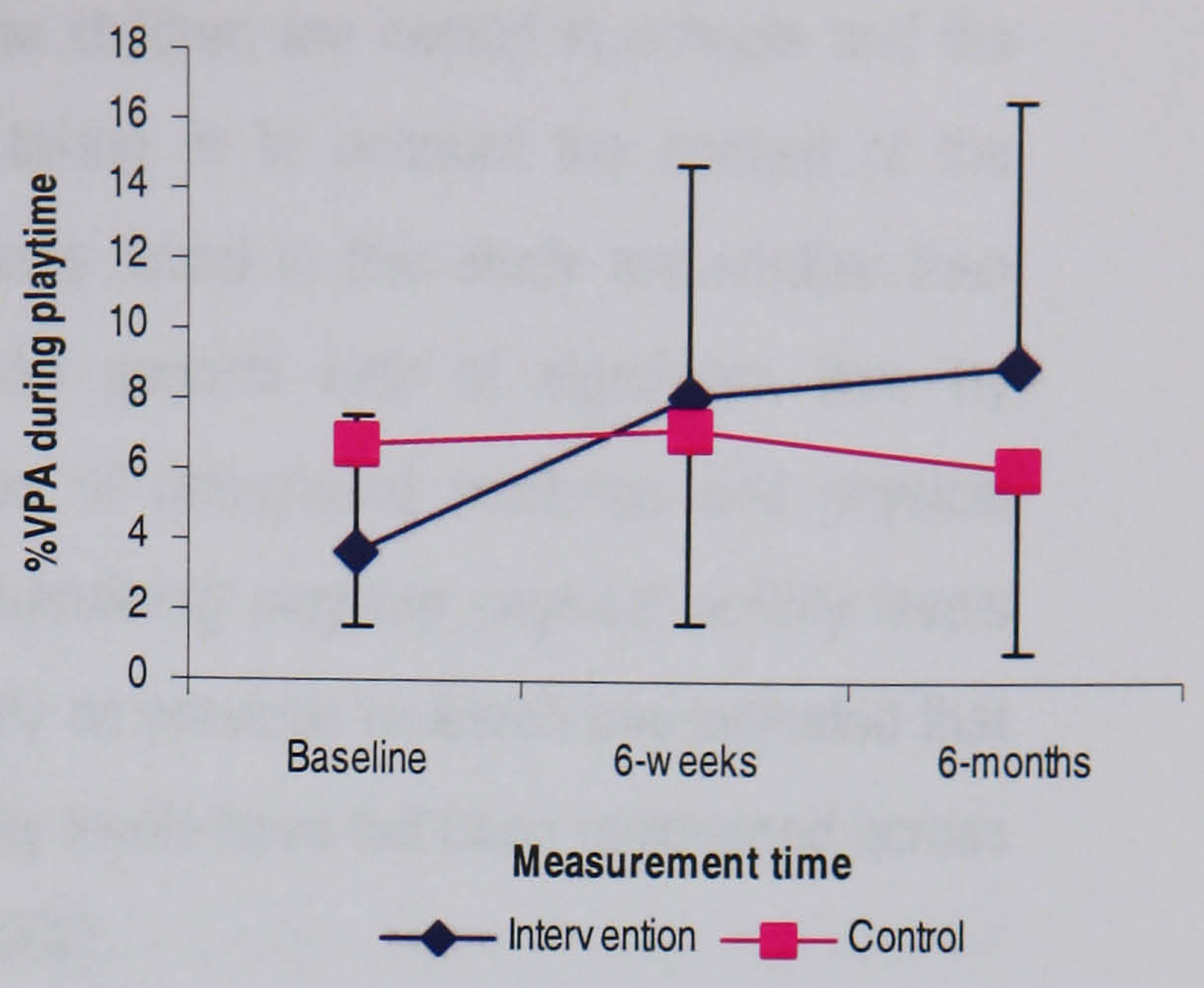


Figure 7.5: Participation in VPA assessed accelerometry during playtime for the intervention and control groups across the study (raw scores).

7.4 Discussion.

The purpose of this study was to evaluate the 6-month effects of a playground markings and physical structures intervention on children's physical activity levels during playtime using combined measures in a large sample of children. A secondary aim of the study was to investigate the influence of pupil-level and school-level covariates on this effect. This study builds on previous playtime intervention studies that have evaluated short-term effects using single measures of physical activity. Moreover, it builds on the study conducted in Chapter 6 by assessing the longer-term effectiveness of the intervention on children's playtime physical activity behaviour (Biddle et al., 2004).

7.4.1. Intervention Effect on Physical Activity during Playtime over Time.

The results of the study revealed that a playground markings and physical structures intervention was effective in increasing children's playtime MVPA and VPA over time. Children in the intervention group engaged in 4 – 4.5% and ~2.5% more MVPA and VPA respectively than children in the control schools. Previous studies that have investigated the effects of school environmental interventions have reported significant short-term effects (Stratton, 2000; Stratton & Mullan, 2005; Verstraete et al., 2006). However, these studies designs have not acknowledged the hierarchical nature of this type of investigation, and have not corrected for school, which can affect the children's behaviour. The present study controlled for the effect of school on children's physical activity levels, because children are nested in schools and the physical activity behaviour can be explained by taking in to account the context of the behaviour (Duncan et al., 1996). While the increases found in this study are smaller than previous playtime intervention studies, though the general lack of significant time by intervention interactions suggest that the provision of playground markings and physical structures are suitable stimuli for increasing and sustaining playtime physical activity levels across time. This is a noteworthy finding, particularly as previous research has indicated that increases observed in both children's physical activity levels have not been maintained across time (Dishman & Buckworth, 1996; Sallis & Owen, 2002).

The time by intervention interaction was significant for VPA when quantified using accelerometry. Specifically, the effect of the intervention on VPA engagement strengthened across time. This is a positive finding from a public health perspective, as although the increases are small, VPA is negatively related to body fat, and it has recently been suggested that the intensity of physical activity may be more important in the prevention of childhood obesity than total physical activity participation (Ruiz et al., 2006). However, caution must be exercised with these findings, as the results are based on one day's monitoring at each phase of the study (baseline, 6-weeks, 6-months). Though shorter time frames may be required in circumstances where stable behaviours are demonstrated (Tudor-Locke & Myers, 2001), and no significant differences were found in physical activity levels across days and seasons (Chapter 4), the increases in VPA are smaller than the daily and seasonal fluctuations previously reported in mean VPA (Chapter 4). The increases in VPA therefore may not be attributable to the effect of the intervention. However, it should be noted that this study used a robust data analysis technique, the 95% confidence interval values were positive leading to the significant findings, and similar increases were reported by accelerometry and heart rate, which suggest that the intervention had a positive effect on VPA levels during playtime. Future studies should use more than one day's monitoring however to investigate changes in VPA in more detail to determine the effects of a playground intervention.

A recent review highlighted that the physical environment, which included permanent structures such as multicolour playground markings, and the availability of facilities and equipment were associated with higher physical activity levels in children (Davison & Lawson, 2006). This study lends support to these findings as a positive and significant playground intervention effect across time was reported for playtime physical activity. This contrasts the findings of Chapter 6 however, where non-significant short-term increases were reported. It has been stated that the physical environment children are exposed to can facilitate physical activity and play behaviour by providing adequate facilities and access, and providing cues and messages about how to be physically active (Giles-Corti & Donovan, 2002; Green et al., 1996; Sallis & Owen, 1999; Stokols et al., 2003). The school playground is a specific aspect of the school environment, which can facilitate physical activity behaviours through the provision of equipment (Verstraete et al., 2006; Zask et al., 2001), multi-colour markings (Stratton, 2000; Stratton & Leonard, 2002; Stratton & Mullan, 2005) and supervision (Evans, 2003; Thomson, 2005). In the present study, the results suggest that physically active behaviours were enabled and reinforced over time by the provision of playground markings and physical structures. It is possible that the children became accustomed to the physical activity and play behaviour cues and opportunities that were provided by the playground over time, as prior to the intervention the playgrounds did not contain any markings, and children may have had to create games and activities for use on the markings and structures. In addition, as children often informally allocate particular areas of the playground to specific forms of play or games, children may have taken time to accept the new zonal structure to the playground that was more prescriptive in encouraging different behaviours on different parts of the playground (Armitage, 2001; Armitage, 2005; Casey, 2003). This may partially explain the non-significant intervention effect at 6-weeks (Chapter 6). Spence and Lee (2003) noted that changes to physical environments might be subtle and manifest themselves over time; a finding that is somewhat supported by the present study. In general, from a social ecological perspective, the results suggest that the playground intervention was effective in encouraging and enabling children to be physically active during playtime by providing increased access to activity opportunities and a supportive physical environment (Giles-Corti & Donovan, 2002; King et al., 2002; Sallis et al., 1997; Welk, 1999). Children appear to have been receptive to the attempts made to improve the playground over time, and recognised the greater range of opportunities provided (Blatchford et al., 1990).

7.4.2. School Level Influences on Intervention Effect.

Individual and group-level variables affect children's physical activity levels and play behaviour during playtime (Pellegrini & Smith, 1993; Zask et al., 2001). In this study, the intervention effect on playtime MVPA and VPA was stronger with increasing daily play duration, and provides further support for the effects reported in Chapter 6. This finding has interesting connotations for school policy on playtime. There has been conflict reported in the play behaviour literature between the value of playtime for children and the impact of playtime on curriculum time and incidents of antisocial and aggressive behaviour displayed on the playground (NAECS/SDE, 2002; Pellegrini & Bohn, 2005; Pellegrini & Smith, 1993; Whitney & Smith, 1993). Playtime has been identified as an ideal and safe environment for children to engage in physical activity and social behaviours (NAESC/SDE, 2002; Stratton, 1999; Wechsler et al., 2000), yet the role of playtime in the school day is still being debated (Blatchford, 1998; Pellegrini & Bohn, 2005). Typically, the time given to playtime has been reduced in response to behavioural problems, such as bullying and fighting (Whitney & Smith, 1993), that occasionally manifest themselves during playtime (Blatchford & Sumpner, 1998; Chmelynski,, 1998; Pellegrini & Bohn, 2005), though these account for only a small percentage of behaviours observed in the playground (Pellegrini, 1995). However, Evans (1996) found that children, particularly boys, disliked short playtimes. Children reported that they preferred longer playtimes (such as lunchtime) as they had more time to engage in a range of freely chosen activities (Evans, 1996). Building on the previous chapter, the results of the present study suggest that providing a wide range of activity opportunities and sufficient time for children to access and explore these options can benefit physical activity levels over time. Future studies should explore this potential relationship further, as the question of optimal play duration that can benefit physical activity, behaviour and learning has been raised (Pellegrini & Smith, 1993), though this has yet to be examined by empirical research.

7.4.3. Pupil Level Influences on Intervention Effect.

The promotion of physical activity among girls has been described as a challenge (Sallis et al., 2003), as girls have been consistently shown to be less active than boys (Biddle et al., 2004; Kohl & Hobbs, 1998; Sallis et al., 2000; USDHHS, 2000). Consequently, girls have been identified as an important target group for physical activity interventions (Sallis et al., 2000). In the present study, no significant gender by intervention effect was found. This indicates that there was no difference in the effect of the intervention between boys and girls on their playtime physical activity levels.

Previous playtime intervention research has reported mixed effects concerning the effects on boy's and girls' physical activity levels. Using a playground markings intervention, Stratton and Mullan (2005) found that boys and girls experienced similar increases in their playtime physical activity (Table 2.5), though boys were more active overall than girls during playtime. Likewise, boys and girls experienced comparable increases in their MVPA during fitness breaks, though boys' VPA increased significantly more than girls (Scruggs et al., 2003). In contrast to these studies, girls gained greater increases in their MVPA and VPA following a games intervention, particularly during morning playtime, compared to boys (Table 2.5), though boys were significantly more active during playtime than girls (Verstraete et al., 2006). In addition, one school based environmental, social marketing and policy intervention study that did not exclusively focus on playtime but aimed to increase leisure-time physical activity levels both in and out of school found that boy's physical activity levels significantly increased while no significant effect was reported for girls (Sallis et al., 2003).

The present study suggests that a playground markings and physical structures intervention increased boys and girls' physical activity levels during playtime to a similar extent, though boys remained more active than girls at each phase of the study. From a health promotion stance this is an encouraging finding as the intervention benefited both boys and girls similarly over time, and avoided unintended consequences, such as decreasing physical activity, which can affect an interventions social validity (Stokols et al., 2003). Alternatively, it could be argued that the playground environment enabled boys to more active than girls, who were identified a-priori as a target group for increasing activity during playtime in Chapter 5. Indeed, the findings from this and previous intervention studies suggest that combinations of interventions, for example, playground markings and games equipment, may be required to increase girls activity and provide more equal opportunities during playtime as a whole. Overall, the present results suggest that a playground markings intervention provided similar increases in boys and girls' MVPA and VPA during playtime, which were sustained over time, and children took the opportunity to be active in suitable and supportive environments.

7.4.4. Study Limitations.

Several limitations exist with this study. The first is the number of missing data at both follow-up measurement points, particularly for HR, which was largely attributable to monitoring difficulties and child absence from school on the testing day. However, it should be noted that MLM analyses can handle missing data whilst estimating the effects of the intervention using their data at baseline, six weeks and six months (Quené & van den Bergh, 2004). A second limitation is that combining HR and accelerometry to quantify physical activity has produced differing results in this study, particularly when the effects of potential covariates on the intervention effect were assessed. However, the use of combined measures could also be considered a strength, as when the adjusted main analysis was conducted, the results from the accelerometry and heart rate data differed by 0.5% for MVPA and 0.11% VPA respectively. Utilising both methods has enabled the assessment of both physiological and mechanical strain, highlighting that playground activities stress the body in different ways.

7.5 Conclusions.

This study utilised a multiple methods approach in a large sample of children to analyse the 6-months effects of a playground markings and physical structures intervention on children's physical activity during school playtime. This has built on previous playtime intervention studies that used smaller populations of children over shorter follow-up periods. The results indicated that playground markings and physical structures contained within specific colour-coded zones contributed to a significant increase in children's playtime physical activity levels over time. Most important, perhaps, was the fact that these increases were sustained across time suggesting that this type of intervention promoted medium-term changes on children's physical activity behaviours.

CHAPTER 8

Critical Appraisal and Future Directions for Research into Children's Physical Activity Levels during Playtime

8.1 The Research Context and Synthesis.

The investigation of primary school children's physical activity levels during playtime has generally focused on examining gender differences or comparing playtime to a physical education context using a cross sectional design (Chapter 2). While the potential of playtime-based interventions as a strategy for increasing children's daily physical activity levels has been recognised (Scruggs et al., 2003; Stratton, 2000; Stratton & Mullan, 2005), these studies have primarily reported short-term effects using small sample sizes. This has limited research efforts to date, as the increases observed may be due to the novelty effect of the intervention on behaviour. Recently, Verstraete and colleagues (2006) built on these initial studies by documenting the effect of a portable playground games equipment intervention three months after the initial implementation in a large sample (n = 235) of children. However, the issue of the sustainability of this approach was not reported, as no short-term follow-up measure was conducted. It is not known whether activity increased or decreased following the implementation of the intervention to the follow-up assessment at three months. A further complication with intervention studies conducted during playtime is that researchers have utilised a range of objective and subjective measures, research protocols and designs to quantify activity, which affects the direct comparison of intervention effects.

There was an identified need to investigate playtime physical activity levels in a large, objectively monitored sample of primary school aged children, to establish the initial effects of a playtime-based intervention on children's physical activity levels while examining the sustainability of the intervention over time using a longitudinal design, and to contextualise these within a physical activity promotion framework (Welk, 1999). Consequently, the aims of this thesis were to a) determine the day-to-day and seasonal effects on children's physical activity levels during playtime; b) quantify the physical activity levels of children during playtime and examine the contribution of playtime to current daily physical activity guidelines; c) evaluate the short-term effects (6-weeks) of a playground markings and physical structures intervention on children's physical activity levels during playtime; and d) assess the longitudinal effects of a playground markings and physical structures intervention on children's physical activity levels during playtime. This approach met the suggestion by Stone et al. (1998) that both short-term and longer-term measures should be implemented to evaluate how the effects of an intervention that aims to increase physical activity change over time.

Study one (Chapter 4) investigated the day-to-day and seasonal effects on children's physical activity levels within the specific context of playtime. Though the study utilised a small sample size, a small number of measures to answer the research question, quantified physical activity levels using only heart rate telemetry, and did not examine gender differences in the data, it did examine differences between seasonal extremes (winter and summer terms), and monitored activity over a short epoch (5 seconds) day by day for a whole week. This use of a short epoch is of note, as shorter monitoring time periods may more accurately record the intermittent and transient nature of children's physical activity (Bailey et al., 1995) and more accurately detect short bouts of children's physical activity (Baquet et al., in press). The data indicated that children's physical activity levels did not significantly differ across consecutive days or seasons, though there was a trend for activity levels to be higher in the winter term compared to the summer term. This suggested that studies might not need to correct for seasonal effects on playtime physical activity, and that moderate-to-vigorous physical activity (MVPA) is generally stable across days of measurement. Greater variability was observed for vigorous physical activity (VPA), which might be linked the patterns of children's physical activity (Bailey et al., 1995), or the relatively small amounts of VPA engaged in, and ensured that some caution should be exercised when interpreting the VPA results. Future studies should investigate the day-to-day and seasonal variability in boys and girls' playtime physical activity using larger sample sizes, a range of objective measures, and measures taken across four seasons. Furthermore, the number of days required to determine children's physical activity levels in this context warrants attention to provide guidance on methodological approaches for future playtime-based studies and enable comparisons between studies. Despite these limitations, the results suggest that MVPA is relatively stable across days of measurement, and one day of monitoring is representative of MVPA during playtime in larger empirical studies. This may be attributed to the playground environment being consistent across days, where the same equipment and supervision was provided at the same time on a daily basis, and children have the opportunity to plan the activities they wish to engage in (Blatchford, 1998).

Study two (Chapter 5) aimed to quantify the physical activity levels of children during school playtime, and to investigate the extent to which playtime could contribute towards daily physical activity recommendations. This study built on previous cross-sectional research by objectively monitoring physical activity levels in a large sample of children using heart rate and accelerometry during all playtime periods timetabled by the schools on one day. In addition, gender and stage of schooling differences were examined, as little UK data exist for these variables (Stratton, 1999; Stratton & Mullan, 2005) yet such information could help to identify target groups for playtime interventions (Baranowski et al., 1998; Gorely, 2005). While the study was limited by the attrition rate due to technical difficulties and school absence, and only physical activity levels of moderate intensity or above were analysed, the study contributed to the paucity of UK data in this context.

This cross-sectional study found that boys were significantly more active than girls, and that this difference was consistent across both stages of schooling (infant and junior), leading to a non-significant age-group difference. The data also indicated that playtime contributed between a quarter to a half for boys and between a sixth and a third for girls towards daily physical activity guidelines, depending on the threshold value used for recommended daily physical activity (Andersen et al., 2006; Biddle et al., 1998). In general, the study suggested that playtime provides an important context for daily activity for boys and girls.

No empirically tested physical activity guideline currently exists for playtime. Stratton and Mullan (2005) extrapolated US physical activity recommendations for PE to playtime, suggesting that children should be active for 50% of playtime. The results of the present study suggest that this threshold value may be too high, with only a small percentage of children attaining this value during playtime. Subsequently, a threshold value of 40% of playtime engaged in at least moderate intensity active was suggested, based on Biddle and co-workers (1998) minimum recommendation as a guide, for playtime to meaningfully contribute towards the accumulation of daily physical activity. This equated to 33 minutes of physical activity during playtime. An interesting area of research would be to investigate what proportion of this suggested threshold should be VPA (Chapter 5). Secondly, research attention could focus on whether children who are physically active for 40% or more during playtime engage in more habitual physical activity than their less active peers. Dale et al. (2000) found that when minimal opportunities for physical activity engagement were provided during school time children do not compensate by engaging in more physical activity out of school. It may be that encouraging physical activity during playtime could be critical in the accumulation of physical activity beyond the school environment. While this issue was beyond the scope of the present study, it may be important in increasing our knowledge of how parts of the day affect habitual physical activity levels and health.

The primary limitation of the baseline study, and the thesis as a whole, is that while behavioural data was collected using direct observation during the course of the investigation, it was outside the remit of the thesis and has not been reported in detail. While gender differences could be explained by playtime behavioural research, it is not known whether girls choose less active games, or whether their opportunities for physically active behaviours were restricted due to the reported dominance of boys in the playground, for example (Blatchford et al., 2003; Epstein et al., 2001; Pellegrini et al., 2004). Using behavioural data in the future would benefit physical activity research within in this context. A second limitation was that the social contexts of the school playgrounds were not detailed, nor was the availability of portable equipment controlled or the frequency and type of supervision documented. There is a need for empirical research combining multidisciplinary methods to establish what behaviours children are engaging in when they are being physically active or inactive, and to consider the social effects of the playground culture on children's behaviour (Blatchford, 1998; Casey, 2003). Furthermore, ascertaining the determinants of playtime physical activity and understanding why children choose active or inactive behaviours could help to inform future playtime-based interventions by identifying key modifiable variables within this context.

Study three (Chapter 6) investigated the short-term effects of a playground markings and physical structures intervention on playtime physical activity levels. A large sample of children was objectively monitored using heart rate telemetry and accelerometry, and the research design incorporated both a control group and a follow-up period in an attempt to decrease the initial novelty effects of the intervention on activity levels. Multilevel modelling was also used to analyse the data in order to control for the effects that different schools have on pupil activity levels (Duncan et al., 1996; Goldstein, 1995; Twisk, 2006), and to examine changes in activity when pupil and school level variables are controlled for (Pellegrini & Smith, 1993). The study found that the effect of the intervention was positive but non-significant when quantified using both heart rate and accelerometry (adjusted model). The increases observed were smaller than those reported by previous studies (Stratton, 2000; Stratton & Mullan, 2005; Verstraete et al., 2006). However, a positive interaction was found between intervention and gender for VPA quantified using heart rate, with the intervention effect stronger for girls compared to boys. Moreover, an inverse interaction effect was found between the intervention effect and age for MVPA and VPA quantified using accelerometry, indicating that the intervention effect was stronger for younger children. However, though it should be noted that this study was limited by the large attrition rate for both objective measures, this study was larger than the intervention studies that have been published to date in the empirical literature.

Study four (Chapter 7) investigated the longitudinal effect of a playground markings and physical structures intervention on playtime physical activity. This was a unique and original aspect of the thesis. This study built on Chapter 6 as it investigated the sustainability of the intervention over time. In addition, the use of multilevel modelling was a strength of the study, as this analysis technique is robust against missing data points (Quené & van den Bergh, 2004). This study found that the playground markings and physical structures intervention was effective in increasing children's playtime MVPA and VPA over time, with similar increases in activity levels being reported by heart rate and accelerometry. In addition, the lack of time by intervention interactions indicates that increases in physical activity were sustained across time.

There are a number of limitations associated with studies three and four, which will be combined and acknowledged here. Firstly, the research design employed was not a randomised control trial design, as the allocation of the funding to implement the intervention in schools was based on socioeconomic status and indices of deprivation (Chapter 3). Secondly, the studies were limited as potential covariates such as playground size, school size, activity prompts, and number of pupils who had access to the playground were not recorded and therefore not included in the analysis. Zask and colleagues (2001) found that physical activity levels were higher in small schools compared to large schools, highlighting that these school level variables can influence physical activity, and should be considered by future playtime studies. However, it should be noted that the overall influence of school on children's activity was controlled for in the analyses. In addition, Pellegrini and Smith (1993) noted that children were more active in spacious environments compared to restrictive environments, while McKenzie et al. (1997a) found that children complied with and maintained physical activity participation following adult encouragement. An interesting consideration here is determining how the population density of playground space at school affects physical activity levels. It is possible that schools, which had a large number of pupils on the playground in relation to its size, affected physical activity behaviour during playtime. Future research should investigate the effects of such contextual variables on physical activity, and incorporate them in to the analyses in order to determine the intervention effect once their effect has been controlled for.

No behavioural data was collected during studies three and four. This is an important consideration for future research, particularly in lieu of the non-significant findings of study three. There is a need to systematically observe both at a group level and at an individual level. Group level observations would help to determine the effects of the intervention on the social context of the playground, and could help to determine which markings and structures are effective at increasing physical activity on the playground, and which markings are popular with children during playtime. Individual observations would help to determine which children (for example less or more active children, boys, girls, younger or older children) access which areas of the playground and different activities, both prior to and following the intervention. Establishing the underlying reasons for these choices and whether they change across time would also be critical in developing knowledge of children's activity and behaviour during playtime.

Throughout the thesis, the aim has been to determine children's physical activity levels with a playtime context and to investigate whether the markings and physical structures were effective in increasing activity levels. However, this was one of two aims of the Zoneparc playground (Youth Sport Trust, 2002). The second aim was to tackle social exclusion and playground issues in schools (Chapter 1). While it was beyond the scope of the present study, future playtime intervention research should investigate the effects of the redesigned playgrounds on psychological and social variables, such as enjoyment, perceptions of competence, peer relations, alongside physical activity measures. This would enable researchers to determine the overall impact of the playground on the school, particularly as playtime is a salient time for children to develop physical skills and confidence in their movement, and build positive peer relationships (Evans, 1996; Pellegrini & Bohn, 2005).

The main outcome variable investigated during all the studies was the percentage of time children were engaging in at least moderate intensity physical activity during playtime. This enabled the comparison to previous studies that have used this outcome variable in this context (Scruggs et al., 2003; Stratton, 2000; Stratton & Mullan, 2005; Verstraete et al., 2006). However, while the intervention was effective in increasing physical activity levels, a question remains concerning the clinical significance of the intervention effect or the minimal worthwhile effect. This is a challenging area, as determining clinical significance may involve the assessment of clinical measures within a laboratory setting. However, future playtime intervention studies could examine this concern in two ways. Firstly, the outcome measure investigated could be the time spent engaged in physical activity, though this may be limited as an approach as playtime durations have been reported to decrease between infant and junior school (Blatchford & Baines, 2006). Secondly, the recorded data could be inputted in to prediction equations, which convert the raw accelerometry data in to units of energy expenditure (Welk, 2002). However, this approach is limited as estimates of energy expenditure have not been highly accurate for individuals in free-living situations (Welk, 2002). Counts per minute have been increasingly used in empirical studies investigating physical activity (Andersen et al., 2006; Riddoch et al., 2004; Ruiz et al., 2006), as this avoids potential errors in estimating energy expenditure, in combination with minutes of physical activity to provide an indication of activity levels against public health targets (Welk, 2002). Adopting this approach in playtime research may help to determine the some of the clinical significance of future intervention studies.

The present thesis has indicated that a number of variables can influence children's physical activity levels during playtime. Future studies should aim to investigate the effects of these multiple variables in combination. While such research studies would be complex, together they would provide a clearer understanding of how the factors interact with each other to influence physical activity levels during playtime. Furthermore, they would enable researchers to detect the most effective approaches to stimulating activity during playtime.

8.2 Conceptual Model.

The promotion of physical activity to youth has been conceptualised by Welk (1999), who examined the effects of determinants and their interactions with other factors on children's physical activity. The Youth Physical Activity Promotion Model (YPAP) is the first model to adopt an ecological approach in the promotion of children's physical activity, and was designed in order to "characterize a variety of influences into a conceptual framework that can then be used to guide interventions and programs" (Welk, 1999, p. 7). While the YPAP does not provide a framework concerning the sustainability of interventions over time, it offers a suitable structure suggest how different variables collectively influence physical activity behaviour in children during playtime, and to identify future directions for playtime interventions [Figure 8.1].

Schools are a rational setting for the promotion of physical activity to young people (Biddle et al., 1998; Cavill et al., 2001; Kohl & Hobbs, 1998; Sallis et al., 1992; Welk, 1999), as school attendance is a generic part of childhood and subsequently a substantial proportion of the child population can be reached. Within the school environment, playtime provides daily physical activity opportunities for children. From this perspective, playtime physical activity can be influenced by enabling, predisposing and reinforcing factors; therefore interventions can target these factors alone or using an integrated approach. In this thesis, the specific focus of the intervention was the physical playground environment, which is an enabling factor in the YPAP (Welk, 1999; Figure 8.1). The findings indicated that changing the playground environment through the use of multicolour markings and physical structures significantly increased physical activity levels during playtime over time. It is likely that this approach created activity opportunities and provided messages to the children about what activities particular spaces had been designed for (Casey, 2003; Cohen et al., 2000; Giles-Corti et al., 2005). In addition, time was an enabling factor that had a consistent effect on physical activity levels following the intervention. This suggests that the time allocated for physical activity both prior to and following an intervention should be investigated to determine the extent to which it facilitates physical activity engagement. Of the demographic factors considered in the thesis, boys were more active in the playground environment than girls, though no differences were observed between infant and junior school children. The gender difference observed in playtime physical activity may be explained by enabling, reinforcing and predisposing factors such as equipment, adult supervision, and perceptions of competence respectively (Sallis et al., 2003; Welk, 1999), Future studies should investigate the extent to which enabling, reinforcing and predisposing factors influence boys and girls' physical activity levels during playtime.

Figure 8.1 indicates that this thesis contributed to current knowledge concerning the effects of the environment on physical activity within a playtime context, which is classed as an enabling factor (Welk, 1999). Figure 8.1 also suggests the direction that future playtime research could take based upon the YPAP Model (Welk, 1999) and the number of studies that have investigated different factors to date. The effect of the Zoneparc intervention on reinforcing and predisposing factors was not investigated in this thesis. However, one could speculate that the intervention effect impacted on predisposing and reinforcing factors, which in turn could have influenced physical activity behaviour. The intervention utilised a zone structure that introduced a variety of activities and playground markings that was relevant to children of primary school age. The blue and yellow zones in particular provided children the opportunity to develop and refine skills in a predominantly self-mastery environment (Youth Sport Trust, 2002). This in turn could affect children's actual and perceived competence, which links into their ability to participate in other playground games (Strong et al., 2005). The YPAP model also indicates that enjoyment is an important factor in physical activity behaviour. Behavioural research has suggested that children enjoy their playtimes and it is a valued component of the school day (Blatchford et al., 1990; Boyle et al., 2003; Evans, 1996). However, mainly focusing on increasing higher levels of physical activity may lead to lower levels of enjoyment (Scruggs et al., 2003). Certainly playground interventions should obtain a measure of enjoyment and determine its effect on physical activity in the future. Another consideration is the influence that school staff had on physical activity levels through providing information, encouragement and prompts (i.e. reinforcing factors). Adult prompts and encouragement have been found to play a role in physical activity engagement (McKenzie et al., 1997a). Future playtime studies should further clarify the effect of adult encouragement on activity levels in this context, and establishing effective training methods that could increase adults' confidence and ability to prompt children's activity may prove to be a feasible intervention strategy.

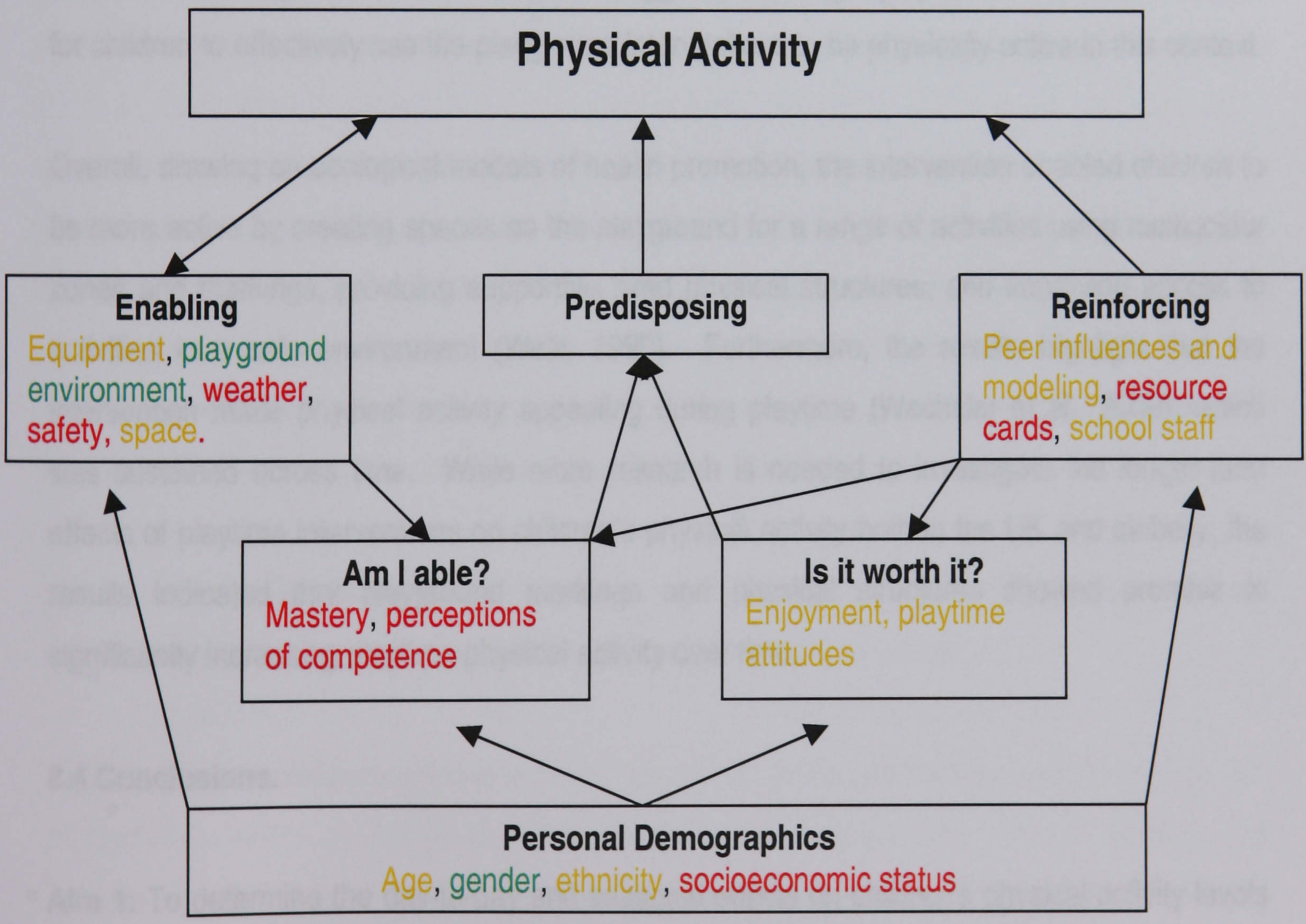


Figure 8.1. *Identifying research directions for future studies investigating physical activity levels during playtime using the Youth Physical Activity Promotion Model (Welk, 1999). Key: No research evidence to date (0 studies); Little research evidence (1-4 studies); More research evidence (5+ studies).*

8.3 Summary.

The findings from the thesis indicate that a playground markings and physical structures intervention significantly increased and sustained playtime physical activity 6-months after the implementation of the intervention. While the short-term increases were not significant, they were similar to those reported at 6-months, and suggest that the novelty effects of playground interventions may explain some of the larger increases observed by previous playtime intervention studies (Stratton, 2000; Stratton & Mullan, 2005). The playground intervention had similar effects on boys and girls' physical activity, highlighted by the lack of gender by intervention interactions, and suggests that both genders took the opportunity to be physically active in suitable playground environments. In addition, a consistent finding was that the effect of the intervention was stronger with increasing daily playtime duration. This provides an interesting counter-argument to schools that have reduced playtime duration due to behavioural problems and curricular pressures (Blatchford & Sumpner, 1998; Pellegrini & Bohn, 2005; Pellegrini & Smith, 1993), as it suggests that longer playtime durations are needed for children to effectively use the playground interventions to be physically active in this context.

Overall, drawing on ecological models of health promotion, the intervention enabled children to be more active by creating spaces on the playground for a range of activities using multicolour zones and markings, providing supportive fixed physical structures, and improving access to activities in a safe environment (Welk, 1999). Furthermore, the results highlight that the intervention made physical activity appealing during playtime (Wechsler et al., 2000), which was sustained across time. While more research is needed to investigate the longer-term effects of playtime interventions on children's physical activity both in the UK and globally, the results indicated that playground markings and physical structures showed promise in significantly increasing playtime physical activity over time.

8.4 Conclusions.

Aim 1: To determine the day-to-day and seasonal effects on children's physical activity levels during playtime (Chapter 4).

In response to the first aim, it was concluded that there were no significant differences between children's MVPA and VPA across consecutive days or seasons, though greater variability was observed between days and seasons for VPA during playtime. Studies may not need to correct for seasonal effects on children's physical activity levels during school when assessing MVPA.

Aim 2: To quantify the physical activity levels of children during playtime and examine the contribution of playtime to daily physical activity guidelines (Chapter 5).

It was revealed that boys engage in significantly more MVPA and VPA during playtime than girls. No significant differences in playtime activity were found between infant and junior school children. This suggests that primary school girls are a priority target group for interventions that aim to increase playtime physical activity levels. The results also indicated that playtime can contribute up to 45% for boys and 37% for girls towards daily physical activity recommendations (Biddle et al, 1998).

Aim 3: To evaluate the short-term effects (6-weeks) of a playground markings and physical structures intervention on children's physical activity levels during playtime (Chapter 6).

Positive but non-significant increases in MVPA and VPA were observed in the short-term following the intervention when potential confounders were added to the analyses. The playground design may have encouraged children to engage in a broader range of activities during playtime, though not all of these may have necessarily promoted higher MVPA and VPA levels. In addition, the intervention effect was greater for younger children, children who were less active at baseline, and children with longer daily playtime duration.

Aim 4: To assess the longitudinal effects of a playground markings and physical structures intervention on children's physical activity levels during playtime (Chapter 7).

The playground markings and physical structures intervention prompted a significant increase in children's MVPA and VPA playtime physical activity levels over time. In addition, the increases were sustained over 6-months, suggesting that this type of intervention promoted medium term changes in children's physical activity behaviours. Overall, the results suggest that physically active behaviours were enabled and reinforced, and children became accustomed to the physical activity and play behaviour opportunities that were provided by the playground environment over time.

8.5 Précis.

This thesis has demonstrated that developing school playgrounds based on the Zoneparc design is a suitable school based intervention for increasing children's playtime MVPA and VPA over time. Increases in playtime MVPA were sustained across time, whilst the intervention effect was stronger at 6 months for VPA. Overall, the results indicate that playground markings and physical structures are an effective method for significantly increasing both boys and girls' playtime physical activity levels in the longer-term.

REFERENCES

References.

Almond, L. & Harris, J. (1998). Interventions to promote health-related physical education. In S.J.H. Biddle, J. Sallis & N. Cavill (Eds.), *Young and Active? Young People and Health-Enhancing Physical Activity - Evidence and Implications* (pp. 133-149). Champaign, IL: Human Kinetics.

Andersen, L.B., Harro, M., Sardinha, L.B., Froberg, K., Ekelund, U., Brage, S. & Anderssen, S.A. (2006). Physical activity and clustered cardiovascular risk in children: A cross-sectional study (The European Youth Heart Study). *Lancet, 368*, 299-304.

Armitage, M. (2001). The ins and outs of school playground play: Children's use of "play places". In J.C. Bishop & M. Curtis (Eds.), *Play Today in the Primary School Playground: Life, Learning and Creativity* (pp. 37-58). Buckingham, UK: Open University Press.

Armitage, N. (2005). The influence of school architecture and design on the outdoor play experience within the primary school. *Paedagogica Historica, 41*, 535-553.

Armstrong, N. (1998). Young people's physical activity patterns as assessed by heart rate monitoring. *Journal of Sports Sciences, 16*, S9-S16.

Armstrong, N. & Bray, S. (1991). Physical activity patterns defined by continuous heart rate monitoring. *Archives of Disease in Childhood, 66*, 245-247.

Armstrong, N., McManus, A., Welsman, J. & Kirby, B. (1996). Physical activity patterns and aerobic fitness among prepubescents. *European Physical Education Review, 2*, 19-29.

Armstrong, N. & Welsman, J. (1997). *Young People and Physical Activity.* Oxford, UK: Oxford University Press.

Armstrong, N. & Welsman, J. (2001). Peak oxygen uptake in relation to growth and maturation in 11- to 17-year-old humans. *European Journal of Applied Physiology, 85*, 546-551.

Bailey, R.C., Olson, J., Pepper, S.L., Porszasz, J., Barstow, T.J. & Copper, D.M. (1995). The level and tempo of children's physical activities: An observational study. *Medicine and Science in Sport and Exercise, 27*, 1031-1041.

Baquet, G., Stratton, G., Van Praagh, E. & Berthoin, S. Physical activity assessment in prepubertal children with high frequency accelerometry monitoring. *Preventive Medicine*, in press.

Baranowski, T. (1988). Validity and reliability of self-report measures of physical activity: An information-processing perspective. *Research Quarterly for Exercise and Sport, 59*, 314-32.

Baranowski, T., Anderson, C. & Carmack, C. (1998). Mediating frameworks in physical activity interventions: How are we doing? How might we do better? *American Journal of Preventive Medicine, 15*, 266-297.

Baranowski, T. & Jago, R. (2005). Understanding the mechanisms of change in children's physical activity programs. *Exercise and Sports Sciences Reviews, 33*, 163-168.

Baranowski, T. & de Moor, C. (2000). How many days was that? Intra-individual variability and physical activity assessment. *Research Quarterly for Exercise and Sport, 71*, 74-78.

Baranowski, T., Thompson. W.O., Durant, R.H., Baranowski, J. & Puhl, J. (1993). Observations on physical activity in physical locations: Age, gender, ethnicity and month effects. *Research Quarterly for Exercise and Sport, 64*, 127-133.

Baranowski, T., Smith, M., Thompson, W.O., Baranowski, J., Hebert, D. & de Moor, C. Intraindividual variability and reliability in a 7-day exercise record. (1999). *Medicine and Science in Sports and Exercise, 31*, 1619-1622.

Barker, R.G. (1968). *Ecological Psychology.* Stanford, CA: Stanford University Press.

Bateson, P. & Martin, P. (1999). *Design for Life: How Behaviour Develops.* London: Jonathan Cape.

Baumgartner, T.A., Jackson, A.S., Mahar, M.T. & Rowe, D.A. (2003). *Measurement for Evaluation in Physical Education and Exercise Science* (7th Ed). New York: McGraw-Hill.

Bauman, A.E., Sallis, J.F., Dzewlatowski, D.A. & Owen, N. (2002). Toward a better understanding of the influences on physical activity: The role of determinants, correlates, causal variables, mediators, moderators and confounders. *American Journal of Preventive Medicine, 23(2S)*, 5-14.

Benhiam-Deal, T. (2005). Preschool children's accumulated and sustained physical activity. *Perceptual and Motor Skills, 100*, 433-450.

Beth-Halachmy, S. (1980). Elementary school children's play behaviour during recess periods. In P. F. Wilkinson (Ed.), *In Celebration of Play* (pp. 135-142). London: Croom Helm.

Biddle, S.J.H., Sallis, J. & Cavil, N. (1998). *Young and Active: Physical Activity Guidelines for Young People in the UK.* London: Health Education Authority.

Biddle, S.J.H., Gorely, T. & Stensel, D.J. (2004). Health-enhancing physical activity and sedentary behaviour in children and adolescents. *Journal of Sports Sciences*, 22, 679-701.

Blair, S.N., Clark, D.G., Cureton, K.J. & Powell, K.E. (1989a). Exercise and fitness in childhood: Implications for a lifetime of health. In C.V. Gisolfi & D.R. Lamb (Eds.), *Perspectives in Exercise Science and Sports Medicine* (pp. 401-430). New York: McGraw-Hill.

Blair, S.N., Kohl, H.W., Paffenbarger, R.S., Clark, D.G., Cooper, K.H. & Gibbons, L.W. (1989b). Physical fitness and all-cause mortality: a prospective study of healthy men and women. *Journal of the American Medical Association, 262*, 2395-2401.

Blair, S.N. & Connelly, J.C. (1996). How much physical activity should we do? The case for moderate amounts and intensities of physical activity. *Research Quarterly for Exercise and Sport, 67*, 193-205.

Blatchford, P. (1989). *Playtime in the Primary School: Problems and Improvements.* Berkshire, UK: NFER-Nelson.

Blatchford, P. (1998). *Social Life in the School: Pupils' Experience of Breaktime and Recess from 7 to 16 Years.* London: Falmer Press.

Blatchford, P. (1999a). Friendships at school: The role of playtime. *Education 3 to 13, 37*, 60-66.

Blatchford, P. (1999b). The state of play in schools. In M. Woodhead & D. Faulkner & K. Littleton (Eds.), *Making Sense of Social Development* (pp. 101-119). London: Routledge.

Blatchford, P. & Baines, E. (2006). A follow up national survey of breaktimes in primary and secondary schools. Final report to the Nuffield Foundation.

Blatchford, P., Baines, E. & Pellegrini, A.D. (2003). The social context of school playground games: Sex and ethnic difference, and changes over time after entry to junior school. *British Journal of Developmental Psychology, 21*, 481-505.

Blatchford, P., Creeser, R., & Mooney, A. (1990). Playground games and playtime: The children's view. *Educational Research, 32*, 163-174.

Blatchford, P. & Sumpner, C. (1998). What do we know about breaktime? Results from a national survey of breaktime and lunchtime in primary and secondary schools. *British Educational Research Journal, 24*, 79-94.

Boreham, C.A. & Riddoch, C.J. (2001). The physical activity, health and fitness of children. *Journal of Sports Sciences, 19*, 915-929.

Boreham, C., Robson, P.J., Gallagher, A.M., Cran, G.W., Savage, J.M. & Murray, L.J. (2004). Tracking of physical activity, fitness, body composition and diet from adolescence to adulthood: The Young Hearts Project, Northern Ireland. *International Journal of Behavioral Nutrition and Physical Activity, 5*, 14.

Boulton, M.J. (1992). Participation in playground activities at middle school. *Educational Research, 34*, 167-181.

Boyle, D.E., Marshall, N.L. & Robeson, W.W. (2003). Gender at play: Fourth-grade girls and boys on the playground. *American Behavioral Scientist, 46,* 1326-1345.

Brage, S., Brage, N., Franks, P.W., Ekelund, U. & Wareham, N.J. (2005). Reliability and validity of the combined heart rate and movement sensor Actiheart. *European Journal of Clinical Nutrition,* 59, 561-570.

Brage, S., Wedderkopp, N., Ekelund, U., Franks, P.W., Wareham, N.J., Andersen, L.B. & Froberg, K. (2004). Features of the metabolic syndrome are associated with objectively measured physical activity and fitness in Danish children: The European Youth Heart Study (EYHS). *Diabetes Care, 27,* 2141-2148.

Buckworth,J. & Dishman, R.K. (2002). Determinants of exercise and physical activity. In J. Buckworth (Ed.), *Exercise Psychology* (pp. 191-209). Champaign, IL: Human Kinetics.

Cale, L.A. & Almond, L. (1992). Children's physical activity levels: A review of studies conducted on British children. *Physical Education Review, 15,* 111-118.

Casey, T. (2003). *Grounds for Learning, sportscotland and Play Scotland: School Grounds Literature Review. Phase One of the Scottish School Grounds Research Project 2002/3.* Edinburgh: Play Scotland.

Caspersen, C.J., Powell, K.E. & Christenson, G.M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports, 100,* 126-131.

Cavill, N., Biddle, S. & Sallis, J.F. (2001). Health enhancing physical activity for young people: Statement of the United Kingdom expert consensus conference. *Pediatric Exercise Science, 13,* 12-25.

Chinn, S. & Rona, R.J. (2001). Prevalence and trends in overweight and obesity in three cross-sectional studies of British children. *British Medical Journal, 322,* 24-26.

Chmelynski, C. (1998). Is recess needed? *The Educational Psychologist, 64,* 67-68.

Coalter, F. & Taylor, J. (2001). *Realising the Potential of Cultural Services: The Case for Play.* London: LGA Publications.

Coe, D., & Pivarnik, J. M. (2001). Validation of the CSA accelerometer in adolescent boys during basketball practice. *Pediatric Exercise Science, 13*, 373-379.

Cohen, D.A., Scribner, R.A. & Farley, T.A. (2000). A structural model of health behaviour: A pragmatic approach to explain and influence health behaviours at the population level. *Preventive Medicine, 30*, 146-154.

Cole, T.J., Bellizzi, M.C., Flegal, K.M. & Dietz, W.H. (2000). Establishing a standard definition for child overweight and obesity worldwide: International surevy. *British Medical Journal, 320*, 1240-1245.

Connolly, P &, McKenzie, T.L. (1995). Effects of a games intervention on the physical activity levels of children at recess. *Research Quarterly for Exercise and Sport (Supplement), 66*, A-60.

Corbin, C.B., Pangrazi, R.P. & Welk. G.J. (1994). Toward an understanding of appropriate physical activity levels for youth. *Presidents Council on Physical Fitness and Sports Research Digest, 1*, 1-8.

Dale, D., Corbin, C.B. & Dale, K.S. (2000). Restricting opportunities to be active during school time: Do children compensate by increasing physical activity levels after school? *Research Quarterly for Exercise and Sport, 71*, 240-248.

Davison, K.K. & Lawson, C.T. (2006). Do attributes in the physical environment influence children's physical activity? A review of the literature. *International Journal of Behavioral Nutrition and Physical Activity, 3*, 19-35.

Dencker, M., Thorsson, O., Karlsson, M.K., Lindén, C., Eiberg, S., Wollmer, P. & Andersen, L.B. (2006). Daily physical activity related to body fat in children aged 8-11 years. *Journal of Pediatrics, 149*, 38-42.

Department of Education and Science. (1989). *Discipline in Schools.* Report of the Committee of Enquiry, and Chair Lord Elton. London: HSMO.

Department for Culture, Sport and Media. (2004). *Getting Serious about Play: A Review of Children's Play.* London: DCMS.

Department for Education and Skills. (2003). *Learning through PE and Sport: A Guide to the Physical Education, School Sport and Club Links Strategy.* London: DfES Publications.

Department for Education and Skills. (2004). *Removing Barriers to Achievements: The Government's Strategy for SEN.* London: DfES Publications (DFES/0117/2004).

Department for Education and Skills. (2005). *Primary Playground Development.* London: DfES Publications (PE/ZP).

Department of Health. (2003). *Health Survey for England 2003.* London: The Stationary Office.

Department of Health. (2004a). *At Least Five a Week: Evidence on the Impact of Physical Activity and its Relationship to Health. A Report from the Chief Medical Officer.* London: Department of Health.

Department of Health. (2004b). *Choosing Health: Making Healthier Choices Easier.* London: Department of Health. (Public Health White Paper).

Dishman, R.K. & Buckworth, J. (1996). Increasing physical activity: A quantitative synthesis. *Medicine and Science in Sports and Exercise, 28*, 706-719.

Dishman, R. K., Washburn, R. A., & Schoeller, D. A. (2001). Measurement of physical activity. *Quest, 53*, 295-309.

Duncan, C., Jones, K. & Moon, G. (1996). Health-related behaviour in context: A multilevel modelling approach. *Social Science and Medicine, 42*, 817-830.

DuRant, R.H., Baranowski, T., Davis, H., Thompson, W.O., Puhl, J., Greaves, K.A. & Rhodes, T. (1992). Relioability and variability of heart rate monitoring in 3-, 4-, or 5-yr-old children. *Medicine and Science in Sports and Exercise, 24*, 265-271.

Epstein, L.H., Paluch, R.A., Kalakanis, L.E., Goldfield, G.S., Cerny, F.J. & Roemmich, J.N. (2001). How much activity do youth get? A quantitative review of heart-rate measured activity. *Pediatrics, 108*, E44.

Ernst, M.P. (2003). Examination of physical activity during a physical activity intervention and recess. *Research Quarterly for Exercise and Sport (Supplement), 2003*, A-43.

Ernst, M.P. & Pangrazi, R.P. (1999). Effects of a physical activity program on children's activity levels and attraction to physical activity. *Pediatric Exercise Science, 11*, 393-405.

Eston, R. G., Rowlands, A. V., & Ingledew, D. K. (1998). Validity of heart rate, pedometry, and acclerometry for predicting the energy cost of children's activities. *Journal of Applied Physiology, 84*, 362-371.

Evans, J. (1996). Children's attitudes to recess and changes taking place in Australian primary schools. *Research in Education, 56*, 49-61.

Evans, J. (2003). Changes to (primary) school recess and their effect on children's physical activity: An Australian perspective. *Journal of Physical Education New Zealand, 36*, 53-62.

Fairclough, S. (2003). Physical activity, perceived competence and enjoyment during high school physical education. *European Journal of Physical Education, 8*, 5-18.

Fairclough, S. & Stratton, G. (2005). 'Physical education makes you fit and healthy'. Physical education's contribution to young people's physical activity levels. *Health Education Research, 20*, 14-23.

Fairclough, S.J. & Stratton, G. (2006). A review of physical activity levels during elementary school physical education. *Journal of Teaching Physical Education, 25*, 239-257.

Faison-Hodge, J. & Porretta, D.L. (2004). Physical activity levels of students with metal retardation and students without disabilities. *Adapted Physical Activity Quarterly, 21*, 139-152.

Fein, A.J., Plotnikoff, R.C., Wild, C. & Spence, J.C. (2004). Perceived environment and physical activity in youth. *International Journal of Behavioral Medicine, 11*, 135-142.

Freedson, P., Melanson, E., Sirard, J. (1998). Calibration of the Computer Science and Applications, Inc. accelerometer. *Medicine and Science in Sports and Exercise, 30*, 777-781.

Gavarry, O., Giacomoni, M., Bernard, T., Seymat, M. & Falgairette, G. (2003). Habitual physical activity in children and adolescents during school and free days. *Medicine and Science in Sports Exercise, 35*, 525-31.

Giles-Corti, B. & Donovan, R.J. (2002). The relative influence of individual, social and physical environment determinants of physical activity. *Social Science and Medicine, 54*, 1793-1812.

Giles-Corti, B., Timperio, A., Bull, F. & Pikora, T. (2005). Understanding physical activity environmental correlates: Increase specificity for ecological models. *Exercise and Sports Sciences Reviews, 33*, 175-181.

Goldstein, H. (1995). *Multilevel Statistical Models* (2nd Ed.). London: Arnold.

Gorard, S. (2003). What is multi-level modelling for? *British Journal of Educational Studies, 51*, 46-63.

Gorely, T. (2005). The determinants of physical activity and inactivity in young people. In L. Cale & J. Harris (Eds.), *Exercise and Young People: Issues, Implications and Initiatives.* Basingstoke, UK: Palgrave Macmillan.

Green, L.W. & Kreuter, M. (1991). *Health Promotion Planning: An Educational and Environmental Approach.* Mountain View CA: Mayfield.

Green, L.W., Richard, L. & Potvin, L. (1996). Ecological foundations of health promotion. *American Journal of Health Promotion, 10*, 270-281.

Guinhouya, C.B., Hubert, H., Dupont, G. & Durocher, A. (2005). The recess period: A key moment of prepubescent children's daily physical activity. *International Electronic Journal of Health Education, 8*, 126-134.

Hagger, M., Cale, L. & Almond, L. (1997). Children's physical activity levels and attitudes towards physical activity. *European Physical Education Review, 3*, 144-164.

Haskell, W.L., Yee, M.C., Evans, A., Irby, P.J. (1993). Simultaneous measurement of heart rate and body motion to quantitate physical activity. *Medicine and Science in Sports and Exercise, 25*, 109-115.

Hardman, K. & Marshall, J. (2000). The state and status of physical education in schools in international context. *European Physical Education Review, 6*, 203-229.

Harrison, W. (2003). Multilevel modeling: Methodological advances, issues, and applications. *Personnel Psychology, 56*, 1081-1084.

Heath, G. (2003). Increasing physical activity in communities: What really works? *Presidents Council on Physical Fitness and Sport Research Digest, 4*, 1-8.

Hendelman, D., Miller, K., Baggett, C., Debold, E. & Freedson, P. (2000). Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Medicine and Science in Sports and Exercise, 32*, S442-S449.

House of Commons. (2003). *Every Child Matters.* London: The Stationary Office (Parliament Green Paper).

Hovell, M.F., Bursock, J.H., Sharkey, R. & McClure, J. (1978). An evaluation of elementary students' voluntary physical activity during recess. *Research Quarterly, 49*, 460-474.

Jago, R. & Baranowski, T. (2004). Non-curricular approaches for increasing physical activity in youth: A review. *Preventive Medicine, 39*, 157-163.

Janz, K. F. (2002). Use of heart rate monitors to assess physical activity. In G. J. Welk (Ed.), *Physical Activity Assessments for Health-Related Research* (pp. 143-161). Champaign, IL: Human Kinetics.

Janz, K.F., Golden, J.C., Hansen, J.R. & Mahoney, L.T (1992). Heart rate monitoring of physical activity in children and adolescents: The Muscatine study. *Pediatrics, 89*, 256-261.

Jenvey, V.B. & Jenvey, H.L. (2002). Criteria used to categorize children's play: Preliminary findings. *Social Behavior and Personality, 30*, 733-740.

Johns, D.P. & Ha, A.S. (1999). Home and recess physical activity of Hong Kong children. *Research Quarterly for Exercise and Sport, 7*, 319-323.

Kelder, S.H., Mitchell, P.D., McKenzie, T.L., Derby, C., Strikmiller, P.K., Luepker, R.V. & Stone, E.J. (2003). Long-term implementation of the CATCH physical education program. *Health Education and Behavior, 30*, 463-475.

Kemper, H.C.G., Twisk, J.W.R., Koppes, L.L.J., van Mechelen, W. & Post. G.B. (2001). A 15-year physical activity pattern is positively related to aerobic fitness in young males and females (13-27 years). *European Journal of Applied Physiology, 84*, 395-402.

Khan, E.B., Ramsey, L.T., Brownson, R.C., Heath, G.W., Howze, E.H., Powell, K.E., Stone, E.J., Jajab, M.W. & Corso, P. (2002). The effectiveness of interventions to increase physical activity. *American Journal of Preventive Medicine, 22(4S)*, 73-107.

Killen, J.D. & Robinson, T.N. (1988). School-based health behavior change research: the Stanford Adolescent Heart Health Program as a model for cardiovascular disease risk reduction. *Review of Educational Research, 15*, 171-200.

King, A.C., Stokols, D., Talen, E. & Brassington, G.S. (2002). Theoretical approaches to the promotion of physical activity: Forging a transdisciplinary paradigm. *American Journal of Preventive Medicine, 23*, 15-25.

Klasson-Heggebø, L., Anderson, L.B., Wennlöf, A.H., Sardinha, L.B., Harro, M., Froberg, K. & Anderssen, S.A. (2006). Graded associations between cardiorespiratory fitness, fatness, and blood pressure in children and adolescents. *British Journal of Sports Medicine, 40*, 25-29.

Kohl, H.W. & Hobbs, K.E. (1998). Development of physical activity behaviors among children and adolescents. *Pediatrics, 101*, 549-554.

Kraft, R.E. (1989). Children at play: Behaviour of children at recess. *Journal of Physical Education, Recreation and Dance, 60*, 21-24.

Lever, J. (1976). Sex differences in the games children play. *Social Problems, 23*, 478-487.

Lindon, J. (2001). *Understanding Children's Play.* Cheltenham, UK: Nelson Thornes.

Lindon, J. (2002). *What is play?* [Fact sheet]. London: Children's Play Information Service.

Liverpool Sport Action Zone (2000). *"Sports Generation". Needs Analysis and Action Plan 2001-2005.* Liverpool Sports Action Zone.

Logan, N., Reilly, J.J., Grant, S. & Paton, J.Y. (2000). Resting heart rate definition and its effect on apparent levels of physical activity in young children. *Medicine and Science in Sports and Exercise, 32*, 162-166.

Loucaides, C.A., Chedzoy, S.M. & Bennett, N. (2003). Pedometer-assessed physical activity in Cypriot children. *European Physical Education Review, 9*, 43-55.

Maas, C.J.M. & Hox, J.J. (2004). Robustness issues in multilevel regression analysis. *Statistica Neerlandica, 58*, 127-137.

Macintyre, C. (2001). *Enhancing Learning through Play. A Developmental Perspective for Early Years Settings.* London: David Fulton Publishers.

Malina, R.M. (1996). Tracking of physical activity and physical fitness across the lifespan. *Research Quarterly for Exercise and Sport (Supplement), 67*, 48-57.

Marshall, S.J., Biddle, S,J., Gorely, T., Cameron, N. & Murdey, I. (2004). Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *International Journal of Obesity and Related Metabolic Disorders, 28*, 1238-1246.

Mâsse, L.C., Fulton, J.E., Watson, K.L., Heesch, K.C., Kohl, H.W., Blair, S.N., & Tortolero, S.R. (1999). Detecting bouts of physical activity in a field setting. *Research Quarterly for Exercise and Sport, 70*, 212-219.

Mâsse, L.C., Dassa, C., Gauvin, L., Giles-Corti, B. & Motl, R. (2002). Emerging measurement and statistical methods in physical activity research. *American Journal of Preventive Medicine, 23(2S)*, 44-55.

McLeroy, K.R., Bibeau, D., Steckler, A. & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education Quarterly, 15*, 351-377.

McKay, H.A., MacLean, L., Petit, M., MacKelvie-O'Brien, K., Janssen, P., Beck, T. & Khan, K.M. (2005). "Bounce at the Bell": a novel program of short bouts of exercise improves proximal femur bone mass in early pubertal children. *British Journal of Sports Medicine,* 39, 521-526.

McKenzie, T.L., Marshall, S.J., Sallis, J.F. & Conway, T.L. (2000). Leisure-time physical activity in school environments: An observational study using SOPLAY. *Preventive Medicine, 30*, 70-77.

McKenzie, T.L., Sallis, J.F., Elder, J.P., Berry, C.C., Hoy, P.L., Nader, P.R., Zive, M.M. & Broyles, S.L. (1997a). Physical activity levels and prompts in young children at recess: A two-year study of a bi-ethnic sample. *Research Quarterly for Exercise and Sport, 68*, 195-202.

McKenzie, T.L., Sallis, J.F., Kolody, B. & Faucette, F.N. (1997b). Long-term effects of a physical education curriculum and staff development program: SPARK. *Research Quarterly for Exercise and Sport, 68*, 280-291.

Morgan, C.F., McKenzie, T.L., Sallis, J.F., Broyles, S.L., Zive, M.M. & Nader, P.R. (2003). Personal, social and environmental correlates of physical activity in a bi-ethnic sample of adolescents. *Pediatric Exercise Science, 15*, 288-301.

Mota, J., Silva, P., Santos, M.P., Ribeiro, L.C., Oliveira, J. & Duarte, J.A. (2005a). Physical activity and school recess time: Differences between the sexes and the relationship between children's playground physical activity and habitual physical activity. *Journal of Sports Sciences, 23*, 269-275.

Mota, J., Silva, P., Aires, L., Santos, M.P., Ribeiro, J.C., Oliveira, J. & Duarte, J.A. (2005b). Differences in physical activity in school recess time among obese and non-obese children. Paper presented at XXIII Pediatric Work Physiology Meeting, Gwatt, Switzerland, 22-25th September.

Mota, J. & Stratton, G. (2003). Gender differences in physical activity during recess in Portuguese primary schools. *Revista Portuguesa de Ciências do Desporto, 3*, 150.

Myers, L., Strikmiller, P.K., Webber, L.S. & Berenson, G.S. (1996). Physical and sedentary activity in school children grades 5-8: The Bogalusa Heart Study. *Medicine and Science in Sports and Exercise, 28*, 852-859.

National Association of Early Childhood Specialists in State Departments of Education (NAECS/SDE) (2002). *Recess and the Importance of Play.* A position statement on young children and recess. NAECS/SDE.

National Playing Fields Association. (2000). *Best Play - What Play Provision should do for Children.* London: National Playing Fields Association.

Nilsson, A., Ekelund, U., Yngve, A. & Sjöström, M. (2002). Assessing physical activity among children with accelerometers using different time sampling intervals and placements. *Pediatric Exercise Science, 14*, 87-96.

Noble, M., Wright, G., Dibben, C., Smith, G.A.N., McLennon, D., Anttila, G., Barnes, H., Mokhtor, C., Noble, S., Avenell, D., Gardner, J., Covizzi, I., Lloyd, M. (2004). Indicies of

Deprivation 2004. Report to the Office of the Deputy Prime Minister. London: Neighbourhood Renewal Unit.

Norton, K., Whittington, N., Carter, L., Kerr, D., Gore, C. & Morfell-Jones. (1996). Measurement techniques in anthropometry. In K. Norton & T. Olds (Eds.), *Anthropemtrica* (pp. 25-75). University of New South Wales.

Ott A.E., Pate, R.R., Trost, S.G., Ward, D.S. & Saunders, R. (2000). The use of uniaxial and triaxial accelerometers to measure children's "free-play" physical activity. Pediatric Exercise Science, 12, 360-370.

Owen, N., Leslie, E., Salmon, J. & Fotheringham, M.J. (2000). Environmental determinants of physical activity and sedentary behaviour. *Exercise and Sport Sciences Reviews, 28*, 153-158.

Pate, R.R., Pratt, M., Blair, S.N., Haskell, W.L., Macera, C.A., Bouchard, C., Buchner, D., Ettinger, W., Heath, G.W., King, A.C., Kriska, A., Leon, A.S., Marcus, B.H., Morris, J., Paffenbarger, R.S., Patrick, K., Pollock, M.L., Rippe, J.M., Sallis, J.F. & Wilmore, J.H. (1995). Physical activity and public health: A recommendation from the Centres for Disease Control and Prevention and the American College of Sports Medicine. *Journal of the American Medical Society, 273*, 403-407.

Pate, R.R., Baranowski, T., Dowda, M. & Trost, S.G. (1996). Tracking of physical activity in young children. *Medicine and Science in Sports and Exercise, 28*, 92-96.

Pate, R.R., Saunders, R.P., Ward, D.S., Felton, G., Trost, S.G. & Dowda, M. (2003). Evaluation of a community-based intervention to promote physical activity on youth: Lessons from active winners. *American Journal of Health Promotion, 17*, 171-182.

Payne, V.G. & Morrow, J.R. (1993). Exercise and VO_2max in children: A meta-analysis. *Research Quarterly for Exercise and Sport, 64*, 305-313.

Pellegrini, A.D. (1995). *School Recess and Playground Behaviour: Developmental and Educational Roles.* New York: SUNY Press.

Pellegrini, A.D. & Blatchford, P. (2002). The developmental and educational significance of recess in schools. *Early Report, 29*, 1-7.

Pellegrini, A. D., Blatchford, P., Kato, K. & Baines, E. (2004). A short-term longitudinal study of children's playground games in primary school: Implications for adjustment to school and social adjustment in the USA and the UK. *Social Development, 13*, 107-123.

Pellegrini, A.D. & Bohn, C.M. (2005). The role of recess in children's cognitive performance and school adjustment. *Educational Researcher, 34*, 13-19.

Pellegrini, A.D. & Davis, P.D. (1993). Relations between children's playground and classroom behaviour. *British Journal of Educational Psychology, 63*, 88-95.

Pellegrini, A.D. & Smith, P.K. (1993). School recess: implications for education and development. Review of Educational Research, 63, 51-67.

Pellegrini, A.D. & Smith, P.K. (1998). Physical activity play: The nature and function of a neglected aspect of play. *Child Development, 69*, 577-598.

Plewis, I. & Fielding, A. (2003). What is multi-level modelling for? A critical response to Gorard (2003). *British Journal of Educational Studies, 51*, 408-419.

Puyau, M.R., Adolph, A.L., Vohra, F.A. & Butte, N.F. (2002). Validation and calibration of physical activity monitors in children. *Obesity Research, 10*, 150-157.

Quené, H. & van den Bergh, H. (2004). On multi-level modelling of data from repeated measures designs: A tutorial. *Speech Communication, 43*, 103-121.

Raitakari, O.T., Porkka, K.V.K., Rasenen, L., Ronnemaa, T. & Viikari, J.S.A. (1994). Clustering and six-year cluster-trakcing of serum total cholesterol, HDL-cholesterol and diastolic blood pressure in children and young adults. *Journal of Clinical Epidemiology, 47*, 1085-1093.

Renold, E. (1997). "All they've got in their brains is football". Sport, masculinity and the gendered practices of playground relations. *Sport, Education and Society, 2*, 5-23.

Riddoch, C.J. (1998). Relationship between physical activity ands physical health in young people. In S.J. Biddle, J. Sallis & N. Cavill (Eds.), *Young and Active? Young People and Health-Enhancing Physical Activity - Evidence and Implications* (pp. 17-48). Champaign, IL: Human Kinetics.

Riddoch, C.J. & Boreham. C.A. (1995). The health-related physical activity of children. *Sports Medicine, 19,* 86-102.

Riddoch, C.J. & Boreham, C. (2000). Physical activity, physical fitness and children's health: current concepts. In A. Armstrong & W. van Mechelen (Eds.), *Pediatric Exercise Science and Medicine* (pp. 243-252). Oxford University Press.

Riddoch, C.J., Mahoney. C., Murphy, N., Cran, G., Boreham, C.A. (1991). The physical activity patterns of Northern Irish schoolchildren ages 11-16 years. *Pediatric Exercise Science, 3,* 300-309.

Riddoch, C.J., Anderson, L.B., Wedderkopp, N., Harro, M., Klasson-Heggebø, L., Sardinha, L.B., Cooper, A.R. & Ekelund, U. (2004). Physical activity levels and patterns of 9- and 15-yr-old European children. *Medicine and Science in Sports and Exercise, 36,* 86-92.

Rippe, J.M., Weissberg, R.P. & Seefeldt, V. (1993). The purpose of play: A framework for improving childhood health and psychological and physical development. *Medicine Exercise Nutrition and Health, 2,* 225-231.

Rosser Sandt, D.D. & Frey, G.C. (2005). Comparison of physical activity levels between children with and without autistic spectrum disorders. *Adapted Physical Activity Quarterly, 22,* 146-159.

Rowe, D.A., Raedeke, T.D. & Mahar, M.T. (2003). Test of a measurement model for investigating the Youth Physical Activity Promotion Model. *Research Quarterly for Exercise and Sport (Supplement), 74,* A-27

Rowland, D., Diguiseppi, C., Gross, M., Afolbi, E., Roberts, I. (2003). Randomised controlled trial of site specific advice on school travel patterns. *Archives of Disease in Childhood, 88*, 8-11.

Rowland, T.W. (1993). Aerobic exercise testing protocols. In T.W. Rowland (Ed.), *Pediatric Laboratory Exercise Testing* (pp. 19-41). Champaign, IL: Human Kinetics.

Rowlands, A.V. (2001). Field methods of assessing physical activity and energy balance. In R.G. Eston & T. Reilly (Eds.), *Kinanthropometry and Exercise Physiology Laboratory Manual. Tests, Procedures and Data, Volume One, Anthropometry* (pp. 151-170). London: Routledge.

Rowlands, A.V., Eston, R.G. & Ingledew, D.K. (1999). The relationship between activity levels, body fat and aerobic fitness in 8-10 year old children. *Journal of Applied Physiology, 86*, 1428-1435.

Rubin, K.H., Fein, G.G. & Vandenberg, B. (1983). Play. In E.M. Hetherington (Ed.), *Handbook of Child Psychology: Vol 4. Socialization, Personality and Social Development* (pp. 693-774). New York: Wiley.

Ruiz, J.R., Rizzo, N.S., Hurtig-Wennlöf, A., Ortega, F.B., Wärnberg, J. & Sjöström, M. (2006). Relations of total physical activity and intensity to fitness and fatness in children: The European Youth Heart Study. *American Journal of Clinical Nutrition, 84*, 299-303.

Sääkslahti, A., Numminen, P., Salo, P., Touminen, J., Helenius, H. & Välimäki, I. (2004). Effects of a three-year intervention on children's physical activity from age 4 to 7. *Pediatric Exercise Science, 16*, 167-180.

Sallis, J.F. (1994). Determinants of physical activity behavior in children. In R.R. Pate & R.C. Hon (Eds.), *Health and Fitness through Physical Education* (pp. 31-43). Champaign, IL: Human Kinetics.

Sallis, J.F., Berry, C.C., Broyles, S.L., McKenzie, T.L. & Nader, P.R. (1995). Varaibility and tracking of physical activity over 2 years in young children. *Medicine and Science in Sports and Exercise, 27*, 1042-1049.

Sallis, J.F., Hovell, M.F., Hofstetter, C.R., Elder, J.P., Hackley, M., Caspersen, C.F. & Powell, K.E. (1990). Distance between homes and exercise facilities related to frequency of exercise among San Diego residents. *Public Health Reports, 105*, 179-185.

Sallis, J.F., Johnson, M.F., Calfas, K.J., Caparosa, S. & Nichols, J.F. (1997). Assessing perceived physical activity environmental variables that may influence physical activity. *Research Quarterly for Exercise and Sport, 68*, 345-351.

Sallis, J.F. & Patrick, K. (1994). Physical activity guidelines for adolescents: Consensus statement. *Pediatric Exercise Science, 6*, 302-314.

Sallis, J.F. & McKenzie, T.L. (1991). Physical education's role in public health. *Research Quarterly for Exercise and Sport, 62*, 124-137.

Sallis, J.F. & Owen, N. (1999). *Physical Activity and Behavioral Medicine.* California, CA: Sage Publications.

Sallis, J.F. & Owen, N. (2002). Ecological models of health behavior. In K. Glanz, B.K. Rimer & F.M. Lewis (Eds.), *Health Behavior and Health Education: Therory, Research, and Practice* (3rd Ed.) (pp. 462-484). San Francisco: Jossey-Bass.

Sallis, J.F., Prochaska, J.J. & Taylor, W.C. (2000). A review of correlates of physical activity of children and adolescents. *Medicine and Science in Sports and Exercise, 32*, 963-975.

Sallis, J.F., Simons-Morton, B.G., Stone, E.J., Corbin, C.B., Epstein, L.H., Faucette, N., Iannotti, R.J., Killen, J.D., Klesges, R.C., Petray, C.K., Rowland, T.W. & Taylor, W.C. (1992). Determinants of physical activity and interventions in youth. *Medicine and Science in Sports and Exercise, 24*, S248-S257.

Sallis, J.F., McKenzie, T.L., Conway, T.L., Elder, J.P., Prochaska, J.J., Brown, M., Zive, M.M., Marshall, S.J. & Alcaraz, J.E. (2003). Environmental interventions for eating and physical activity: A randomized control trial in middle schools. *American Journal of Preventive Medicine, 24*, 209-217.

Sarkin, J.A., McKenzie, T.L. & Sallis, J.F. (1997). Gender differences in physical activity during fifth-grade physical education and recess periods. *Journal of Teaching in Physical Education, 17*, 99-106.

Scruggs, P.W., Beveridge, S.K. & Watson, D.L. (2003). Increasing children's school time physical activity using structured fitness breaks. *Pediatric Exercise Science, 15*, 156-169.

Shephard, R.J. (1997). Curricular Physical Activity and Academic Performance. *Pediatric Exercise Science, 9*, 113-126.

Shephard, R.J., Jequier, J., Lavallee, H., La Barre, R. & Rajic, M. (1980). Habitual physical activity: effects of sex, milieu, season, and acquired activity. *Journal of Sports Medicine, 20*, 55-65.

Simons-Morton, B.G. (1994). Implementing health-related physical education. In R.R. Pate & R.C. Hohn (Eds.), *Health and Fitness through Physical Education* (pp. 137-146). Champaign, IL: Human Kinetics.

Sirard, J. R. & Pate, R. R. (2001). Physical activity assessment in children and adolescents. *Sports Medicine, 31*, 439-454.

Sleap, M. & Tolfrey, K. (2001). Do 9- to 12 yr-old children meet existing physical activity recommendations for health? *Medicine and Science in Sports and Exercise, 33*, 591-596.

Sleap, M. & Warburton, P. (1992). Physical activity levels of 5-11-year old children in England as determined by continuous observation. *Research Quarterly for Exercise and Sport, 63*, 238-245.

Sleap, M. & Warburton, P. (1996). Physical activity levels of 5-11 year-old children in England: Cumulative evidence from three direct observation studies. *International Journal of Sports Medicine, 17*, 248-253.

Smith, P.K. & Vollstedt, R. (1985). On defining play: An empirical study of the relationship between play and various play criteria. *Child Development, 56*, 1042-1050.

Spence, J.C. & Lee, R.E. (2003). Toward a comprehensive model of physical activity. *Psychology of Sport and Exercise, 4*, 7-24.

Sport England (2003). *Young People and Sport in England.* Sport England.

Stevens, J. (1996). *Applied Multivariate Statistics for the Social Sciences* (3rd Ed.). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Stokols, D. (1996). Translating social ecology theory into guidelines for community health promotion. *American Journal of Health Promotion, 10*, 282-298.

Stokols, D., Grywacz, J.G., McMahan, S. & Phillips, K. (2003). Increasing the health promotive capacity of human environments. *American Journal of Health Promotion, 18*, 4-13.

Stone, E.J., McKenzie, T.L., Welk, G.J. & Booth, M.L. (1998). Effects of physical activity interventions in youth: Review and synthesis. *American Journal of Preventive Medicine, 15*, 298-315.

Strath, S.J., Bassett, D.R. & Swartz, A.M. (2003). Comparison of MTI accelerometer cut-off points for predicting time spent in physical activity. *International Journal of Sports Medicine, 24*, 298-303.

Stratton, G. (1996). Children's heart rates during physical education lessons: A review. *Pediatric Exercise Science, 8*, 215-233.

Stratton, G. (1999). A preliminary study of children's physical activity in one urban primary school playground: differences by sex and season. *Journal of Sport Pedagogy, 2*, 71-81.

Stratton, G. (2000). Promoting children's physical activity in primary school: an intervention study using playground markings. *Ergonomics, 43*, 1538-1546.

Stratton, G., Canoy, D., Boddy, L.M., Taylor, S.R., Hacket, A.F. & Buchan, I.E. Cardio-respiratory fitness and body mass index of English 9-11 year-old children: A serial cross-sectional study from 1998 to 2004. *International Journal of Obesity,* in press.

Stratton, G. & Leonard, J. (2002). The effects of playground markings on the energy expenditure of 5-7-year-old school children. *Pediatric Exercise Science, 14,* 170-180.

Stratton, G. & Mota, J. (2000). Girls' physical activity during primary school playtime: A validation study using systematic observation and heart rate telemetry. *Journal of Human Movement Studies, 38,* 109-121.

Stratton, G. & Mullan, E. (2005). The effect of multicolor playground markings on children's physical activity levels during recess. *Preventive Medicine, 41,* 828-833.

Strong, W.B., Malina, R.M., Blmikie, C.J.R., Daniels, S.R., Dishman, R.K., Gutin, B., Hergenroeder, A.C., Must, A., Nixon, P.A., Pivarnik, J.M., Rowland, T., Trost, S. & Trudeau, F. (2005). Evidence based physical activity for school-age youth. *Journal of Pediatrics, 146,* 732-737.

Swartz, A.M, Strath, S.J., Bassett, D.R., O'Brien, W.L., King, G.A. & Ainsworth, B.E. (2000). Estimation of energy expenditure using CSA accelerometers at hip and wrist sites. *Medicine and Science in Sports and Exercise, 32,* S450-S456.

Tabachnick, B.G. & Fidell, L.S. (2001). *Using Multivariate Statistics* (4th Ed.). Needham Heights, MA: Allyn and Bacon.

Taylor, M.J., Mazzone, M. & Wrotiak, B.H. (2005). Outcome of an exercise and educational intervention for children who are overweight. *Pediatric Physical Therapy, 17,* 180-188.

Telama, R., Yang, X., Viikari, J., Vaälimäki, I., Wanne, O. & Raitakair, O. (2005). Physical activity from childhood to adulthood: A 21-year tracking study. *American Journal of Preventive Medicine, 28,* 267-273.

Thomson, S. (2004). Just another classroom? Observations of primary school playgrounds. In P. Vertinsky & J. Bale (Eds.), *Sites of Sport: Space, Place, Experience* (pp. 73-84). London: Routledge.

Thomson, S. (2005). 'Territorialising' the primary school playground: Deconstructing the geography of playtime. *Children's Geographies, 1*, 63-78.

Titman, W. (1992). *Play, Playtime, and Playgrounds.* Devon, UK: Southgate Publishers.

Titman, W. (1994). *Special Places, Special People: The Hidden Curriculum of School Grounds.* Godalming: World Wide Fund for Nature/Learning through Landscapes.

Tobias, J., Steer, C., Mattocks, C., Riddoch, C. & Ness, A. Habitual levels of physical activity influence bone mass in 11 year-old children from the UK: Findings from a large population-based cohort. *Journal of Bone and Mineral Research,* in press.

Trost, S.G. (2001). Objective measurement of physical activity in youth: Current issues, future directions. *Exercise and Sports Science Reviews, 29*, 32-36.

Trost, S.G., Kerr, L.M., Ward, D.S. & Pate R.R. (2001). Physical activity and determinants of physical activity in obese and non-obese children *International Journal of Obesity and Related Metabaloic Disorders, 25*, 822-829.

Trost S.G., Pate, R.R., Freedson, P.S., Sallis, J.F. & Taylor, W.C. (2000). Using objective physical activity measures with youth: How many days of monitoring are needed? *Medicine and Science in Sports and Exercise, 32*, 426-431.

Tryon, W.W. & Williams, R. (1996). Fully proportional actigraphy: a new instrument. *Behavior Research Methods, Instruments and Computers, 28,* 392-403.

Tudor-Locke, C.E. & Myers, A.M. (2001). Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Research Quarterly for Exercise and Sport, 72*, 1-12.

Tudor-Locke, C., Burkett, L., Reis, J.P., Ainsworth, B.E., Macera, C.A. & Wilson, D.K. (2005). How many days of monitoring predict weekly physical activity in adults? *Preventive Medicine, 40,* 293-8.

Twisk, J.W.R. (2006). *Applied Multilevel Analysis.* Cambridge: Cambridge University Press.

Twisk, J.W.R., Kemper, H.C.G. & van Mechelen, W. (2002). The relationship between physical fitness and physical activity during adolescence and cardiovascular disease risk factors at adult age: The Amsterdam Growth and Health Longitudinal Study. *International Journal of Sports Medicine, 23,* S8-S14.

United States Department of Health and Human Services (USDHHS). (2000). *Healthy people 2010: understanding and improving health.* Washington: DHHS.

van Mechelen, W. & Kemper, H.C.G. (1995). Habitual physical activity in longitudinal perspective. In H.C.G Kemper (Ed.), *The Amsterdam Growth Study: A Longitudinal Analysis of Health, Fitness, and Lifestyle* (pp. 135-158). Champaign, IL: Human Kinetics.

Verstraete, S.J.M, Cardon, G.M., De Clercq, D.L.R., De Bourdeaudhuij, I.M.M. (2006). Increasing children's physical activity levels during recess periods in elementary schools: The effects of providing game equipment. *European Journal of Public Health, 16,* 415-419.

Vincent, W.J. (1999). *Statistics in Kinesiology* (2nd Ed). Champaign, IL: Human Kinetics.

Vuori, I. (1998). Experiences of heart rate monitoring in observational and intervention studies. *Journal of Sports Sciences, 16,* S25-S30.

Wechsler, H., Devereaux, A.B., Davis, M. & Collins, J. (2000). Using the school environment to promote physical activity and healthy eating. *Preventive Medicine, 31,* S121-137.

Weiss, M.R. & Ferrer-Caja, E. (2002). Motivational orientations and sport behaviour. In Horn, T.S. (Ed.), *Advances in Sport Psychology* (pp. 101-183). Champaign, IL: Human Kinetics.

Welk, G.J. (1999). The Youth Physical Activity Promotion model: A conceptual bridge between theory and practice. *Quest, 51*, 5-23.

Welk, G. J. (2002). Use of accelerometry-based activity monitors to assess physical activity. In G. J. Welk (Ed.), *Physical Activity Assessments in Health-Related Research* (pp. 125-141). Champaign, IL: Human Kinetics

Welk, G.J., Corbin, C.B. & Dale, D. (2000). Measurement issues in assessment of physical activity in children. *Research Quarterly for Exercise and Sport, 71*, 59-73.

Welk, G. J., & Wood, K. (2000). Physical activity assessments in physical education: A practical review of instruments and their use in the curriculum. *Journal of Physical Education, Recreation and Dance, 71*(1), 30-40.

Whitney, I. & Smith, P. (1993). A survey of the nature and extent of bully/victim problems in junior/middle and secondary schools. *Educational Research, 35*, 3-25.

Wold, B. & Hendry, L. (1998). Social and environmental factors associated with physical activity in young people. In S.J.H. Biddle, J. Sallis & N. Cavill (Eds.), *Young and Active? Young People and Health-Enhancing Physical Activity - Evidence and Implications* (pp. 119-132). Champaign, IL: Human Kinetics.

Wu, Y-W.B. & Wooldridge, P.J. (2005). The impact of centering first-level predictors on individual and contextual effects in multilevel data analysis. *NursingResearch, 54*, 212-216.

Youth Sport Trust. (2002). *Sporting Playgrounds - Zoneparc.* Empress Nottingham Limited.

Zask, A., van Beurden, E., Barnett, L., Brooks, L.O. & Dietrich, U.C. (2001). Active school playgrounds - Myth or reality? Results of the "Move It Groove It" Project. *Preventive Medicine, 33*, 402-408.

APPENDIX 1
Ethical Approval

liverpool JMU
Faculty of Education, Community & Leisure

The REACH Group.
Research into Exercise, Activity and Children's Health.

Liverpool John Moores University
School of Physical Education, Sport and Dance
IM Marsh Campus
Barkhill Road
Liverpool
L17 6BD

Dear parent/carer,

[NAME OF SCHOOL] is involved with an important research project, which in investigating the impact of redesigning the school playground environment on physical activity levels and behaviour during school playtime. The Liverpool Sporting Playgrounds Project is part of the national Sporting Playgrounds Project that is investing £10 million in to school playgrounds across the country. In order to investigate the impact of the playground over time, we would like your child to take part in the project that will take place over the next two years. Participation may involve him/her:

- Wearing a light-weight heart rate monitor (40g)*
- Wearing a movement counter attached to their waist band *
- Videoing their playground activity
- Completing questionnaires and interviews on how they feel about their playtime*

- * Randomly selected children

Confidentiality is very important so we will ensure that only those people involved in the project will be able to see the information collected using the methods mentioned above. We would like as many children as possible to take part in our project, so please sign and return the attached form to the school by (DATE) ______________________________ giving permission for your child to take part. If you have any questions about the project, please feel free to contact Nicola Ridgers on 0151 231 5381.

The school and the REACH Group believe that the project will be an interesting, enjoyable and rewarding experience for all the children and schools involved whilst helping to promote physical activity and positive behaviour. Thank you for your co-operation.

Yours sincerely,

Dr. Gareth Stratton   Nicola Ridgers

Child's Name ______________________ Gender M/F ____________

Date of Birth ______________________ Form/Class ____________

LIVERPOOL JOHN MOORES UNIVERSITY
FORM OF CONSENT (B) (CARER)

Thank you for wishing to be involved in this study. Please read the following carefully. **Add your signature to section 1X (bold) and return this form back to school as soon as possible. An independent witness needs to sign box 3.**

Title: A Longitudinal Investigation into the Children's Physical Activity and Behaviour at Playtime

Purpose of Study and Brief Description of Procedures: To investigate children's activity during playtime over time. Filming of playtime, activity monitoring, interviews and short questionnaires will be completed by children during school time.

All information is confidential and used for this research only. No names are released. Contact Nicola Ridgers on 0151 231 5381 if you need further questions answered.

1. I, X ______________________ (Carer/parent/guardian's full name)* am the carer/parent/guardian for ______________________ **(Child's name). I understand the methods to be used, and I allow my child to take part in this project.**

Signed X ______________________ **Date** ______________

2. I, **NICOLA RIDGERS** confirm that the details of this project/procedure have been fully explained and described in writing to the carer/parent/guardian** named above and have been understood by him/her.

3. I ______________________ (Witness' full na me)* confirm that the details of this project have been explained in writing and are followed by the child's carer/parent/guardian**

Signed ______________________ **Date** ______________
(Witness)

N.B. The witness must be an independent third party.

* please print in block capitals

** delete as appropriate

Parent Information Sheet.

A member of the research team will visit the school and will fully explain the procedure to be undertaken on that day. Participation is voluntary and children can withdraw from any procedures at anytime. During the school day, a number of procedures will be undertaken. These are described below. The research team will visit the school on four occasions over the next 2 years. Please note all members of the research team are CRB checked.

Heart rate monitor:
To look at physical activity levels during playtime, heart rate will be monitored using a heart rate monitor, which is fixed around the chest using an adjustable elastic strap. The monitor will be given to the children during registration, and worn until the conclusion of their last playtime. The children will be advised to remove the monitor in the event of it becoming uncomfortable.

Motion sensor:
Eleven children will also be randomly selected to wear an accelerometer, which is similar to a pedometer. It is a lightweight monitor worn around the waist on the right hip. It doesn't get in the way and children soon forget they have them on. The monitor will be given to the children during registration, and worn until the conclusion of their last playtime.

Playground behaviour:
Children will be filmed playing normally in the playground environment to allow for assessment of play and interaction behaviour. Videos will be securely locked away and only viewed by a member of the research team. All video material will be stored for 5 years. This was approved by the University Ethics Committee. At the end of the 5 years, all the recordings made will be destroyed. Parents will be contacted prior to each visit to advise them that filming of the playground is scheduled to take place.

Interviews and Questionnaires.
Children will be asked about their playground, and how they feel about playtime.

<u>If you have any questions or concerns, please contact Nicola Ridgers (Principle Researcher) on 0151 231 5381 or Dr. Gareth Stratton (Project Leader) on 0151 231 4334.</u>

Yours sincerely

Dr. Gareth Stratton
Project Leader

Nicola Ridgers
Principle Researcher

APPENDIX 2
Associated Publications

Associated Publications.

- Stratton, G. & Ridgers, N.D. (2003). Sporting playgrounds project - An overview. *British Journal of Teaching Physical Education, 34*, 23-25.

- Ridgers, N.D. & Stratton, G. (2005). Physical activity during school recess - The Liverpool Sporting Playgrounds Project. *Pediatric Exercise Science, 17*, 281-290.

- Ridgers, N.D., Stratton, G. & Fairclough, S.J. (2005). Assessing physical activity during recess using accelerometry. *Preventive Medicine, 41*, 102-107.

- Ridgers, N.D., Stratton, G., Curley, J. & White, G. (2005). Liverpool Sporting Playgrounds Project. *Education and Health, 23*, 50-52.

- Ridgers, N.D., Stratton, G. & Fairclough, S.J. (2006). Physical activity levels of children during school playtime. *Sports Medicine, 36*, 359-371.

- Ridgers, N.D., Stratton, G., Clark, E., Fairclough, S.J. & Richardson, D.J. (2006). Day-to-day and seasonal variability of physical activity during school recess. *Preventive Medicine, 42*, 372-374.

- Ridgers, N.D., Stratton, G., Fairclough, S.J. & Twisk, J.W.R. Long-term effects of a playground markings and physical structures intervention on children's recess physical activity levels. *Preventive Medicine* (in press).

Published Abstracts.

- Ridgers, N.D. & Stratton, G. (2005). Children's physical activity levels during school playtime. *Journal of Sports Sciences, 23,* 134. In British Association of Sport and Exercise Sciences, Liverpool John Moores University, UK, 7-9 September. [Oral Presentation].

- Ridgers, N.D., Stratton, G., Clark, E., Fairclough, S.J. & Richardson, D.J. (2005). Physical activity during playtime: Examining seasonal and sex differences. *Journal of*

Sports Sciences, 23, 1216. In British Association of Sport and Exercise Sciences Annual Conference, Loughborough University, UK, 4-7 September. [Oral Presentation].

- Stratton, G., Ridgers, N.D., Fairclough, S.J. & Richardson, D.J. (2005). The physical activity levels of normal and overweight girls and boys during primary school recess: The Liverpool Sporting Playgrounds Project. *Journal of Sports Sciences, 23*, 1225-1226. In British Association of Sport and Exercise Sciences Annual Conference, Loughborough University, UK, 4-7 September. [Poster presentation].

Sporting Playgrounds Project – An Overview

Gareth Stratton and Nicola Ridgers

INTRODUCTION

Physical activity is widely acknowledged as an integral part of a healthy lifestyle, with the relationship between physical activity and health risk factors such as obesity, diabetes, osteoporosis and coronary heart disease (CHD) well documented (Bailey et al., 1995). With research indicating that an inactive lifestyle in childhood is linked to a sedentary lifestyle in adulthood, it is thought that promoting a physically active lifestyle to children could reduce the risks associated with inactivity; ultimately benefiting health in adult life (Blair and Connelly, 1996). Despite this, British children are not meeting recommendations for daily physical activity, which may lead to detrimental effects on their own health and that of future generations (Stratton, 2002).

With this in mind, research into the promotion of physical activity within the school setting merits attention. However, with hours committed to physical education dropping due to the pressures on curricular time (Sheppard, 1997), school playtime may provide an ideal opportunity for children to be physically active. Furthermore activity in school playgrounds can make a significant contribution to the recommended 60 minutes of moderate-to-vigorous physical activity a day, especially during the winter months (MVPA; Biddle et al., 1998). With children experiencing up to 600 playtimes a year (based on 3 times a day, 5 days per week, 39 weeks per year; Stratton, 2000), playtime offers not only the opportunity of accumulating the recommended 60 minutes MVPA a day but also the chance of promoting positive attitudes to physical activity in general.

PLAYGROUND PROJECT

The DfES in partnership with Nike have invested £10,000,000 into the development of "Sporting Playgrounds" in primary schools across England. In order to investigate the impact of playtime on physical activity in primary school children, a project, conducted by the REACH Group (Research into Exercise, Activity and Children's Health) based at Liverpool John Moores University, has been developed. 20 schools across Liverpool are participating in the Sporting Playgrounds Project, which is tracking the effects of playground redesigns on children's fitness, playground behaviour, sports participation and school attendance over two academic years. The REACH Group are conducting the research in partnership with Liverpool's LEA, local Sport and Education Action Zones and Sport England, and have identified several aims for the project. These are to:

- investigate the impact of playground redesign on physical activity levels
- research the use of the playground as a motivational and educational tool
- identify changes in playground behaviour
- investigate potential changes in attainment and self-esteem
- assess the playground redesigns potential as an intervention for developing children's social and physical behaviour
- track the sustainability of the playground intervention over 18 months.

The schools involved in the project will develop and redesign their playground area around a standard Zoneparc model. Each of the schools has secured £20,000 funding from the DfES to implement this intervention.

ZONEPARC

The main aims of the Zoneparc model are to:

- tackle social exclusion and playground issues in schools
- increase activity levels for young people.

The redesign involves the division of the playground into three principle areas; Red, Blue and Yellow Zones. The Red Zone is designed to be the sports zone, where children engage in activities such as football, cricket and basketball. This area is often enclosed. The Blue area is the action zone, where games and activities such as target work, fitness and skills are the focus. Lastly, the Yellow area is the chill out zone, where non-active mental and physical activities such as word games, clapping games, and games like chess are encouraged (Youth Sport Trust, 2002). The Blue and Yellow Zones tend not to be enclosed because of the nature of the activities occurring within them. An example of a Zoneparc is illustrated in figure 1 on page 25.

The schools participating in the project are actively involved in the playground design. Children, teachers and AOT's were involved in how the playground should be constructed. Playground markings which are contained within each of these three distinctive zones are appropriate to the individual zones' overall objectives, with schools identifying the markings they would like from a broader choice.

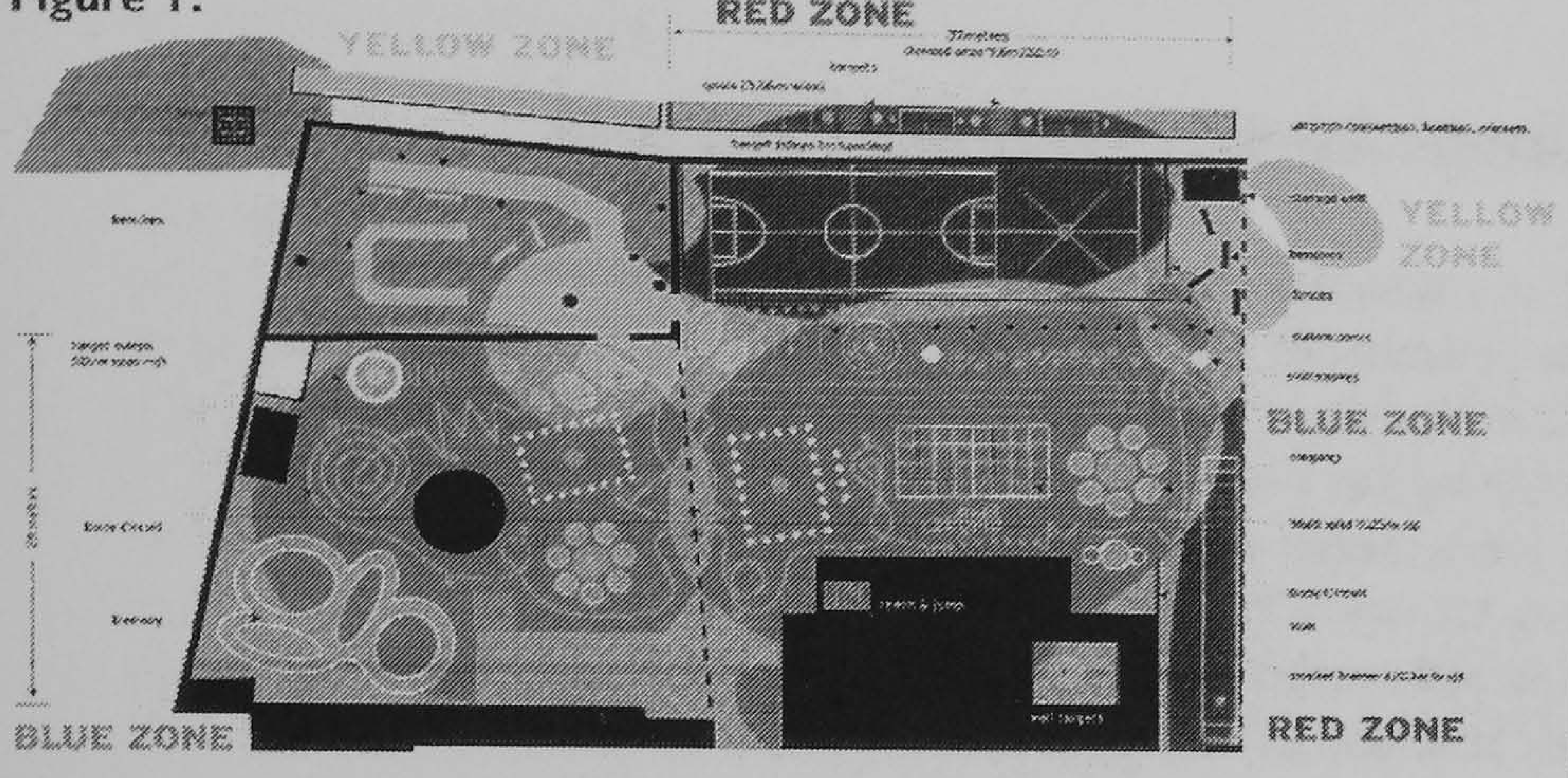
PROJECT OVERVIEW

The research programme is split into three phases and will be conducted over the two academic years. It should be noted here that the phases have been designed in such a way as to take into account seasonal effects and sustainability of the playground as a stimulus for behaviour change. These phases are:

- ***Phase 1:*** baseline measures obtained prior to playground redesign and painting
- ***Phase 2:*** 6-month follow-up – reassessment of schools following redesign of playground
- ***Phase 3:*** 16-18 month follow-up – reassessment of schools following redesign of playground.

The schools involved in the project are scheduled to undergo their playground redesigns in Autumn 2003, and the conclusion of the research in anticipated in July 2005. The advantage of this current research is that it offers the opportunity to determine the medium term effects of the playground markings and redesign on the children's behaviour. Previous research

Figure 1.



(Source: www.dfes.gov.uk/pess/content (accessed 15/09/2003)

into the effectiveness and sustainability of playground markings is lacking. Indeed, of the research conducted prior to this current project, the longest follow-up period following the intervention had been 6 weeks (Stratton and Leonard, 2002), although Health Promotion Wales used CCTV to estimate that activity was above baseline in a similar intervention 18 months after the playground was painted.

This project is intended to benefit the pupils and staff of the twenty schools, some of which are based in the most deprived areas of the city. Indicative of some of the problems faced by some pupils are highlighted by available statistics and the latest OFSTED reports, which indicate that the number of children having free school meals in the schools ranges from 31 – 80%. In reality, some schools fall within the boundaries of one ward on Liverpool, which has the 3rd highest rate of child poverty in the country. On top of this, available data suggests that educational attainment and school attendance are below the national average. Can changing the school outside environment have an effect on these worrying statistics? This project aims to address these issues in part.

CHARACTERISTICS OF PLAY

Research into children's physical activity has identified a number of characteristics which warrant attention. These characteristics are:

- Children's activity is often spontaneous and intermittent (Bailey et al., 1995)
- Children's physical activity is highly transitory, with them engaging in short, frequent bursts of energy (Welk, Corbin and Dale, 2000)
- Physical activity levels decrease across age, with girls activity declining at a greater rate than boys (Armstrong and Welsman, 1997)
- Children accumulate physical activity best in free unstructured play environments.

Therefore, environments which promote physical activity, whether it encourages spontaneous or somewhat sustained activity, may not only allow children to accumulate the necessary physical activity a day in order to gain health benefits, but may also develop positive attitudes to sport and physical activity in general. This latter point is particularly important when it is ascertained that children who have active childhoods are more likely to be physically active in adulthood. Despite these points, the potential of the playground as a promoter of physical activity in children, particularly in the long-term, remains largely untapped and underdeveloped. Of the research that has been conducted, the results indicate that:

- Most children engage in activity which is light in intensity during playtime
- Playground markings increased the amount of time children spent in MVPA (Stratton, 2000)
- Playground markings did increase the levels of vigorous physical activity (VPA) in children during playtime (Stratton, 2000)
- Energy expenditure during play increased following the redesign intervention (Stratton and Leonard, 2002)
- Boys are more active than girls during play, engaging in greater amounts of higher intensities, though data suggests girls energy expenditure increased similarly to that observed for boys during the intervention (Stratton and Leonard, 2002)
- Playground markings stimulate children to play in games of short duration and high intensity, ideally suiting their characteristics of play (Stratton, 2000).

It should be acknowledged that the main limitation of this body of research concerning playground markings is that it investigated the short-term impact on physical activity. Stratton and Mullan (2003) note that children's enthusiasm for playing on the markings may decrease over time, with the novelty of a new playground wearing off across time. Is this concern true, and how will it affect physical activity? This study will directly address this question.

CONCLUSION

The playtime during a school day offers an ideal opportunity for researchers to broaden their knowledge of promoting and encouraging children's physical activity. This current project is investigating a strategy which may, potentially, impact heavily on the way educators approach the promotion of healthy behaviours and sports activity to British school children. This approach could also improve children's self-esteem, motor skills and social skills through giving them a focus and providing a variety of new games to play in the playground. Improved behaviour may also be achieved, and children may be more attentive in classtime after experiencing an enjoyable playtime. A new playground may also promote a positive learning environment through offering different tasks and challenges to stimulate the children, and improve their willingness to learn during classtime. With these important areas in mind, this current project concerning playtime may be indicative of future approaches encouraging physical activity in children, increasing social and motor competencies, and developing positive school time behaviour. We welcome comments from the profession on the project.

REFERENCES

Armstrong, N. and Welsman, J. (1997). Young People and Physical Activity. Oxford, UK: Oxford University Press.

Bailey, R.C., Olson, J., Pepper, S.L., Porszasz, J., Barstow, T.J. and Copper, D.M. (1995). The level and tempo of children's physical activities: An observational study. Medicine and Science in Sport and Exercise, 27, 1031-1041.

Biddle, S.J.H., Sallis, J. and Cavil, N. (1998). Young and Active: Physical Activity Guidelines for Young People in the UK. London: Health Education Authority.

Blair, S.N. and Connelly, J.C. (1996). How much physical activity should we do? The case for moderate amounts and intensities of physical activity. Research Quarterly for Exercise and Sport, 67, 193-205.

Shephard, R.J. (1997). Curricular Physical Activity and Academic Performance. Pediatric Exercise Science, 9, 113-126.

Stratton, G. (2000). Promoting children's physical activity in primary school: An intervention study using playground markings. Ergonomics, 43, 1538-1546.

Stratton, G. (2002). The IMMPACT Projects. Promoting Health Related Physical Activity in Primary School Playgrounds. A Research Monograph.

Stratton, G. and Leonard, J. (2002). The metabolism of the elementary school playground: The effects of an intervention study on children's energy expenditure. Pediatric Exercise Science, 14, 170-180.

Stratton, G. and Mullan, E. (2003). The effect of multicolour playground markings on children's physical activity levels.

Welk, G.J., Corbin, C.B. and Dale, D. (2000). Measurement issues in the assessment of physical activity in children. Research Quarterly for Exercise and Sport, 71, 59-73.

Youth Sport Trust. (2002). Sporting Playgrounds – Zoneparc. Empress Nottingham Limited.

Pediatric Exercise Science, 2005, 17, 281-290

Physical Activity During School Recess: The Liverpool Sporting Playgrounds Project

Nicola D. Ridgers and Gareth Stratton

Recess offers primary school age children the opportunity to engage in physical activity, though few studies have detailed the physical activity levels of children in this environment. The physical activity levels of 270 children ages 6–11 years from 18 schools were monitored on 1 school day using heart rate telemetry. Data revealed that boys engaged in higher levels of moderate-to-vigorous and vigorous physical activity (MVPA) than did girls during recess (26 and 20 min, respectively). These results suggest that recess can make a worthwhile contribution to the recommended 60 min of MVPA per day.

The importance of a physically active lifestyle has been well documented (17). Studies that have investigated the relationships between physical activity (PA) and health, primarily in adult populations, indicate that higher levels of PA are associated with a reduced risk of coronary heart disease, osteoporosis, diabetes, stroke, some cancers, and obesity (11,18,24). Psychological benefits of a physically active lifestyle have also been documented, with PA being used as a treatment to improve psychological well-being (6). Although relationships between activity and health are not as clear in children (17), it is hypothesized that a physically active lifestyle in childhood will reduce the health risks associated with inactivity and will benefit health in adult life (3,9).

In order to enhance quality of life and promote health, guidelines suggest that children should engage in 60 min of daily moderate-to-vigorous physical activity (MVPA; 2). There is growing concern, however, that children do not engage in enough PA to promote health. A study by Riddoch et al. (19) found that children were active for less than 1 hr a day, and 14- to 16-year-old children were less active than their 11- to 13-year-old counterparts. More recently, Armstrong and Welsman (1) and Sleap and Warburton (26) reported that considerable numbers of young children did not participate in enough sustained activity to promote cardiorespiratory fitness (25). A study by Sleap and Tolfrey (25), however, which included light, moderate, and vigorous PA thresholds, found that children exceeded daily PA recommendations. The authors concluded that the thresholds used and the interpretations of research findings could influence the way in which children's PA levels are interpreted. Whereas methodological problems in PA research remain

---

Ridgers is with the REACH Group, School of Physical Education, Sport and Dance, Liverpool John Moores University, Barkhill Road, Liverpool, L17 6BD, UK. Stratton is with the REACH Group and the Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Henry Cotton Campus, 15–21 Webster Street, Liverpool, L3 2ET, UK.

unresolved, the majority of studies on PA in children have found that PA levels are low and need to be improved. Therefore, studies that aim to promote active lifestyles in children are needed (18).

PA is a multidimensional and complex behavior (18). A number of psychological, environmental, and social factors have been reported to influence PA behaviors in children; these include maturation, perceived barriers to activity, parental and peer behaviors, self-efficacy, and facilities available to the children (9). One recommended setting for PA promotion is the school (31). Because children spend a substantial proportion of their day at school, this context can play a critical role in the development of PA behaviors (9). Within the school environment, physical education classes and recess represent the two main opportunities for children to be active (21). With the time available for physical education decreasing as a result o increasing pressures on curricula time (23), however, school recess might prove to be the main opportunity for children to be physically active (30), particularly because the time spent in recess exceeds that spent in structured physical education classes (10). In the United Kingdom, children experience up to 600 recess periods a year (based on 3 times a day, 5 days per week, 39 weeks a year; 27). Recess could, therefore, contribute considerably to the accumulation of the recommended 60 min of MVPA a day (2). Although no PA recommendations have been developed for recess, it has been suggested that children should engage in MVPA for 50 % of the time available (29). This suggestion was extrapolated from physical education guidelines recommending that children should engage in MVPA for 50% of lesson time (31).

Although children best accumulate PA in free, unstructured environments (14), scant attention has been paid to school recess, which has been described as "probably the most enjoyable part" of the school day (5, p. 170). In studies that have focused on PA during recess, it is generally reported that boys are more active than girls (10,29,33). Unfortunately, these investigations have been on a small scale and involved low numbers of children in few schools; much larger studies that measure PA objectively are required.

The purpose of this study was to quantify the PA levels of children during school recess and to assess gender and age differences on the dependent variables. A secondary aim of this study was to determine the extent to which recess could contribute to PA recommendations and to ascertain whether the children met the proposed 50% MVPA threshold during school recess (29).

Method

Participants and Setting

One hundred and forty-nine boys and 147 girls randomly selected from 18 schools in the northwest of England provided informed signed parental consent to participate in the study. The mean age of the children was 8.0 years (± 1.5 years), with 75 classed as early primary children (38 boys, 37 girls, mean age = 6.2 ± 0.7 years) and 221 classed as late primary children (111 boys, 110 girls, mean age = 8.6 ± 1.1 years). The mean body mass index (BMI) for the whole group was 17.53 (± 2.84) kg/m^2.

All the children participating in the project followed their normal daily school routine. The recesses monitored were morning, lunch, and afternoon. The mean daily recess time available for the children to engage in PA on the playground was 84 (± 12.3) min. Recess time was measured from the time the school bell rang to start recess to the time it rang to conclude recess. The total time for morning, lunchtime, and afternoon recesses was 19 (± 4.5), 60 (± 7.7), and 15 (± 2) min, respectively. All the schools were located in the same geographical area, and none of the schools had new playground markings at the time of the current study. This study was carried out as part of the Liverpool Sporting Playgrounds Project (LSPP); the full details have been reported elsewhere (30).

Instrumentation

The Polar Team System (Polar Electro Oy, Kempele, Finland) heart rate monitor was used to measure the children's physiological response to recess. Heart rate was recorded every 5 s. The children's resting heart rate (RHR) was determined by averaging the 5 lowest recorded heart rate values during the period of data collection (8). This definition was used because it is the most common in the literature, and it takes into account the effect that age and fitness can have on children's RHR (12). Heart rate reserve (HRR) values of 50 (HRR_{50}) and 75 (HRR_{75}) per cent were used as threshold values to represent MVPA and VPA (vigorous physical activity), respectively. HRR_{50} equates to a brisk walk (1), and HRR_{75} equates to a measure of VPA because it is thought that this intensity increases cardiorespiratory fitness in children (15,28). Maximum heart rate was set at 200 bpm (28).

Heart rate telemetry has been validated for use with children (24) and it has good test–retest reliability when used in the playground context (32). Of the initial 296 children in the study, complete data sets for 135 boys (32 early primary and 103 late primary) and 135 girls (32 early primary and 103 late primary) were used in subsequent analyses. Twenty-six children's heart rate data were lost through electronic interference. HRR was subsequently used to calculate HRR_{50} (MVPA) and HRR_{75} (VPA) thresholds for each child. The percentage of absolute time per day each child spent at or above HRR_{50} and HRR_{75} was calculated and used in subsequent analyses.

Procedure

The heart rates of 18 children from each school were monitored on 1 school day between July and November 2003. Measurements of stature and body mass were recorded using the Seca scales (Seca Ltd, Birmingham, UK) and the Leicester Height Measure (Seca Ltd, Birmingham, UK) before fitting the monitors. Heart rate monitors were fitted to the children at the beginning of the school day. During this time children were instructed to seek the researchers for refitting if the monitors became detached. Children were then asked to follow their normal daily routine. Children wore the monitors during morning and lunch recess, and children from 10 schools wore the monitors during an afternoon recess. Monitors were removed at the end of the school day.

Data Analysis

Heart rate data were downloaded using the Polar Team System Interface and analyzed using the Polar Precision Performance™ 3.0 Software (Polar Electro Oy, Kempele, Finland). All data were analyzed using the Statistical Package for the

Social Sciences (SPSS®) version 11. The dependent variables were the percentage of time and absolute time (min) spent in MVPA and VPA during recess over the entire school day. The independent variables used to group the data were gender and age. Descriptive data for age, stature, body mass, Body Mass Index (BMI), RHR, HRR_{50}, HRR_{75}, and mean heart rates during each recess period for gender and age group were also determined. Independent t tests were used to examine gender and age group differences. Initial exploratory analyses were conducted on the data to establish whether any differences existed between the percentage MVPA and VPA accumulated across two (morning and lunch) or three (morning, lunchtime and afternoon) recess periods, as well as the time of data collection. The main analysis consisted of a 2 × 2 (gender × age group) analysis of covariance in order to analyze gender and age differences on the dependent variables (with play duration and BMI as the covariates). The alpha level was set at $p < .05$.

Results

Descriptives

The mean (± *SD*) values for the children's anthropometric and physiological characteristics are shown in Tables 1 and 2.

Exploratory Analyses

Recess Periods. One-way analyses of variances (ANOVAs) revealed no significant differences between the children's percentage of MVPA, $F_{(1, 268)} = 0.2$; $p > .05$, and VPA, $F_{(1, 268)} = 0.1$; $p > .05$, whether they engaged in two recess periods or three. The MVPA and VPA data from the differing number of recess periods were subsequently collapsed into total recess time, and number of recess periods was not used as a factor in the ensuing analyses.

Seasonal Differences. One-way ANOVA's revealed no significant differences between the children's total percentage MVPA, $F(1, 268) = 2.4$; $p > .05$, and

Table 1 Participants' Physiological Characteristics and Heart Rate Variables (Mean ± *SD*)

	Whole group	Boys	Girls	Early primary	Late primary
Age	8.0 ± 1.5	7.9 ± 1.5	8.0 ± 1.4	6.2 ± 0.7[a]	8.6 ± 1.1[a]
Body mass (kg)	30.9 ± 8.1	31.4 ± 7.9	30.5 ± 8.3	25.3 ± 5.3[a]	32.8 ± 8.1[a]
Stature (m)	1.32 ± 0.91	1.33 ± 0.09	1.31 ± 0.09	1.23 ± 0.07[a]	1.35 ± 0.08[a]
BMI (kgm^{-2})	17.5 ± 2.8	17.6 ± 2.8	17.4 ± 2.9	16.6 ± 2.5[a]	17.8 ± 2.9[a]

[a]Significant t test interage group results: early primary < late primary, $p < .01$.

Table 2 Participant's Heart Rate Variables (Mean ± *SD*)

	Whole group	Boys	Girls	Early primary	Late primary
RHR (bpm^{-1})	87 ± 10	86 ±10	88 ± 10	88 ± 8	87 ± 10
HRR_{50}	143 ± 6	143 ±6	144 ± 6	143 ± 7	143 ± 6
HRR_{75}	172 ± 3	171 ±3	172 ± 3	172 ± 3	172 ± 3
Morning recess HR	136 ± 19	140 ±18[a]	132 ± 19[a]	139 ± 22	135 ± 18
Lunch HR	129 ± 15	129 ±16	128 ± 14	128 ± 14	129 ± 15
Afternoon recess HR	127 ± 22	127 ±23	127 ± 22	125 ± 16	129 ± 26

Note: RHR = resting heart rate; HRR= heart rate reserve.
[a]Significant t test intergender results: boys < girls, $p < .01$.

VPA, $F(1, 268) = 1.1; p > .05$) across the period of testing. The MVPA and VPA data from the summer and the autumn term were subsequently collapsed into one testing period in the main analyses.

Main Analyses

MVPA. Boys and girls engaged in MVPA for 31 (± 17) and 24 (± 17) percent of recess time, respectively. ANCOVA revealed a significant main effect for gender, $F(1, 235) = 8.1; p < .01$, but not age ($p > .05$). The gender-by-age group-interaction effect was not significant, $F(1,235) = 1.2; p > .05$. The results indicate that boys engaged in almost 26 min of MVPA during school recess compared with 20 min for girls (see Figure 1).

VPA. Boys and girls engaged in VPA for 11 (± 11) and 8 (± 10) percent of recess time, respectively (Table 3). The ANCOVA revealed a significant main effect for gender, $F(1, 235) = 8.8; p < .01$, but no main effect for age on VPA was found. The gender-by-age group-interaction effect for VPA was not significant, $F(1, 235) = 2.1; p > .05$. The results indicate that boys engaged in 9 min of VPA during school recess compared with 7 min for girls; the absence of an interaction suggests that this difference was constant over time.

Discussion

This study investigated the PA levels of children during school recess. This has taken recent work by Stratton et al. (27,28) forward by using a larger sample of children and assessing PA against recently proposed guidelines (29). Data revealed that the boys engaged in significantly more MVPA and VPA than girls, which supports the results of previous studies (10,21,22,27,29,33). The results contrasted with the findings of Mota and Stratton (13) and Santos et al. (20), however, who

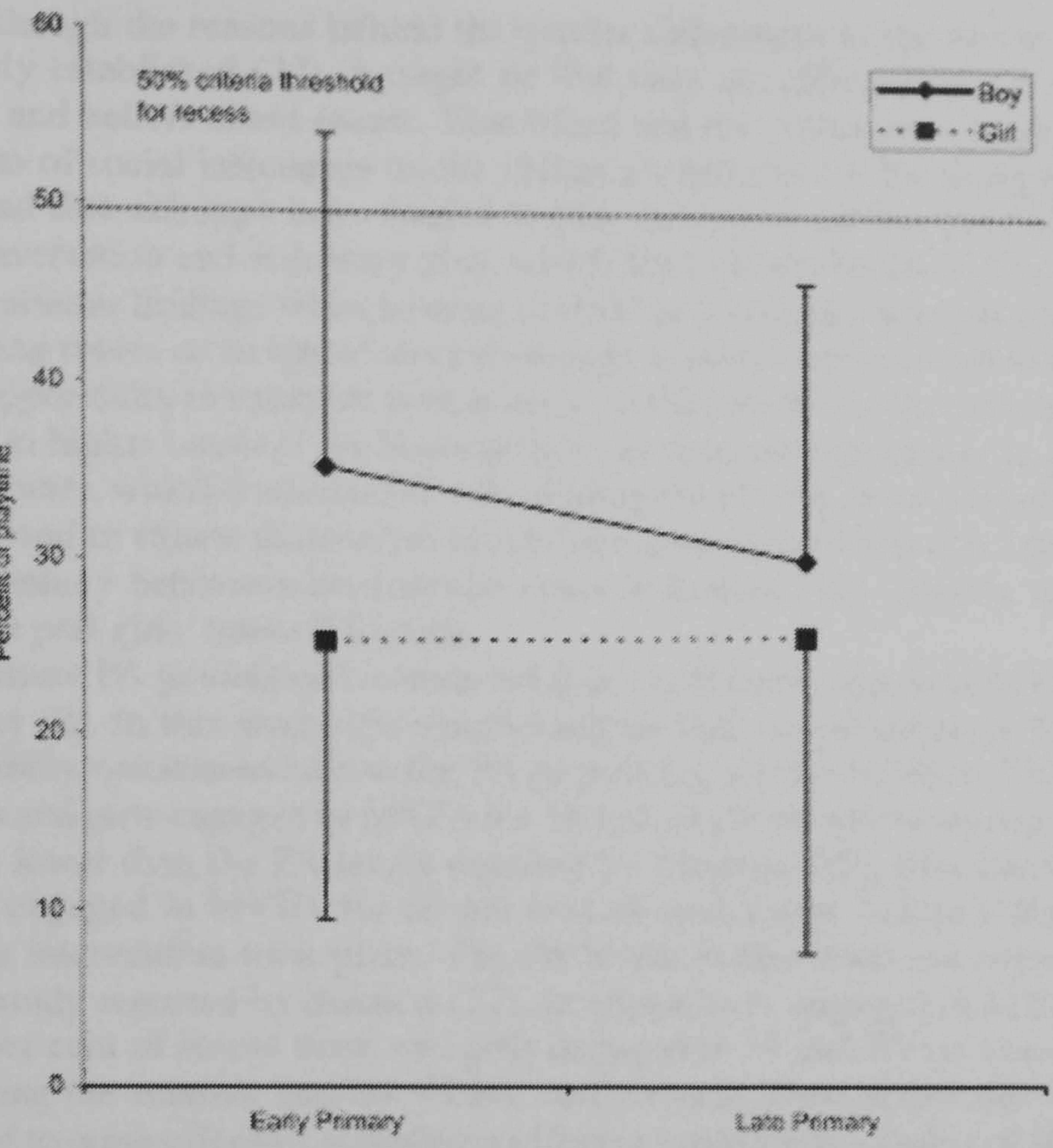


Figure 1 — Early and late primary boys and girls MVPA during school recess using raw scores (mean ±*SD*). The 50 per cent threshold value is marked on the graph (29). [a]Significant intergender difference: boys > girls, $p < .01$.

Table 3 Percentage of Time Spent in MVPA and VPA During Recess (raw scores: Mean ± *SD*)

	Whole group	Boys	Girls	Early primary	Late primary
MVPA	28 ± 17	31 ± 17[a]	24 ± 17[a]	30 ± 26	27 ± 17
VPA	9 ± 9	11 ± 10[a]	8 ± 8[a]	15 ± 19	9 ± 8

[a]Significant intergender difference, boys > girls, $p < .01$.

found that girls engaged in significantly more MVPA during recess. The latter studies were conducted with Portuguese children, suggesting that cultural reasons might underlie this finding, although this possibility was not reported by these studies.

Although the reasons behind the gender differences in the levels of PA are not widely established (22), it might be that they are affected by the children's attitudes and beliefs about recess. Blatchford and his colleagues (4) investigated the effects of social influences on the children's behavior in the playground, and they found that although boys tended to play more ball games, girls engaged in more conversation and sedentary play, which led to lower levels of PA. Evans (7) reported similar findings when looking at children's attitudes towards recess, with boys seeing recess as an opportunity to engage in active games, whereas girls saw it as an opportunity to socialize with friends. In the present study, boys might have engaged in higher levels of PA because they saw it as an opportunity to play competitive games, which dominate the school playground (16). In such circumstances, the girls tend to situate themselves around the perimeter of this area, engaging in more sedentary behaviors because the space is limited (16). This, in turn, could explain in part girls' lower PA levels.

Current PA guidelines recommend that all children engage in MVPA for 60 min a day (2). In this study, the results indicate that recess accounts for about a third of daily recommendations for PA in primary school children. The findings that boys and girls engaged in MVPA for 31 and 24 per cent of recess time, respectively, is lower than the PA levels reported by Stratton (28), who found that the children engaged in MVPA for 35 per cent of recess time before a playground-markings intervention took place. The PA levels in this study are higher than in another study reported by Stratton (27), in which boys engaged in MVPA for 15 and 29 per cent of recess time, and girls engaged in 15 and 23 per cent of recess time during the summer and the winter, respectively. These differences might be attributed to more effective sampling and larger sample sizes in this study. Results from this investigation also contrast with the findings of Santos et al. (20), in which girls were found to engage in MVPA for 38 % of recess time compared with 31% in boys. Although the results reported vary across the studies, no studies met the recommendation of spending 50% of recess time in MVPA as proposed by Stratton and Mullan (29).

In this investigation boys engaged in 26 min of MVPA during recess time, just 4 min short of the minimum PA recommendation of 30 min of MVPA a day for children (2). The girls were two-thirds (20 min) of the way toward meeting this minimum recommendation. In the study, a total of 56 boys (20.7%) and 37 girls (13.7%) engaged in 30 min or more of MVPA during recess. This suggests that recess represents a significant context for PA promotion in some children. Methods for promoting PA behaviors during recess should be paramount, particularly in the light of growing concerns that the numbers of overweight and obese children are increasing across Europe (11).

There are no published targets for PA during recess. Data from this study, however, suggests that a threshold of 40% of PA during recess might be a more achievable health-promotion target for schools because it corresponds to just over 30 min of MVPA per day. In the present study, 43 boys (15.9%) and 30 girls (11.1%) engaged in MVPA for over 40% of the playtime available. Some primary-age schoolchildren might therefore meet the minimum daily recommendation through recess alone, potentially benefiting health both in childhood and in later life. Future studies are needed, however, to determine first, whether this threshold is a suitable marker for children's activity within the playground context and second, whether it represents a useful approach for achieving minimum daily PA recommendations in a school context.

Whereas the current study attempted to investigate the PA levels of primary school children, the use of heart rate telemetry to quantify PA has a number of limitations. The recorded heart rate can be affected by factors including emotional state, level of fitness, and the type of muscle contractions used (19,27). The recording interval used can also present a problem, with longer recording intervals being less sensitive to children's intermittent PA patterns compared with shorter intervals, though this study attempted to counter this by monitoring heart rate every 5 s. Heart rate monitoring is also a reactive method because the children know that they are being monitored and might alter their playground behavior accordingly (19). Nevertheless, heart rate is a widely used method for the assessment of PA, and it is valid and socially acceptable to use with pediatric populations. Furthermore heart rate monitoring enables the assessment of the frequency, intensity, and duration of activity in a nonrestrictive manner.

A further limitation to this study was that children's PA was monitored on 1 school day. Though there are no reported data on children's day-to-day variation in PA during recess, this study attempted to overcome this limitation by using a relatively large sample size. Studies that have investigated children's daily habitual activity using heart rate have monitored children for 4 consecutive days (25) to gather data that was representative of daily PA. Because playgrounds represent a more stable context in the school day of a child, further investigation is needed to determine the stability and pattern of PA behavior in this setting.

Conclusion.

The aims of this study were to determine the PA levels of girls and boys during recess and to analyze data by gender and age. A further aim was to establish the extent to which school recess contributed to daily PA accumulation. The results of the study indicated that boy's PA was higher than girls', and that larger numbers of boys than girls met the proposed marker of 40% of playtime spent in MVPA. Because recess offers children their main opportunity to be physically active during the school day (21), schools can play a significant role in promoting the activity levels of children by adopting measures to achieve this threshold. Educators and health promoters need to identify strategies that focus on the promotion of PA through recess, so that the short-term and longer-term effects on the children's PA patterns can be identified.

Acknowledgments

We would like to thank Sport England and the Liverpool Department for Lifelong Learning for funding the project, as well as Gary White of Liverpool Sport Action Zone. We would also like to thank John Curley, Adam Hale, and Ruth McLoughlin for their assistance in the collection of data.

References

1. Armstrong, N., and J. Welsman. *Young People and Physical Activity.* Oxford, UK: Oxford University Press, 1997.

2. Biddle, S.J.H., J. Sallis, and N. Cavill (Eds.). *Young and Active: Physical Activity Guidelines for Young People in the UK.* London: Health Education Authority, 1998.
3. Blair, S.N., and J.C. Connelly. How much physical activity should we do? The case for moderate amounts and intensities of physical activity. *Res. Q. Exerc. Sport.* 67:193-205, 1996.
4. Blatchford, P., E. Baines, and A.D. Pellegrini. The social context of school playground games: sex and ethnic difference, and changes over time after entry to junior school. *Brit. J. Dev. Psycho.* 21:481-505, 2003.
5. Blatchford, P., R. Creeser, and A. Mooney. Playground games and playtime: the children's view. *Educ. Res.* 32:163-174, 1990.
6. Calfas, K.J., and W.C. Taylor. Effects of physical activity on psychological variables in adolescents. *Pediatr. Exerc. Sci.* 6:406-423, 1994.
7. Evans, J. Children's attitudes to recess and changes taking place in Australian primary schools. *Res. Educ.* 56:49-61, 1996.
8. Janz, K.F. Use of heart rate monitors to assess physical activity. In: *Physical Activity Assessments for Health-Related Research,* G.J. Welk (Ed.). Champaign, IL: Human Kinetics, 2002, pp. 143-161.
9. Kohl, H.W., and K.E. Hobbs. Development of physical activity behaviours among children and adolescents. *Pediatrics.* 101:549-554, 1998.
10. Kraft, R.E. Children at play: behaviour of children at recess. *JOPERD* 60:21-24, 1989.
11. Livingstone, M.B.E. Childhood obesity in Europe: a growing concern. *Pub. Health Nutr.* 4:109-116, 2001.
12. Logan, N., J.J. Reilly, S. Grant, and J.Y. Paton. Resting heart rate definition and its effect on apparent levels of physical activity in young children. *Med. Sci. Sports Exerc.* 32:162-166, 2000.
13. Mota, J., and G. Stratton. Gender differences in physical activity during recess in Portuguese primary schools. *Revista Portuguesa Ciências do Desporto.* 3:S150, 2003.
14. Pate, R.R., T. Baranowski, M. Dowda, and S.G. Trost. Tracking of physical activity in young children. *Med. Sci. Sport Exerc.* 28:92-96, 1996.
15. Payne, V.G., and J.R. Morrow. Exercise and VO_2 max in children: a meta-analysis. *Res. Q. Exerc. Sport.* 64:305-313, 1993
16. Renold, E. "All they've got in their brains is football." Sport, masculinity and the gendered practices of playground relations. *Sport Educ. Soc.* 2:5-23, 1997.
17. Riddoch, C.J. Relationship between physical activity ands physical health in young people. In *Young and Active? Young People and Health-Enhancing Physical Activity—Evidence and Implications,* S.J. Biddle, J. Sallis and N. Cavill (Eds.). Champaign, IL: Human Kinetics, 1998, pp.17-48.
18. Riddoch, C.J., and C. Boreham. Physical activity, physical fitness and children's health: current concepts. In: *Pediatric Exercise Science and Medicine,* N. Armstrong and W. van Mechelen (Eds.). Oxford University Press, 2000, pp. 243-252.
19. Riddoch, C.J, C. Mahoney, N. Murphy, C. Boreham, and G. Cran. The physical activity patterns of Northern Irish schoolchildren ages 11–16 years. *Pediatr. Exerc. Sci.* 3:300-309, 1991.
20. Santos, P., P. Silva, S. Guerra, J.C. Riberio, J. Oliveira, J.A.R. Duarte, and J. Mota. Gender differences in physical activity during recess time. *Revista Portuguesa Ciências do Desporto.* 3:S150-151, 2003.
21. Sarkin, J.A., T.L. McKenzie, and J.F. Sallis. Gender differences in physical activity during fifth-grade physical education and recess periods. *J. Teach. Phys. Educ.* 17:99-106, 1997.

22. Scruggs, P.W., S.K. Beveridge, and D.L. Watson. Increasing children's school time physical activity using structured fitness breaks. *Pediatr. Exerc. Sci.* 15:156-169, 2003.
23. Shephard, R.J. Curricular physical activity and academic performance. *Pediatr. Exerc. Sci.* 9:113-126, 1997.
24. Sirard, J.R., and R.R. Pate. Physical activity assessment in children and adolescents. *Sports Med.* 31:439-454, 2001.
25. Sleap, M., and K. Tolfrey. Do 9 to 12 year old children meet existing physical activity recommendations for health? *Med. Sci. Exerc. Sport.* 33:591-596, 2001.
26. Sleap, M., and P. Warburton. Physical activity levels of 5-11 year-old children in England: cumulative evidence from three direct observation studies. *Int. J. Sport Med* 17:248-253, 1996.
27. Stratton, G. A preliminary study of children's physical activity in one urban primary school playground: differences by sex and season. *J. Sport Pediatr.* 2:71-81, 1999.
28. Stratton, G. Promoting children's physical activity in primary school: an intervention study using playground markings. *Ergonomics.* 43:1538-1546, 2000.
29. Stratton, G., and E. Mullan. The effect of playground markings on children's physical activity level. *Revista Portuguesa Ciências do Desporto.* 3:S137, 2003.
30. Stratton, G., and N.D. Ridgers. Sporting Playgrounds Project—an overview. *Brit. J. Teach. Phys. Educ.* 24:23-25, 2003.
31. United States Department of Health and Human Services. *Healthy People 2010: Understanding and Improving Health.* Washington: DHHS, 2000.
32. Whitehurst, M., D.R. Groo, and L.E. Brown. Prepubescent heart rate response to indoor play. *Pediatr. Exerc. Sci.* 8:245-250, 1996.
33. Zask, A., E. van Beurden, L. Barnett, L.O. Brooks, and U.C. Dietrich. Active school playgrounds—myth or reality? Results of the "Move It Groove It" project. *Prevent. Med.* 33:402-408, 2001.

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

ELSEVIER

Preventive Medicine 41 (2005) 102–107

Preventive Medicine

www.elsevier.com/locate/ypmed

Assessing physical activity during recess using accelerometry

Nicola D. Ridgers, M.Sc.[a,b,*], Gareth Stratton, Ph.D.[a,b], Stuart J. Fairclough, M.Sc.[b,c]

[a] School of Sport and Exercise Sciences, Liverpool John Moores University, Henry Cotton Campus, 15-21 Webster Street, Liverpool, L3 2ET, UK
[b] The REACH (Research into Exercise, Activity and Children's Health) Group, Liverpool John Moores University, IM Marsh Campus, Liverpool, L17 6BD, UK
[c] School of Physical Education, Sport and Dance, Liverpool John Moores University, IM Marsh Campus, Barkhill Road, Liverpool, L17 6BD, UK

Available online 18 December 2004

Abstract

Background. Physical activity guidelines recommend children should engage in 60 min of moderate-to-vigorous physical activity (MVPA) a day. School recess presents an opportunity for children to be physically active during the school day. Limited research has investigated children's activity levels during recess and its contribution to physical activity recommendations. Moreover, no target for physical activity during recess has been set.

Methods. One hundred sixteen boys and 112 girls (aged 5–10 years) from 23 schools had their physical activity during recess quantified using a uniaxial accelerometer during three recess breaks on one school day. The percentage of time spent engaged in moderate, high, and very high intensity activity was calculated using existing thresholds.

Results. Boys engaged in more moderate, high, and very high intensity activity than girls. On average, boys and girls spent 32.9% and 23% of recess engaged in physical activity, respectively.

Conclusions. Boys engaged in higher intensity activities than girls. The results suggest that recess can contribute 28 min for boys and 21.5 min for girls toward the accumulation of recommended daily physical activity. However, the physical activity intensities that children engaged in were low during recess. On average, children in this study did not achieve 50% of recess time in physical activity. Interventions for increasing the physical activity of children in the playground are warranted.

Keywords: Schools; Children; Recess; Physical activity; Accelerometry

Introduction

Physical activity is an integral component of a healthy lifestyle. Sedentary behaviors increase the risk of developing obesity, coronary heart disease, diabetes, and osteoporosis [1,2]. The importance of promoting physical activity in childhood has received widespread attention on the basis that physical activity behavior tracks from childhood into adulthood [3]. While limited research currently supports this notion [4], it seems logical that providing opportunities for physical activity in childhood could increase the likelihood of being physically active in adulthood.

Current physical activity guidelines suggest that children should engage in 60 min of moderate-to-vigorous physical activity (MVPA) each day [5]. However, studies have indicated that English children do not engage in enough physical activity in order to gain health benefits, and the activity recorded did not meet the activity guidelines [6,7]. In light of this, the value of the school for developing physical activity behaviors has been identified [8–10]. In the school context, physical education and recess provide the two main opportunities for children to be active [9]. Recess generally occurs in the mornings, at lunchtimes, and often in the afternoons, and accounts for nearly a quarter of the average primary school day [11]. Therefore, recess presents an ideal opportunity to encourage children's physical activity behaviors and contributes to physical activity recommendations [12].

Presently in the school environment, physical activity guidelines exist for physical education but not for recess. In order for physical education to meaningfully contribute toward the accumulation of physical activity, it has been

* Corresponding author. Fax: +44 151 231 5357.
E-mail address: n.ridgers@livjm.ac.uk (N.D. Ridgers).

0091-7435/$ - see front matter © 2004 Elsevier Inc. All rights reserved.
doi:10.1016/j.ypmed.2004.10.023

recommended that children are active for at least 50% of class time [13]. A second recommendation stated that schools should provide daily physical education lessons for children of all ages [13]. However, evidence suggests that children do not meet the 50% guideline during the majority of physical education classes [14]. Furthermore, the time allocated to physical education is being reduced in primary schools in the UK [15]. The advantage that recess has over physical education is that it provides daily opportunities for physical activity participation. Thus, Stratton and Mullan [16] extrapolated the USDHHS [13] physical education criterion to recess, suggesting that children should be physically active for 50% of recess time. However, empirical testing of this threshold is required to ascertain whether it is a suitable target for children to achieve during recess periods.

In order to quantify children's physical activity, valid and reliable measures are needed [17]. While there is no gold standard method of measuring physical activity, accelerometry has been validated for use with pediatric populations [18]. Accelerometers are unobtrusive, nonreactive devices for assessing the duration and pattern of physical activity at different intensities and intensities [17–19]. On the other hand, uniaxial accelerometers fail to detect activity during cycling or change in acceleration while walking up or down a gradient. Triaxial accelerometers are thought to be better suited for measuring children's physical activity, as they may be more sensitive to children's activities such as climbing [20–22]. On the other hand, since recordings from the tri- and uniaxial accelerometers were highly correlated [22], it is likely that the uniaxial accelerometer accurately reflects the frequency, duration, and intensity of children's physical activity.

Rowlands [23] stated that in order to measure physical activity of children the method used must be sensitive enough to monitor their highly transitory and spontaneous movements that characterize children's play behavior [24]. Accelerometers record activity over different time lengths or epochs in order to depict physical activity. Nilsson et al. [25] noted that short bursts of activity are accurately recorded if the time intervals used are shorter than 60 s. By recording children's movement over 5 s epochs, a detailed picture of their activity levels can be established.

The purpose of this study was 2-fold: (a) to compare the physical activity of boys and girls during recess, and (b) to establish whether the target of 50% of recess engaged in at least moderate activity is an appropriate health promotion criterion for schools to adopt.

Methods

Participants and setting

One hundred sixteen boys and 112 girls randomly selected from 23 schools in the North West of England returned signed parental informed consent to participate in the study. The mean age of the children was 8.1 ± 1.4 years, with 56 classed as early primary children (32 boys, 24 girls, mean age = 6.3 ± 0.6 years) and 151 classed as late primary (76 boys, 75 girls, mean age = 8.7 ± 1.1 years). The mean body mass index (BMI) for the whole group was 17.7 ± 2.9 kg m^{-2}. The mean BMI for boys was 17.7 ± 2.8 kgm^{-2}, and for girls it was 17.8 ± 3.1 kg m^{-2}.

All children participating in the study followed their normal daily school routine. Physical activity was monitored during morning, lunch, and afternoon recess on the same day. The mean daily recess time available for the children to engage in physical activity in the playground was 85 (±16.5) min. All schools were located in the same geographical urban area of Northwest England. This study was conducted as part of the Liverpool Sporting Playgrounds Project (LSPP), the outline having been detailed elsewhere [12]. These schools will receive new multicolor playground markings and physical structures as part of the LSPP. During this study, there were no new markings to stimulate physical activity in the playgrounds. The research protocol received ethical approval from the University Ethics Committee.

Instrumentation

The ActiGraph (Model 7164, MTI Health Services, FL, USA) is a uniaxial accelerometer that measures vertical acceleration of human motion. The detected accelerations are filtered, converted to a numerical value, and subsequently summed over a specified time interval or epoch set prior to the commencement of data collection [26]. The recorded counts for each epoch represent the intensity of the activity undertaken during that time period. At the end of each epoch, the summed value is stored in the memory and the ActiGraph is automatically reset to zero [26]. The epoch time length for the current study was set at 5 s as recommended by Nilsson et al. [25].

Activity count thresholds were used to determine the amount of time the children engaged in physical activity at moderate, high, and very high intensities [25]. These were represented by 163–479, 480–789, and ≥790 counts per 5 s epoch, respectively [25]. Total absolute (min) and relative (percentage) time spent within each activity threshold during recess were calculated and used in the subsequent analyses. Complete data sets for 207 children (108 boys, 99 girls) were obtained for further analysis. Accelerometer data for 21 children (8 boys, 13 girls) were lost through electronic interference and monitor malfunction.

Procedure

Ten children per school were monitored on one school day between July 2003 and March 2004. Measurements of body mass (to the nearest 0.1 kg) and stature (to the nearest 0.1 cm) were recorded using Seca scales (Seca Ltd., Birmingham, UK) and the Leicester Height Measure (Seca

Table 1
Children's physiological characteristics (mean ± SD)

	Age (years)	Body mass (kg)	Stature (m)	Body mass index (kg m^{-2})
Whole group	8.0 ± 1.4	31.3 ± 8.5	1.32 ± 0.09	17.7 ± 2.9
Boys	7.9 ± 1.4	31.2 ± 7.7	1.32 ± 0.09	17.7 ± 2.8
Girls	8.2 ± 1.5	31.4 ± 9.4	1.31 ± 0.10	17.8 ± 3.1
Early primary	6.3 ± 0.6	24.9 ± 5.2	1.23 ± 0.07	16.5 ± 2.4
Late primary	8.7 ± 1.1	33.8 ± 8.3	1.36 ± 0.08	18.2 ± 2.9

Ltd.) prior to attaching the monitors. At the start of the school day, the accelerometers were attached to the children on the right side of the hip using a tightly fitted elastic belt. This followed a familiarization period where the children became acquainted with the units. Children were then asked to follow their normal daily routine. All children wore the monitors during morning and lunch recess, and children from 14 schools wore the monitors during an afternoon recess. Accelerometers were removed at the end of the school day, and the data were immediately downloaded.

Data analysis

Accelerometer data were downloaded using a reader interface unit connected to a computer and analyzed using the ActiSoft Analysis Software Version 3.2 (MTI Health Services). Data were analyzed using the Statistical Package for the Social Science version 11 (SPPS Inc., Chicago, IL, USA). The dependent variables were the percentage of time spent at each physical activity intensity level and the time spent engaged in physical activity across recess. The independent variables were gender and age group. Means and SD were calculated to describe the characteristics of the children. The main analysis consisted of a 2 × 2 (sex × age group) analysis of covariance (ANCOVA) to establish any gender and age differences on the dependent variables. Play duration and BMI were used as the covariates. All assumptions for using the ANCOVA to analyze the data were satisfied. The alpha level was set at $P < 0.05$.

Results

The mean (±SD) values for the children's physiological characteristics are shown in Table 1.

Moderate intensity physical activity

ANCOVA revealed a significant main effect for sex ($F(1,202) = 17.45$, $P = 0.001$), as boys engaged in significantly more moderate intensity physical activities as a proportion of recess than girls (Fig. 1). No main effect for age group was found. The sex × age group interaction was not significant ($P > 0.05$).

High intensity physical activity

The main effect for sex approached significance ($F(1,202) = 2.746$, $P = 0.1$), as boys engaged in more high intensity physical activities as a proportion of recess than girls (Fig. 1). Neither main effects for age or the sex × age group interaction were significant ($P > 0.05$).

Very high intensity physical activity

ANCOVA revealed a significant main effect for sex ($F(1,202) = 4.080$, $P = 0.03$), with the boys engaging in significantly more very high intensity physical activity during recess than girls (Fig. 1). No main effect for age group was found. The sex × age group interaction was not significant ($P > 0.05$).

Physical activity during recess

The mean time the children spent in each physical activity intensity level across recess is presented in Table 2. Boys engaged in 28 min of physical activity during recess compared to 21.5 min for girls. This equated to 32.9% and 25.3% of recess, respectively, spent at physical activity levels of a moderate intensity or higher (Fig. 2).

Discussion

The purpose of this study was to examine the physical activity levels of boys and girls during recess and to establish whether 50% of recess time in at least moderate activity was an appropriate health promotion target for schools [9,24]. The results suggest that most children engaged in at least moderate intensity physical activity. Light intensity activity was most prevalent in the playground as it accounted for the largest proportion of recess activity. Gender differences were found in moderate and very high intensity activity, where boys

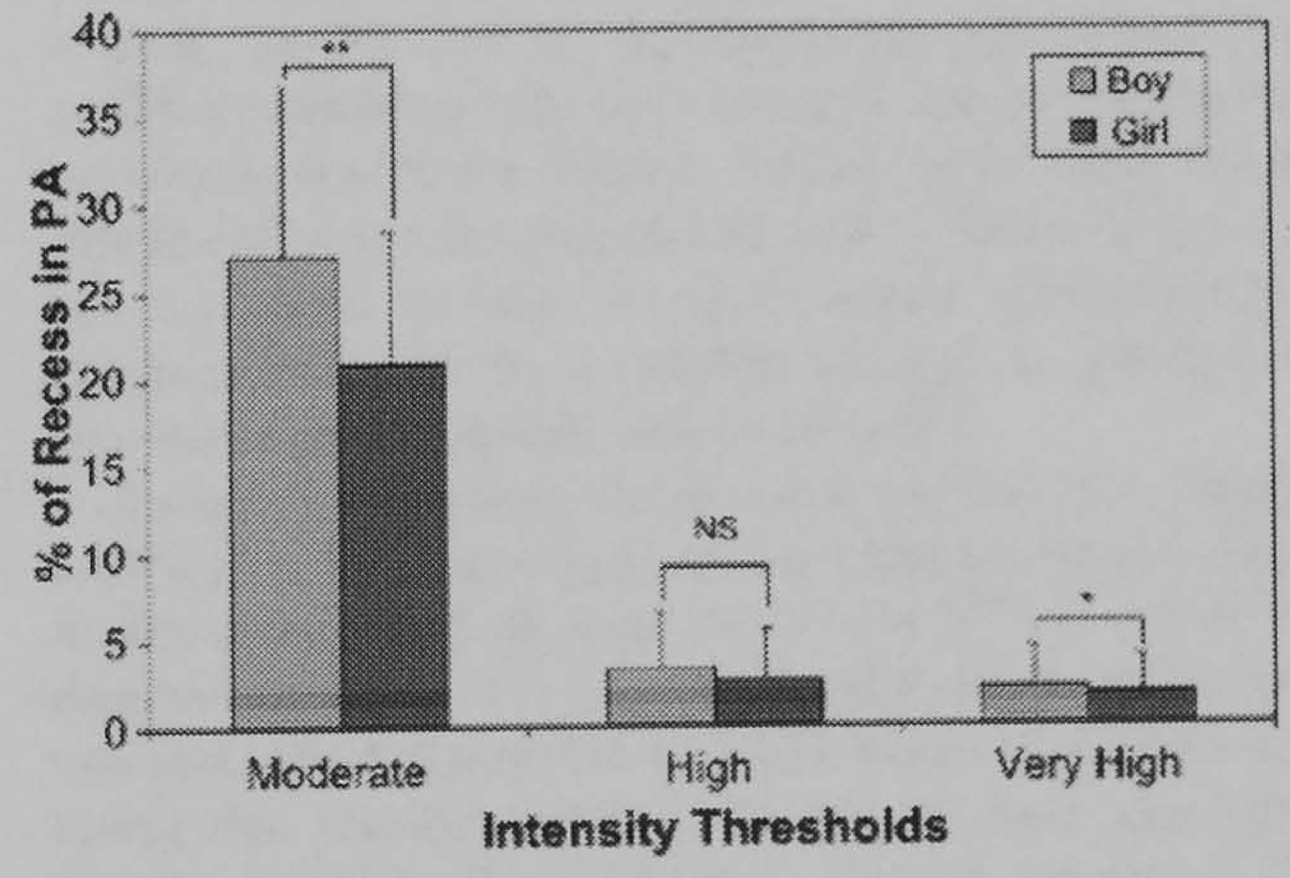


Fig. 1. Physical activity of boys and girls at each intensity level during recess (mean ± SD) *$P < 0.05$, **$P < 0.01$.

Table 2
Time spent at each intensity level (mean ± SD)

	Recess available			
	Whole recess	Moderate	High	Very high
Whole group (min: s)	24:53 ± 10:55	20:44 ± 8:32	2:39 ± 2:42	1:30 ± 1:42
Boys (min: s)	28:13 ± 11:46	23:25 ± 9:23	2:58 ± 2:43	1:49 ± 1:47
Girls (min: s)	21:22 ± 8:41	17:53 ± 6:27	2:19 ± 2:40	1:10 ± 1:34
Early primary (min: s)	26:29 ± 11:25	22:27 ± 9:13	2:38 ± 2:27	1:24 ± 1:22
Late primary (min: s)	24:17 ± 10:42	20:05 ± 8:12	2:40 ± 2:48	1:32 ± 1:49

engaged in significantly more physical activity than girls. These findings are consistent with previous studies [9,10,27].

While the reasons underlying gender differences in physical activity levels are not widely known [27], they may be partly attributable to the social context of playgrounds. Blatchford et al. [28] investigated the nature of the games played in primary schools and the frequency of involvement by boys and girls during activities. The results indicated that boys were more likely to be involved in ball games, while girls were more likely to engage in sedentary play, conversation, and skipping [28]. Ball activities require more intense movement, which could account for the higher physical activity levels in boys compared to girls. Conversely, the girls' activities involved less frequent or intense movement resulting in lower physical activity levels during recess.

Consistent with other work [16], no differences in physical activity were found between the early primary and late primary children. This result suggests that the physical activity levels of children during primary school are relatively similar across time and that they do not decrease as a result of their stage of schooling. While the underlying reasons for this finding are not widely known, it is possible that the schools afford the same opportunities for early primary children as their older counterparts to be active during school recess. However, it is a concern that early primary girls maintain similar activity levels as the late primary girls, as their activity levels are lower than the boys at both stages for schooling. In light of these initial findings,

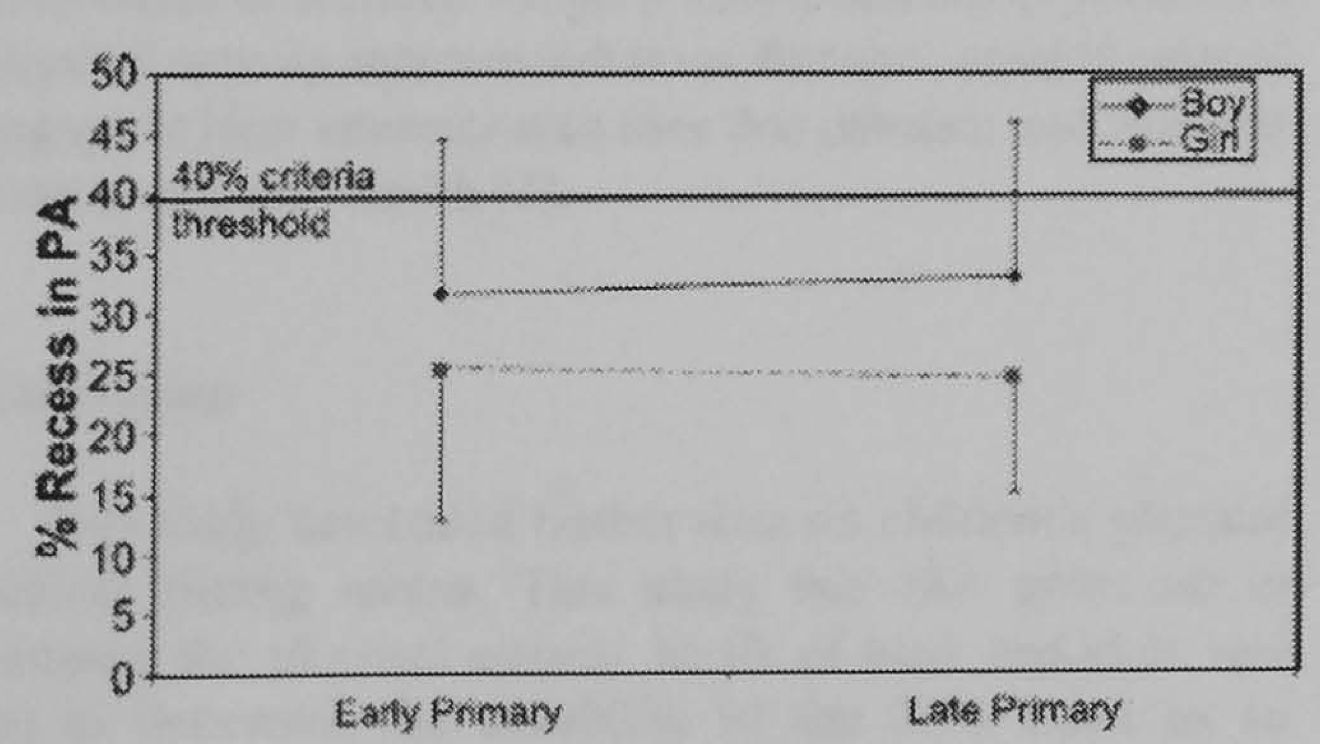


Fig. 2. Early and late primary boys' and girls' activity as a proportion of recess (mean ± SD). The 40% threshold value, an alternative threshold suggested in light of the results, is marked on the graph.

encouraging girls to be active during early primary may motivate them to engage in higher activity levels in the late primary phase of schooling.

The data suggested that the physical activity levels of children were low compared to previous studies that have investigated recess physical activity prior to intervention in the same geographical area [29]. However, it was encouraging that children accumulated one-third of their daily, recommended level of physical activity during recess. Forty boys (19.3%) and 15 girls (7.2%) accumulated 30 min of moderate to very hard intensity physical activity through recess, meeting the minimum recommendation for daily physical activity [5]. While children should optimally engage in 60 min of at least moderate intensity activity [5], two boys but no girls accumulated 60 min of moderate to very hard physical activity during the total school recess time available.

These data indicate that recess provided a salient opportunity for children to take part in physical activity of different intensities and provided them with a context to achieve minimum daily physical activity guidelines. More boys than girls met the minimum daily physical activity guidelines of 30 min of at least moderate intensity activity, suggesting that recess may need to be restructured so that boys and girls receive equal opportunities to be physically active. This supports the recommendations proposed by Sarkin et al. [9]. Another study aimed to increase physical activity during recess by painting playgrounds with multicolor markings [30], and although the study was limited by a small sample size, in the short-term playgrounds with markings increased both boys and girls energy expenditure. In schools that had markings, children were more equally distributed across the playground, and as the markings were not designated as boys' or girls' games, painting school playgrounds could be a suitable strategy to increase the activity levels of primary school children.

Using PE guidelines for physical activity [13], Stratton and Mullan [16] hypothesized that children should engage in moderate to hard physical activity for 50% of recess. The data indicated that 12 boys (5.8%) and 1 girl (0.5%) met this criterion, which equated to 42.5 min across total recess time. Using this recommendation, the results from our investigation highlight that children's physical activity during recess is low, particularly in girls. This is similar to the findings of other studies, where children have been found to engage in activities of at least a moderate intensity for 35% [29] and 37% [16] of recess. Since so few children met the 50% threshold in this study and other studies that have been conducted during recess, it suggests that unlike physical education, it may be an unrealistic target for children to meet during school recess.

In light of this, an alternative suggestion based on minimum activity recommendations [5] is proposed. A threshold value of 40% may be more achievable during total school recess, since this value equated to an average of 34 min of available recess time for activity. Thirty-one boys (14.9%) and nine girls (4.3%) in this study met the 40% value. While girls' activity is still worryingly low, helping children to work toward this value using appropriate stimuli may be the way forward. Furthermore, recent research found that children who were active during the school day engaged in more activity outside school hours compared to those whose school activity was restricted [31]. It is worth noting that Dale et al. [31] found that when minimal physical activity opportunities were provided during school time children did not compensate by increasing their physical activity out of school. This illustrates the importance of recess in the provision of activity opportunities during the school day. Moreover, encouraging play during recess could be critical in children's accumulation of activity beyond the school environment, particularly as children spend one-fifth of their school life in the recess context [32].

Children's physical activity is characteristically spontaneous, intermittent, and highly transitory [24]. Across the whole of recess, high and very high intensity activity together accounted for 4 min of the children's recess time while moderate intensity activity accounted for 21 min of recess. This supports the work by Bailey et al. [24] who found that short intense bursts of activity were combined with variable intervals of moderate and light intensity activity. Nilsson et al. [25] suggested that shorter-time periods more accurately reflect the nature of children's physical activity, highlighting that in order to capture the typical characteristics of children's play, shorter recording periods should be utilized. This also allows the detailed assessment of children's high intensity activity in relation to physical activity recommendations that state children should engage in high intensity activities that enhance and maintain musculoskeletal health [5].

Conclusion

This study has added further data on children's physical activity during recess. This study had two aims: (a) to compare the physical activity levels of boys and girls, and (b) to determine the suitability of the 50% value as an appropriate physical activity target for school recess. Girls' lower physical activity levels suggest that strategic interventions are needed in order to provide equal opportunities for boys and girls to be physically active during the school day. These interventions could include playground markings and the use of equipment to stimulate activity. The data indicated that the 40% threshold for recess represents a realistic health-promoting target for schools to ensure that they offer children the opportunity to accumulate the minimum requirement of daily physical activity during school recess. Thus, it is important that health promoters and schools use recess time to encourage physical activity.

Acknowledgments

This project was funded by the Liverpool City Council Department for Life-Long Learning and Sport England. We would like to thank Gary White of Liverpool Sport Action Zone, John Curley, Adam Hale, Ruth McLoughlin, and Tom Langford for assistance in data collection, and all the children who participated in the study.

References

[1] Blair SN, Connelly JC. How much physical activity should we do? The case for moderate amounts and intensities of physical activity. Res Q Exerc Sport 1996;67:193–205.
[2] Bouchard C, Shephard RJ, Stephens T, editors. Physical activity, fitness and health: international proceedings and consensus statement. Champaign: Human Kinetics; 1994. p. 61–3.
[3] Malina RM. Adherence to physical activity from childhood to adulthood: a perspective from tracking studies. Quest 2001;53: 346–55.
[4] Riddoch CJ, Boreham C. Physical activity, physical fitness and children's health: current concepts. In: Armstrong A, van Mechelen W, editors. Pediatric exercise science and medicine. Oxford: Oxford Univ. Press. p. 243–52.
[5] Biddle SJH, Sallis J, Cavill N, editors. Young and active: physical activity guidelines for young people in the UK. London: Health Education Authority; 1998.
[6] Armstrong N, Welsman J, editors. Young people and physical activity. Oxford: Oxford Univ. Press; 1997.
[7] Riddoch CJ, Mahoney C, Murphy N, Boreham C, Cran G. The physical activity patterns of Northern Irish schoolchildren age's 11–16 years. Pediatr Exerc Sci 1991;3:300–9.
[8] Kohl HW, Hobbs KE. Development of physical activity behaviours among children and adolescents. Pediatrics 1998;101:549–54.
[9] Sarkin JA, McKenzie TL, Sallis JF. Gender differences in physical activity during fifth-grade physical education and recess periods. J Teach Phys Educ 1997;17:99–106.
[10] Stratton G. A preliminary study of children's physical activity in one urban primary school playground: differences by sex and season. J Sport Ped 1999;2:71–81.
[11] Boulton MJ. Participation in playground activities at middle school. Educ Res 1992;34:167–81.
[12] Stratton G, Ridgers ND. Sporting playgrounds project—An overview. Br J Teach Phys Educ 2003;24:23–5.
[13] United States Department of Health and Human Services. Healthy people 2010: understanding and improving health. Washington: DHHS; 2000.
[14] Stratton G. Children's heart rates during physical education lessons: a review. Pediatr Exerc Sci 1996;8:215–33.
[15] Hardman K, Marshall J. The state and status of physical education in schools in international context. Eur Phys Educ Rev 2000;6:203–29.

[16] Stratton G, Mullan E. The effect of playground markings on children's physical activity levels. Rev Port Ciênc Desporto 2003;3:S137.

[17] Sirard JR, Pate RR. Physical activity assessment in children and adolescents. Sports Med 2001;31:439–54.

[18] Rowlands AV, Eston RG, Ingledew DK. The relationship between physical activity levels, aerobic fitness and body-fat in 8- to 10-year-old children. J Appl Physiol 1999;86:1428–35.

[19] Coe D, Pivarnik JM. Validation of the CSA accelerometer in adolescent boys during basketball practice. Pediatr Exerc Sci 2001;13:373–9.

[20] Eston RG, Rowlands AV, Ingledew DK. Validity of heart rate, pedometry and accelerometry for predicting the energy cost of children's activities. J Appl Physiol 1998;84:362–71.

[21] Janz KF. Validation of the CSA accelerometer for assessing children's physical activity. Med Sci Sports Exerc 1994;26:369–75.

[22] Ott AE, Pate RR, Trost SG, Ward DS, Saunders R. The use of uniaxial and triaxial accelerometers to measure children's "free-play" physical activity. Pediatr Exerc Sci 2000;12:360–70.

[23] Rowlands AV. Field methods of assessing physical activity and energy balance. In: Eston RG, Reilly T, editors. Kinanthropometry and exercise physiology laboratory manual Tests, procedures and data, anthropometry, vol. 1. London: Routledge; 2001. p. 151–70.

[24] Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children's physical activities: an observational study. Med Sci Sports Exerc 1995;27:1033–41.

[25] Nilsson A, Ekelund U, Yngve A, Sjöström M. Assessing physical activity among children with accelerometers using different time sampling intervals and placements. Pediatr Exerc Sci 2002;14:87–96.

[26] Tryon WW, Williams R. Fully proportional actigraphy: a new instrument. Behav Res Methods Instrum Comput 1996;28:392–403.

[27] Scruggs PW, Beveridge SK, Watson DL. Increasing children's school time physical activity using structured fitness breaks. Pediatr Exerc Sci 2003;15:156–69.

[28] Blatchford P, Baines E, Pellegrini AD. The social context of school playground games: sex and ethnic difference, and changes over time after entry to junior school. Br J Dev Psychol 2003;21:481–505.

[29] Stratton G. Promoting children's physical activity in primary school: an intervention study using playground markings. Ergonomics 2000;43:1538–46.

[30] Stratton G, Leonard J. The effects of playground markings on the energy expenditure of 5–7-year-old school children. Pediatr Exerc Sci 2002;14:170–80.

[31] Dale D, Corbin BC, Dale KS. Restricting opportunities to be active during school recess: do children compensate by increasing physical activity levels after school? Res Q Exerc Sport 2000;71:240–8.

[32] Tizard B, Blatchford P, Burke J, Farquhar C, Plewis I, editors. Young children at school in the inner city. London: Lawrence Erlbaum Associates; 1988.

Nicola Ridgers is the Research Assistant at REACH (Research into Exercise and Children's Health) Group, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University,Liverpool. Email:N.Ridgers@ljmu.ac.uk

Nicola D. Ridgers, Gareth Stratton, John Curley & Gary White

Liverpool Sporting Playgrounds Project

The purpose of this article is to provide an overview of the initial findings from the project to date and discuss baseline measures of physical activity, gender issues and school approaches to developing health promoting playgrounds.

Playtime is a break period, often held outdoors, for children during school time (Pellegrini, 1995). In Britain, children can experience up to 600 playtimes a year (based on 3 times a day, 5 days a week, 39 weeks a year; Stratton, 2000). Weather permitting, playtime occurs in the school playground, an area that varies greatly in size, shape, and the way that it is managed (Pellegrini, 1995). The playground is considered by children to be their domain (Evans, 1996), enabling them to engage in activities that are gradually more restricted elsewhere and allowing free interaction among similar aged peers (Pellegrini, 1995).

Playtime has an important role in children's physical and social development, affording children the opportunity to develop physical skills and confidence in their movement, and to build positive peer relationships (Evans, 1996). Children can also learn social skills such as sharing, cooperating, turn taking and the rules of a variety of playground games. Whilst playtime accounts for approximately one quarter of the school day (Evans, 1996) and one-fifth of a child's school life (Tizard et al., 1988), it lays claim to being the forgotten part of the school day (Blatchford, 1989). The extent to which playtime can contribute to a child's daily physical activity is greatly under researched.

Physical Activity - The Role of the School

It is widely acknowledged that physical activity is an integral part of a healthy lifestyle, and that engaging in regular physical activity can decrease the risk of obesity, coronary heart disease and diabetes (Biddle et al., 1998). It is recommended that children should engage in sixty minutes of moderate-to-vigorous physical activity (MVPA) a day (Biddle et al., 1998). However, there is concern that children are not engaging in sufficient daily physical activity in order to gain health benefits associated with physical activity (Armstrong & Welsman, 1997).

Recently, the school has been identified as a suitable context for the promotion of physical activity and healthy lifestyles to children. The main opportunities for children to be physically active during the school day is during physical education (PE) lessons and playtime (Sarkin et al., 1997). Moreover, the promotion of a physically active lifestyle within the school environment has traditionally been undertaken through physical education (PE) lessons.

However, with concerns growing that curriculum time allocated towards PE is not meeting statutory expectations (Hardman & Marshall, 2000), playtime may offer an ideal alternative setting to promote children's physically active lifestyles. Additionally, school playgrounds have been identified as an alternative environment to PE where physical activity can be promoted to children and contribute towards daily physical activity guidelines (Stratton & Ridgers, 2003).

Playtime may develop positive attitudes towards physical activity and sport in general by offering children the opportunity to experience a number of different activities and developing fundamental movement skills which are key components of successful sports participation (van Beurden et al., 2003). Moreover, playtime has a positive impact on learning, with children more attentive in class when they experience regular breaks from their work (Pellegrini & Davis, 1993). In order for children to make choices about their playtime activities, schools should also provide adequate supervision and playground environments to facilitate this choice.

Zoneparc Playgrounds

A national Sporting Playgrounds Initiative has addressed the need for children to have the opportunity to engage in a variety of activities and to access adequate facilities during playtime.

In May 2002, the DfES in partnership with Nike invested £10 million into the development of Sporting Playgrounds in 600 primary schools across England. The primary schools are situated within 27 Local Education Authorities. Over half of the schools involved in this national initiative chose to implement the Zoneparc playground developed by the DfES and Nike. Zoneparc playgrounds have two major aims:

- Tackle social exclusion and playground issues in schools
- Increase physical activity levels for young people

The Zoneparc playground involves the division of the playground into three specific colour coded areas. The specific areas are the Red, Blue and Yellow Zones. Zoning the playground is designed to contain dominant activities, provide a safe space for other activities to take place, and encourage children to participate in a number of activities, especially children who are intimidated by the playground context or excluded from games (DfES, 2005).

The Red Zone

The Red Zone is the sports zone, where children can engage in activities such as football, basketball, cricket and tennis. This area is often enclosed using fencing so that the domination of ball games such as football on the playground are restricted and children can engage in other activities in the available space (Evans, 1996). This area is important in the development of sports skills for children, and the static equipment such as goal posts can be used during playtime, PE lessons and for out of hours sports activities.

The Blue Zone

The Blue Zone is the action zone, where children can engage in games and activities such as target work, fitness and skills. Typical markings in this area of the playground include clocks, compasses, hopscotch, targets, jump lines and number snakes. Such markings can be used for playground games which develop children's fundamental movement skills during playtime, and can be used to support the curriculum in teaching children how to count and tell the time for example. Indeed, it has been stated that 50% of the National Curriculum can be taught in school playgrounds and surrounding grounds (Titman, 1992).

The Yellow Zone

The Yellow Zone is classed as the chill out zone, where children can engage in non-active games such as word games, clapping games, and board games such as chess and draughts (Stratton & Ridgers, 2003). This zone typically comprises of playground markings such as chessboards, and benches so that children can sit down and interact with others away from the vigorous playground games (Titman, 1992).

Examples of the zones can be accessed on the REACH Group's website in the LSPP research monograph[1]. The use of zones and the different markings are important in the promotion of physical activity and health as they reduce the restrictions usually placed on children and increase the choices they have for outdoor activities. Additionally, they provide support for teaching different aspects of the National Curriculum, including PE and Maths, for example.

Liverpool Sporting Playgrounds Project (LSPP)

In order to investigate the impact of the playground redesigns on children's physical activity levels and play behaviour, and to assess the contribution of playtime to daily physical activity guidelines, the Liverpool Sporting Playgrounds Project (LSPP) was developed. For a more comprehensive overview about the LSPP, the reader is directed to Stratton and Ridgers (2003). The purpose of this article is to provide an overview of the initial findings from the LSPP to date. We discuss baseline measures of physical activity, gender issues and school approaches to developing health promoting playgrounds.

In Liverpool, the LSPP has been actively researching children's physical activity and play behaviours in the playground for two years. The project is being run by the REACH Group (Research into Exercise, Activity, and Children's Health) at Liverpool John Moores University in conjunction with Liverpool LEA, Liverpool Sport Action Zone and Sport England. Twenty primary schools have secured £20,000 to redesign their playground, based on the Zoneparc model, from the national initiative funded by the DfES and Nike (Stratton & Ridgers, 2003). At the end of the summer term, all 20 schools had received their "Sporting Playground". Sixteen of these schools had chosen the Zoneparc playground. A further 10 schools are involved in the project as postcode matched controls, resulting in approximately one quarter of the primary schools in the city being monitored as part of the project.

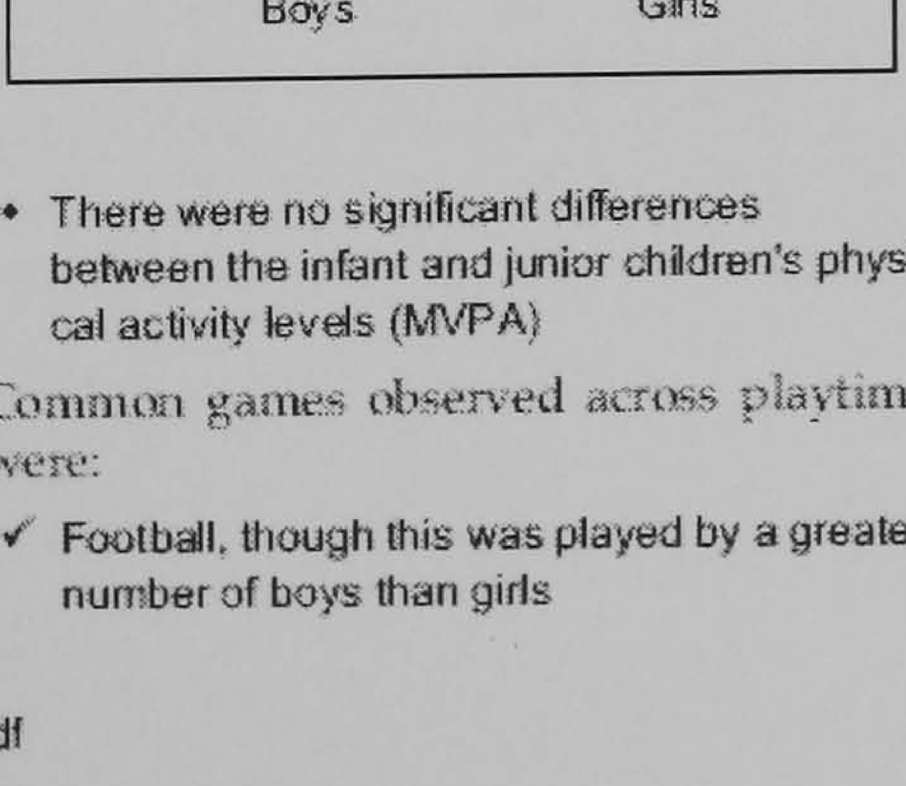
To date, 506 children aged 5-11 years of age have had their physical activity monitored and their playground behaviour observed. Over 50 detailed semi structured interviews have been conducted with children and school staff to examine their attitudes towards playtime and play behaviours, and to determine the types of activities children enjoy playing in the playground. Additionally, approximately 150 hours of playground interactions and behaviours have been observed and recorded during playtime. This enables a comprehensive analysis of children's physical activity and their social behaviour during playtime to be conducted.

Play in Schools - Initial Findings.

The baseline phase of the project, conducted from July 2003 to July 2004, has yielded a number of findings, which are highlighted below. These findings focus not only on the physical activity of the children, but also on their range of play, their attitudes towards play, and the differences observed between boys and girls.

- The average play length was 84 minutes in the schools tested. Therefore, during one school week, children spend 420 minutes or 7 hours engaged in playtime activities.
- Boys engaged in more moderate to vigorous physical activity (MVPA) during playtime than girls (see Figure 1)

Figure 1



- There were no significant differences between the infant and junior children's physical activity levels (MVPA)

Common games observed across playtime were:

- ✓ Football, though this was played by a greater number of boys than girls
- ✓ Chasing games such as tick and hide and seek
- ✓ Skipping
- ✓ Dancing, though this was more popular with girls than boys
- ✓ Talking with friends
- ✓ Other ball games such as basketball
- ✓ Fantasy and pretend play
- ✓ Incidents of rough play and play fighting were higher in playgrounds where play equipment was limited
- ✓ Children of all ages look forward to and enjoy playtimes.

A selection of quotes discussing the positive aspects of playtime are shown here:

" ... we don't have to do work (Year 3 boy)

" It's our time during the day (Year 3 girl)

" Because I want to play football (Year 6 boy)

" [I enjoy] playing with my mates and talking (Year 5 boy)

" You can do whatever you want (Year 4 girl)

A number of children stated that they did not enjoy playtime. Reasons for this included:

" There's nothing really for girls (Year 4 girl)

" There's nothing to do (Year 4 girl)

" It's a bit boring because you play the same stuff (Year 5 boy)

" There's not many markings and you can't sit [down] (Year 4 boy)

These results suggest that children of all ages look forward to their playtime and use this time to engage in activities of their own volition. The finding that boys are more physically active than girls during playtime supports work conducted by other researchers who have noted similar results in both the United States (Sarkin et al., 1997) and in Britain (Stratton, 2000). It is possible that these findings are linked to the range of activities that children participate in during playtime. The baseline study has indicated that the most common activity for boys to engage in is football, and it is not unusual to see multiple soccer games played parallel to each other on the playground. Observations revealed that girls tend to engage in more sedentary social activities such as talking with friends. This again is consistent with previous research (Evans, 1996). More active games such as skipping and dancing are also popular with the girls, with the social aspects of these games highly important to them.

Football tends to dominate...

One of the main concerns highlighted by girls and members of staff in the playground was that football tends to dominate the available play space and girls were often located around the perimeter of the playground. As one head stated "you need to have your football because if you don't have your football the kids will probably just be a pain". The

1. http://cwis.livjm.ac.uk/psd/reach/ResearchMonographNR.pdf

fact that boys are more active than girls could also be explained, in part, by this use of the play space for different activities. Therefore, the effect of zoning the playground into three areas, one for sports, one for skills, and one for non-active games is an interesting element of the project. The reader is directed towards Stratton & Ridgers (2003) for a detailed discussion of the Zoneparc initiative. The effect of playground redesign on children's physical activity represents the first key aim of the project over the ensuing twelve months.

Higher incidents of rough play...

An interesting finding in this phase of the project was that there were higher incidents of rough play and play fighting when equipment on the playground was limited. It was more common in boys' activities, and the underlying reasons have not been widely established. It may be linked to a lack of activities that the playgrounds currently offered to the children during playtime. With the Zoneparc model offering a choice of activities for children to engage in through the zones' markings and equipment, the impact that this has on the children's play behaviours during playtime represents the second major aim of the project.

Proposing a time and efficiency guideline

The baseline results indicate that the average playtime length across the school day was 84 minutes. Recent physical activity guidelines recommend that children should engage sixty minutes of MVPA, and at least a minimum of thirty minutes a day (Biddle et al., 1998). However, there are currently no physical activity recommendations for playtime. Based on the results of this study, if children engage in MVPA for 40% of the playtime available, they will achieve the minimal guideline of thirty minutes through playtime alone (33 ½ minutes exactly). This proposed guideline gives schools a physical activity target for their children to achieve during playtime.

It is suggested...

It is suggested that schools should look towards ways of developing their own playground area to promote physical activity during playtime. Strategies could include the provision of playground markings and equipment, training of children and staff to supervise and facilitate activities and games, and placing physical education specialists into the play areas to teach new games to children. These may also promote more positive attitudes towards playtime from children who currently do not look forward to playtimes because of a lack of available activities.

Conclusion

The aim of this article was to educate physical educators and health promoters about the Sporting Playground initiative being undertaken in Liverpool, and to highlight a number of the initial findings from the baseline work.

The project has suggested that playtime is an enjoyable aspect of the school day for children, and that they use this time to play and to develop social relations with peers. Playtime also offers an ideal opportunity to promote physical activity behaviours to children of all ages in a context that children feel is their own (Evans, 1996). Playtime has been described as the neglected part of the school day (Blatchford et al., 1990). The LSPP aims to address this issue, and to investigate how children's physical activity and play behaviours change as a result of the Zoneparc playground redesign being implemented in the schools.

The project will also continue to investigate the longer-term effects of the playground redesign on children's activity and behaviour, tracking the children monitored during the baseline phase of the project for twelve months. Further updates of the effects of the playground redesign on children's physical activity and behaviour will be documented over the next phases of the LSPP.

Referencs

Biddle, S. J. H., Sallis, J. F., & Cavill, N. (1998). *Young and Active: Physical Activity Guidelines for Young People in the UK*. London: Health Education Authority.

Blatchford, P. (1989). *Playtime in the Primary School: Problems and Improvements*. Berkshire, UK: NFER-Nelson.

Blatchford, P., Creeser, R., & Mooney, A. (1990). Playground games and playtime: The children's view. *Educational Research*, 32, 163-174.

Department for Education and Skills. (2005). *Primary Playground Development*. DfES Publications.

Evans, J. (1996). Children's attitudes to recess and changes taking place in Australian primary schools. *Research in Education*, 56, 49-61.

Hardman, K. & Marshall, J. (2000). The state and status of physical education in schools in international context. *European Physical Education Review*, 6, 203-229.

Pellegrini, A.D. (1995). *School Recess and Playground Behaviour: Educational and Developmental Roles*. New York: SUNY Press.

Pellegrini, A.D. & Davis, P.D. (1993). Relations between children's playground and recess behaviour. *British Journal of Educational Psychology*, 63,, 88-95.

Sarkin, J. A., McKenzie, T. L., & Sallis, J. F. (1997). Gender differences in physical activity during fifth-grade physical education and recess periods. *Journal of Teaching in Physical Education*. 17, 99-106.

Stratton, G. (2000). Promoting children's physical activity in primary school: An intervention study using playground markings. *Ergonomics*, 43, 1538-1546.

Stratton, G., & Ridgers, N. D. (2003). Sporting Playgrounds Project - An overview. *British Journal of Teaching in Physical Education*. 24, 23-25.

Titman, W. (1992). Play, *Playtime and Playgrounds*. Devon, UK: Southgate Publishers.

Tizard, B. Blatchford, P., Burke, J., Farquhar, C. & Plewis, I. (1988). *Young Children at School in the Inner City*. London: Lawrence Erlbaum Associates.

Van Beurden, E., Barnett, L.M., Zask, A. Dietrich, U.C>, Brooks, L.O. & Beard, J. (2003). Can we skills and activate children through primary school physical education lessons? "Move it Groove it" - a collaborative health promotion intervention. *Preventive Medicine*, 36, 493-501.

Acknowledgements.
This project is funded by Sport England and Liverpool Department for Lifelong Learning. The authors would like to thank Emily Clark, Adam Hale, Ruth McLoughlin and Tom Langford for assistance with data collection, and all the participating schools involved in the project.

urine sample, were weighed and their haematocrit and haemoglobin were determined. Heart rate and aural temperature were measured throughout each test and sweat was collected from the arms immediately after completion of each trial. After each trial participants received 20 ml · kg^{-1} body mass water (based on pre-trial body mass) and an energy bar (Science In Sport), which were consumed within 30 min. Repeat venous blood samples were taken after the last trial only. Following appropriate checks on underlying assumptions, fully repeated-measures factorial analyses of variance (ANOVA) were used to examine changes in body mass, urine osmolality, serum osmolality, heart rate, aural temperature, sweat rates, Na^+ concentration of sweat and performance times following glycerol and placebo ingestion. Statistical significance was set at $P \leq 0.05$.

Fluid retention (indicated by changes in body mass) was greater following glycerol ingestion ($P < 0.001$). There were no differences in serum osmolality, plasma volume, performance times, heart rate, aural temperature or sweat rates (P at least 0.32). Urine osmolality was higher for the glycerol group until pre-trial two ($P < 0.001$). The Na^+ concentration of sweat was higher for the second trial for the placebo group ($P = 0.02$). These results support the time-course of glycerol rehydration reported by Robergs and Griffin (1998: *Sports Medicine,* 26, 145–167) in which urine osmolality reaches similar levels as that of water hyperhydration five hours after ingestion. However, the higher Na^+ concentration of sweat found in the placebo group at this point, suggests the intracellular fluid was less concentrated in the glycerol group, indicating water might still be retained within the intracellular space. The results suggest that despite improved hydration status, glycerol does not improve performance.

62. Children's Physical Activity Levels during School Playtime

Nichola D Ridgers, Gareth Stratton,

The REACH Group, Faculty of Education, Community and Leisure, Liverpool John Moores University, I.M. Marsh Campus, Birkhill Road, Liverpool, L17 6BD

Physical activity guidelines recommend that children should engage in 60 min of moderate-to-vigorous physical activity a day (Biddle *et al.,* 1998: *Young and Active: Physical Activity Guidelines for Young People in the UK.* London: HEA). School playtime may present an ideal opportunity for children to be physically active. The objective of this study was to establish the physical activity levels of primary school children during playtime.

Table 1. Activity Levels for Boys and Girls (mean ± S)

	Overall	Boys	Girls
Moderate %	22.9 ± 8.6	25.7 ± 8.8	20 ± 7.4
High%	2.2 ± 2.4	2.7 ± 2.3	1.7 ± 2.4
Very High%	1.7 ± 2.1	2.2 ± 2.3	1.1 ± 1.7

One hundred and sixty five children (85 boys, 80 girls) aged 5–11 years from 17 schools participated in the study. The children's physical activity during playtime was measured using the uni-axial MTI Health Services ActiGraph (Florida, USA). The epoch length was set at 5 s. Counts per epoch thresholds of 163–479, 480–789, and >790 represented moderate, high and very high intensity levels respectively (Nilsson *et al.,* 2002: *Pediatric Exercise Science,* **14,** 87–96). A series of one-way ANOVAs were used to compare sex differences in the physical activity of children during their playtime on one school day (mean playtime=84 min).

Boys engaged in significantly more moderate ($F_{1,163}$=19.7; $P<0.01$), high ($F_{1,163}$=6.1; $P<0.05$) and very high ($F_{1,163}$=12.4; $P<0.01$) intensity exercise than girls (Table 1). Overall, the boys engaged in 26 min of physical activity within these three intensity levels, whilst the girls engaged in 19 min of activity. The boys and girls spent 31% and 23% of playtime engaged in physical activity respectively.

The results suggest that most children do engage in moderate to very high intensity physical activity during playtime, with moderate intensity activities being the most prevalent in the playground environment. Boys also engaged in physical activities which recorded more frequent and higher movement intensities than did the girls. The results indicate that children are not meeting physical activity recommendations using playtime alone, but playtime can contribute to the daily accumulation of physical activity for school-age children. Interventions for increasingly physical activity of children in the playground are warranted.

72. Muscle oxygenation and pulmonary gas exchange on-kinetics during moderate and supra-maximal cycle exercise in man

Daryl P. Wilkerson and Andrew M. Jones

Dept of Exercise and Sport Science, Manchester Metropolitan University, Hassall Road, Alsager, ST7 2HL

Considerable controversy surrounds the issue of whether or not O_2 availability represents a principal limitation to the rate at which oxygen uptake ($\dot{V}O_2$)

REVIEW ARTICLE

Sports Med 2006; 36 (4): 359-371
0112-1642/06/0004-0359/$39.95/0

Physical Activity Levels of Children during School Playtime

Nicola D. Ridgers,[1,2] *Gareth Stratton*[1,2] and *Stuart J. Fairclough*[3,2]

1 Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK
2 REACH (Research into Exercise, Activity and Children's Health) Group, Liverpool John Moores University, Liverpool, UK
3 Centre for Physical and Outdoor Education, Liverpool John Moores University, Liverpool, UK

Contents

Abstract ... 359
1. Definitions ... 361
2. Physical Activity Recommendations ... 361
3. Method ... 361
4. Studies Investigating Physical Activity Levels During Playtime ... 361
5. Playtime-Based School Interventions Promoting Physical Activity ... 366
6. Future Research Directions ... 368
7. Conclusion ... 369

Abstract

School represents a suitable setting for intervention programmes aiming to promote physical activity to benefit health. During the school day, physical education and school playtime offer children regular opportunities to engage in physical activity. However, there is growing concern that, internationally, curricular time allocated to physical education is not meeting statutory guidelines. The effectiveness of the playground environment to promote physical activity has been considered as a complementary setting to physical education.

Physical activity guidelines state that children should engage in at least 1 hour of moderate intensity physical activity a day. Currently no empirically tested guidelines exist for physical activity levels during playtime. However, studies cited in this article indicate that playtime can contribute between 5–40% of recommended daily physical activity levels when no interventions have been utilised.

The limited school-based investigations that have been reported in the literature suggest that boys engage in more physical activity during playtime than girls. Studies that have implemented intervention strategies in order to promote physical activity levels indicate that playtime can substantially contribute towards daily optimal physical activity guidelines. Energy expenditure and physical activity levels have increased during playtime following the implementation of playtime-based interventions. In order to advance knowledge of children's physical activity during playtime, a number of key issues for consideration in future research are detailed. Research on children's use of playtime to be physically active and the extent of the contribution of playtime to daily physical activity guidelines is warranted.

The benefits of a physically active lifestyle have been extensively documented in adults, with inverse relationships between physical activity and diseases including obesity, coronary heart disease, hypertension, diabetes mellitus, certain cancers and osteoporosis.[1-3] Additionally, a physically active lifestyle has been linked to psychological well-being.[4]

In recent years, considerable interest has been directed towards determining physical activity levels amongst paediatric populations. Research suggests that an active lifestyle during childhood reduces the risk of health problems in later years,[5] and that levels of physical activity during childhood track into adulthood, although this tracking evidence is weak.[3,6] Whilst the relationship between child physical activity and health is weak compared with stronger relationships found between adult health and physical activity,[3] health promoters consistently endorse regular moderate intensity physical activity for children with the objective of benefiting current and future health.[1] However, research has indicated that substantial numbers of children in the UK,[7,8] Europe[9,10] and the US[11,12] do not engage in sufficient activity during childhood to gain health benefits.

Opportunities for children to engage in daily physical activity are dependent on a number of socio-economic, environmental and personal factors. Competition from sedentary leisure-time activities, such as television viewing, on the time available for children to be active has been acknowledged,[13,14] although recent data suggest that sedentary behaviours not only compete but also coexist with physical activity.[15] Marshall et al.[15] noted that promoting physical activity whilst maintaining the behavioural preferences of children is an important consideration. School-based interventions may provide the scope for physical activity promotion whilst allowing children to choose their leisure-time activities freely. Consequently, the importance of the school environment warrants attention.

During the school day, physical education (PE) and playtime enable children to engage in regular physical activity.[16,17] Interventions that have sought to increase physical activity levels in PE lessons, such as SPARK (Sports, Play and Active Recreation for Kids), CATCH (Coordinated Approach to Child Health) and M-SPAN (Middle-School Physical Activity and Nutrition) have generally been successful in raising the short- and long-term physical activity levels of elementary children.[18-20] Whilst these large-scale projects have been well funded, they have been implemented in the US and the costs of the intervention programmes are unknown.[21] These studies have significantly increased physical activity in focused settings such as PE, although these increases have made a small contribution to total daily physical activity.

Internationally, there is growing concern that the curricular time allocated for PE is not meeting statutory guidelines, with PE making way for supposedly more valuable areas of the curriculum, such as numeracy and literacy.[22] In light of these concerns, the effectiveness of the playground environment and playtime in physical activity promotion may complement PE interventions. Playtime is a mandatory part of the school day where children usually spend the majority of their time outside on the playground.[23,24] With children experiencing up to 600 playtimes a year (based on 3 times a day, 5 days a week, 39 weeks a year),[25] playtime offers a significant amount of time where children can be physically active. The purpose of this article is to appraise the research that has investigated the physical activity levels of children during school playtime. Moreover, it considers interventions that have been used to increase physical activity levels during this part of the school day. Key issues that emerge from the extant literature on playtime may provide clues about the delivery of a successful and sustainable intervention for physical activity promotion.

1. Definitions

For the purpose of this article, the term 'children' includes the age range 4–12 years. 'Physical activity' is a broad term, which is defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure'.[26] This article focuses on children's physical activity, which is characteristically spontaneous and intermittent.[11,27] 'Playtime' is considered as the non-curriculum time allocated by schools between lessons for children to engage in leisure activities (known as 'recess' in the US). 'School playgrounds' are regarded as the outdoor area of the school available for children to use during their playtimes. They can encompass both grass and tarmac areas, and may contain playground markings and equipment for children to use.

2. Physical Activity Recommendations

The following physical activity recommendation has generally been accepted for the maintenance of health among children and will be used in this review: 'all young people should participate in physical activity of at least moderate intensity for 1 hour per day'.[28] Moderate-intensity physical activity here is defined as '[an] activity usually equivalent to brisk walking, which might be expected to leave the participant feeling warm and slightly out of breath'.[28] Vigorous physical activity (VPA) here is defined as '[an] activity usually equivalent to at least slow jogging, which might be expected to leave the participant out of breath and sweaty'.[28] This article will discuss moderate-to-vigorous physical activity (MVPA) where a child engages in at least moderate intensity activity that encompasses bouts of VPA.

No empirically tested guidelines currently exist for physical activity levels during playtime. However, it has recently been suggested by Ridgers et al.[29] that in order for playtime to contribute meaningfully towards the accumulation of daily physical activity, children should engage in at least moderate-intensity physical activity for 40% of playtime. Ridgers et al.[29] found that 40% of playtime engaged in physical activity equated to 34 minutes of daily MVPA in their study when playtime across the school day was measured. This exceeded the minimum recommendation of 30 minutes of at least moderate-intensity physical activity for children who currently participate in little or no daily physical activity.[28] This threshold value was considered a realistic target for children to achieve during playtime, and it will be utilised throughout this article.[29]

3. Method

A literature search was conducted for studies that measured children's physical activity levels during playtime and were published in the English language between 1970 and 2004. The search used the key words 'playtime', 'recess' and 'playgrounds' using the Web of Knowledge and SportDiscus online databases, and a manual search of conference proceedings was also performed. Both cross-sectional and intervention studies were included to establish the physical activity levels of children in different school playtime contexts. Additional inclusion criteria for studies were: (i) physical activity levels during school playtime evaluated using objective measures; and (ii) participants were between 4–12 years of age.

4. Studies Investigating Physical Activity Levels During Playtime

Despite being popular with pupils[23] and accounting for a significant amount of school time,[30] playtime has been referred to as 'the forgotten part of the school day'.[23] Little empirical research has focused on the physical activity levels of children within the playground and the merit of playtime strategies in this context.

Children best accumulate physical activity in unstructured environments where they are free to interact with their peers.[31] Playtime offers children an opportunity to be physically active during the school day, as the unstructured environment lends itself to the highly transitory activity patterns of children.[11,32] It is only recently, however, that research has attempted to quantify both the physical activity levels of children during playtime, and their contribution towards physical activity guidelines.

The determination of children's physical activity during school playtime has been undertaken using direct observation, heart rate monitoring and accelerometry. Direct observation enables the assessment of the pattern, frequency and intensity of behaviours as well as contextual information concerning the physical activity behaviour. Whilst this method is time consuming and can cause reactivity, it is considered the most practical method for assessing patterns of activity and their related behaviours.[33,34] Heart rate monitoring provides an indication of the relative stress placed on an individual's cardiorespiratory system during movement.[35] It is cost-effective for use in moderately sized samples and is relatively unobtrusive.[33] However, maintaining contact between the monitor and the chest is a problem, particularly in smaller children because of the size of their ribcage, and recordings can be affected by factors not associated with the children's movement such as emotional state and level of fitness.[35] Accelerometry detects the body movement connected with physical activity. It is increasingly popular for assessing physical activity in field settings, as the monitors are small, non-invasive, and can store large amounts of data, thus detailing physical activity patterns over time.[36] The ability to use adjustable recording settings to monitor activity is an advantage of accelerometry.[37] Tri-axial accelerometers are thought to be better suited for measuring children's physical activity than uni-axial accelerometers, as they may be more sensitive to children's activities.[33] However, uni- and tri-axial accelerometer recordings are highly correlated,[38] supporting the use of uni-axial accelerometry as one of the commonly used methods in paediatric populations.[39] These methods of assessment are reliable and valid for use with children (see Sirard and Pate[33] for a review).

Table I summarises 13 studies that have investigated the physical activity levels of children aged 4–12 years in the school playground, where six studies have used the criterion measure of direct observation on individual children and two studies have used scanning procedures on school playgrounds.

Sex differences in children's physical activity levels have been found, with boys generally participating in more MVPA during playtime than girls.[17,25,45-48] Whilst the reasons behind sex differences are not widely established, links have been made to sex roles, with boys viewing playtime as an opportunity to engage in competitive games while girls view it as an opportunity to socialise with friends.[24] Conversely, two studies of Portuguese children found that girls engaged in more MVPA than boys,[41,42] although the authors were concerned about children's low levels of physical activity participation. These studies were limited by the small sample sizes and single day of monitoring of physical activity. Further studies are needed to examine whether the differences found in these studies could be, in part, explained by cultural differences between different countries by using representative sampling and monitoring larger numbers of children.

Stratton[25] investigated sex and seasonal differences in playtime physical activity in a sample of 27 children and found that whilst boys engaged in higher levels of physical activity than the girls in the winter months, there was no difference in their activity levels in the summer months. Boys' and girls' activity was higher in the winter months compared with summer.[25] While a small sample was used, these data suggest that establishing the underlying determinants for the girls' higher MVPA and the reduction of the children's activity in the summer months could have important implications for the promotion of physical activity over the academic year. On this basis, studies that aim to determine the seasonal influences on children's playtime physical activity using a larger sample of children are warranted.

Playtime offers an opportunity for children to be physically active at a sufficient level to meet minimum daily physical activity recommendations.[29] Table II demonstrates the extent to which playtime can contribute to daily physical activity recommendations. This has been possible for studies that re-

Table I. Summary of studies investigating children's physical activity (PA) during playtime. Table ordered by sample size (smallest to largest)

Study	Participants	Design and PA assessment	Results	Other comments
Stratton and Mota[40]	9 English and 9 Portuguese girls aged 10y	Direct observation: CARS HR telemetry: 15 sec intervals Playtime video recorded Correlations	English girls PA: 'slow/easy translocation' and 'stationary with movement' Portuguese girls PA: 'stationary with movement' and 'fast/hard translocation' Low correlation's between HR and CARS	Only morning playtime monitored Difficult to synchronise HR and CARS Sensitivity of measures Small sample size
Santos et al.[41]	10 boys and 12 girls aged 8–10y (Portugal)	HR telemetry: measured morning and afternoon playtime on 1 day	Girls MVPA > boys Girls spent 38% and boys 30.8% of play in MVPA Girls PA contributed 19% to PA guidelines; boys 15.4%	Children engaged in PA for small percentage of playtime Opportunities for PA to be encouraged in schools Small sample size
Stratton[25]	14 boys and 13 girls aged 7–11y from one primary school (England)	HR telemetry during morning playtime 1 boy and 1 girl per playtime filmed Summer: Jun–Jul Winter: Jan–Feb	Winter PA > summer PA Boys winter PA > girls Boys summer PA ↔ girls HR winter > summer	Seasonal influences examined 30 playtimes observed (500+ min) Only morning playtime measured Other variables affecting HR Small sample size
Mota and Stratton[42]	16 boys, 23 girls aged 8–9y (9.3 ± 0.4y) grade 4 (Portugal)	HR telemetry: 15 sec intervals HR measured during morning playtime (20 min) – 4wk ANOVA	Boys HR < girls Boys MVPA < girls Boys spent 19% and girls 34% in MVPA	Children engaged in some light activity Only morning break monitored Small sample size
Johns and Ha[43]	40 children aged 6–8y (Hong Kong)	Direct observation: BEACHES 4 × 1h and 6 × 20 min observations (mean 5.5h) per child Chi-squared tests	23.3% of time children were seated during playtime 40.5% of time children were standing 28.1% of time children were walking VPA only 3.3% of time	Inter-observed results not given Cultural influences on PA considered Sex differences on PA not indicated Small sample size
Dale et al.[16]	40 boys and 38 girls (M age = 9.3 ± 0.68y) [US]	Accelerometry 4 school days monitored: 2d 70 min of PE and playtime, 2d no school activity, dependent t-tests	PA active day > non-active day Playtime and PE PA active day > non-active day PA after school on non-active days < active school days	Examined restriction effects on PA PA threshold values not used to quantify PA duration or intensity 1 min epoch used – pattern of activity not shown
Sarkin et al.[17]	49 boys and 61 girls grade 5 (boys M age = 11.29 ± 0.53; girls M age = 11.18 ± 0.51) [US]	Accelerometry: PA measured in PE and playtime on 3 separate days 2 × 2 mixed model ANOVA for sex differences	Boys playtime PA > girls Boys PE PA ↔ girls Girls PA PE > girls PA playtime	Assessed PE and playtime on same days – controls for contextual variables School part of PE intervention

Continued next page

Table I. Contd

Study	Participants	Design and PA assessment	Results	Other comments
Sleap and Warburton[14]	93 boys and 86 girls aged 5–11y over 5y (UK)	Direct observation: CPAF procedure School day, 1 weekday evening and 1 × 4h period during weekend observed	PE PA < playtimes PA MVPA as total observation time in morning playtime (55.4%), afternoon playtime (59.8%) and lunch (46.3%)	Seasonal effects addressed Observations conducted by undergraduate students Observed at school on 1d only
Hovell et al.[44]	133 boys and 141 girls, grades 3–6 (US)	Direct observation: PA observed during morning playtime or lunch (10–20 min in length) Mar–Apr 50 × 5 sec interval observations per child	Grade 3 girls lower- and upper-body PA > grade 4 and grade 6 girls ↔ between boys on PA Boys lower-body PA > girls Boys upper-body PA < girls	First study to look at PA in playtime Linked behaviour to PA levels Based on 5 min of observation
McKenzie et al.[45]	E-A: 65 boys, 50 girls; M-A: 90 boys and 82 girls M age: baseline: 4.4y, follow-up 6.6y (US)	Direct observation: BEACHES technique 2 observations per child (minimum = 10 min) at preschool and elementary Paired t-tests	IOA%: 94.3–99.9% Boys PA > girls E-A PA > M-A PA Elementary PA > preschool PA	Longitudinal study 16% attrition rate Limited generalisability Playtime duration differed across schools
Kraft[46]	201 boys, 168 girls grades K-3 (US)	Direct observation: active and passive behaviour recorded every 5 sec 1 child observed for 5 min	IOA reliability: r = 0.91 Vigorous activity = 21% of time Physical play = 59% of playtime Boys PA > girls	Classified active behaviour and extent of social interactions Descriptive: based on 5 min of observation
McKenzie et al.[47]	24 schools, M enrolment 1081 pupils, grades 6–8 (US)	SOPLAY direct observation procedure 3d per school (72d total) 2 × 5 ANCOVAs	IOA%: 88–97% ICC: 0.76–0.99 Boys MVPA > girls MVPA Boys EE > girls EE More boys visit PA area than girls	Large scale study focusing on playtime behaviour SOPLAY focuses on PA of groups >20% students enrolled observed Scanning procedure used in school playground
Zask et al.[48]	3912 children year K-6 18 rural Australian schools	Direct observation: CAST procedure (based on SOFIT) Correlation and paired t-tests Multi-level regression model	IOA reliability: activity level = 0.79, category identification = 0.95. ICC MVPA = 0.94, VPA = 0.77 Lunch PA > playtime PA Boys PA > girls PA	Effect of play duration on PA stated Schools viewed on 1d only CAST not widely used in literature Scanning procedure used in school playground Environmental effects on PA considered

ANCOVA = analysis of covariance; **ANOVA** = analysis of variance; **BEACHES** = Behaviors of Eating and Activity for Children's Health Evaluation System; **CARS** = Children's Activity Rating Scale; **CAST** = Children's Activity Scoring Tool; **CPAF** = Children's Physical Activity Form; **E-A** = European American; **EE** = energy expenditure; **HR** = heart rate; **ICC** = intra-class correlation; **IOA** = inter-observer agreement; **M** = mean; **M-A** = Mexican American; **MVPA** = moderate-to-vigorous physical activity; **PE** = physical education; **r** = correlation coefficient; **SOFIT** = System for Observing Fitness Instruction Time; **SOPLAY** = System for Observing Play and Leisure Activity in Youth; **VPA** = vigorous physical activity; ↔ indicates no significant difference; > indicates significantly greater than; < indicates significantly less than.

Table II. Mean playtime duration, percentage of moderate-to-vigorous physical activity (MVPA), time spent in MVPA and contribution to daily physical activity (PA) guidelines (60 min) for boys and girls

Study	Mean playtime duration (min)	MVPA (%)		MVPA time (min)		Contribution to daily PA (%)	
		boys	girls	boys	girls	boys	girls
Stratton[25]	17.6 (summer)	15.8	15.4	2.8	2.7	4.7	4.5
	17.6 (winter)	29.1	22.5	5.1	3.9	8.5	6.5
Kraft[46]	28	45	38	12.6	10.6	21	17.7
McKenzie et al.[45]	25.9 (PS: E-A)	52.2	41	13.5	10.6	22.5	17.7
	25.9 (PS: M-A)	41.1	40	10.6	10.4	17.7	17.3
	14.1 (EL: E-A)	56.3	50.7	7.9	7.1	13.2	11.8
	14.1 (EL: M-A)	47.1	44.5	6.6	6.3	11	10.5
McKenzie et al.[47]	35.5 (lunch)	67.7	51.7	24	18.4	40	30.7
Mota and Stratton[42]	20	19	34	4	6.5	6.7	10.8
Zask et al.[48]a	16 (morning)	46.2	36.7	7.4	5.8	12.3	9.7
	30 (lunch)	51.4	41.6	15.4	12.5	25.7	20.8

a Based on a school size of 200 children.

E-A = European American; EL = elementary school; M-A = Mexican American; PS = pre-school.

ported the mean length of time children spent in playtime. Sleap and Warburton[14] provided a detailed breakdown of time children spent engaged in MVPA for each playtime. They found that the children engaged in an average of 8.3 minutes of MVPA during morning break, 8.5 minutes during the afternoon break, and 18.9 minutes during the lunch break. This equated to 55.4%, 59.8% and 46.3% of the average observation period for the children during each respective playtime, although the playtime length and sex differences in physical activity were not stated.[14] Encouragingly, children engaged in an average of 35.7 minutes of MVPA during all playtime, which is over half the recommended 60 minutes of MVPA a day.[28]

Table II highlights a number of key points that warrant attention:

1. Playtime contributed 4.7–40% of the recommended MVPA a day for boys and 4.5–30.7% for girls, suggesting that it can make a considerable contribution to the accumulation of daily MVPA.

2. The duration of playtime available for children to be active is an important consideration. Zask et al.[48] suggested that the increased physical activity levels observed at lunchtime compared with morning playtime were influenced by the longer play duration at lunchtime. Schools should therefore provide adequate time periods during the school day for children to engage in physical activity, which could contribute to activity guidelines.

3. Children in four studies achieved the threshold value of at least moderate-intensity physical activity for 40% of playtime.[29] However, further empirical testing is needed to establish its applicability across schools in differing geographical areas. Since these studies also utilised different measures for quantifying physical activity, verification of activity cut points in relation to different physical activity measures are also needed.

4. The study of McKenzie et al.[45] suggests that physical activity levels may vary in children from different ethnic backgrounds. European-American children engaged in higher levels of physical activity compared with their Mexican-American counterparts. Possible reasons included Mexican-American

children enjoying physical activity less, having lower self-efficacy and a greater difficulty in overcoming barriers compared with European-American children.[49] Research into ethnicity and school playtime physical activity is required to address this issue further.

5. The stage of the child's schooling may influence physical activity levels. The study of McKenzie et al.[45] showed that, although elementary children had shorter playtime duration than pre-schoolers, they engaged in higher levels of physical activity. It has been suggested that young children use playtime as an opportunity to practise physical skills, develop motor skills and to become confident in their movement.[50] Conversely, older children use playtime to develop social skills and to play games with other children.[51] Determining the physical activity levels of children of different ages during playtime would enable educators and health promoters alike to establish whether interventions are needed at different stages of schooling.

In general, the findings from these studies suggest that playtimes can contribute up to one-third of daily MVPA, although strategies for increasing physical activity levels are needed if playtime is to achieve its potential in promoting physical activity to children.

5. Playtime-Based School Interventions Promoting Physical Activity

Blatchford[23] noted that whilst educational policies have focused on curricular areas such as literacy and numeracy, scant attention has been paid towards the improvement of school playtimes. Individual schools have initiated many changes to school play, with the provision of equipment being a common strategy. However, the wider benefit of the playground for teaching physical skills and promoting peer and other social interactions with school staff through informal and formal games is greatly under researched.[24] Surprisingly, it is only recently that playtime-based interventions have been investigated as a way of increasing physical activity through the use of playground markings[52] and structured fitness playtimes (table III).[53]

In the UK, Stratton[52] investigated the short-term effects of playground markings as a strategy for increasing the physical activity of primary-aged (4–11 years) school children. He found that playground markings increased the amount of time that children spent in MVPA by 18 minutes a day compared with their pre-intervention activity levels.[52] This equated to children spending 45% of their time in the playground participating in MVPA.[52] Levels of VPA increased by 40% and 60% in infant and junior schools, respectively, following the playground marking intervention.[56] This is of note, as VPA promotes muscular strength and bone health over and above that expected from participating in moderate-intensity physical activity.[28] Additionally, total energy expenditure and rate of energy expenditure was found to increase by 35% and 6%, respectively, following a playground marking intervention.[55]

Whilst the playground marking interventions increased physical activity levels, the studies were limited by their short-term follow-up periods where a novelty effect of the environment may have influenced children's physical activity levels. The longer-term effects of these interventions were not investigated. While playtime duration was used as a covariate in the analyses,[52,53,55] the impact of the interventions on playtime supervisors' encouragement of playtime activity, management or organisation of the playground, and the individual school's playtime regulations were not detailed. These factors could also have positively influenced physical activity levels. Further research is needed to address these issues to determine the longer-term effects of playground marking interventions and to address the impact that the management of the playground environment has on physical activity during playtime.

In the US, Scruggs et al.[53] utilised fitness breaks (FB) in an attempt to increase children's physical activity. The use of FB was first suggested by Gabbard[57] and aimed to increase children's VPA. FB were 15 minutes in duration and consisted of a 400m obstacle course that contained moderate-to-vigorous intensity activities such as running, crawling over objects and fitness activities such as crunches and

Table III. Summary of intervention studies investigating children's physical activity (PA) during playtimes. Table ordered by sample size (smallest to largest)

Study	Participants	Design and PA assessment	Intervention	Results	Other comments
Scruggs et al[53]	10 boys, 17 girls – grade 5 (boys M age = 11.03 ± 0.32; Girls M age = 10.91 ± 0.27) [US]	HR telemetry and pedometers Morning playtime, lunch and FB monitored for 3 consecutive days Repeated measures ANOVAs	FB	FB MVPA > morning and lunch playtime MVPA FB VPA > morning and lunch playtime VPA Boys FB enjoyment > girls Boys FB VPA > girls	Intervention benefited both boys and girls PA Girls lower enjoyment of FB Limited generalisability Short-term intervention Possible novelty effects Small sample size
Connolly and McKenzie[54]	56 elementary children (US)	Self-report, accelerometry, direct observation Each day: 1 games playtime, 1 standard playtime Paired t-tests	Games playtime	Games PA > standard PA Boys self-report PA ↔ girls Games playtime enjoyment ↔ standard playtime Boys enjoyment ↔ girls enjoyment (both playtimes)	Benefited boys and girls Enjoyment similar for both playtime types Possible novelty effects Short-term intervention Games played not detailed
Stratton[52]	Exp: 18 boys, 18 girls Con: 12 boys, 12 girls Aged 5–7y (England)	3 children per school monitored each day HR telemetry 4wk follow-up ANCOVA	Playground markings	Play duration increased during intervention MVPA increased 18 min/d post-intervention Exp MVPA and VPA increased 11.1% and 4.7%	PA increased after painting Play time duration increased Short-term follow-up Possible novelty effects
Stratton and Leonard[55]	32 boys, 30 girls aged 5–7y (England)	1wk pre- and 1wk post-painting measures taken HR telemetry RM ANCOVA (covariates: BM and play duration)	Playground markings	Rate of EE increased 6.1% during intervention Total EE increased 35% during intervention Boys total EE 23% higher than girls	Intervention benefited both sexes Short-term follow-up Most effective markings unknown Potential novelty effects
Stratton and Mullan[56]	Exp: 60 boys, 60 girls (4 schools) Con: 60 boys, 60 girls (4 schools) Aged 4–11y (Wales, England)	Baseline: 4wk pre-painting Intervention: 4wk post-painting HR telemetry 3 ANCOVAs (covariates: BM and play duration)	Playground markings	Boys PA > girls Exp MVPA > Con MVPA Exp VPA > Con VPA Exp MVPA increased from 36.7% to 50.3% Con MVPA decreased from 39.9% to 33.4%	Painting benefited both sexes Possible seasonal effects on control groups PA levels Increases in MVPA may link to novelty effects Short-term follow-up

ANOVA = analysis of variance; **ANCOVA** = analysis of covariance; **BM** = body mass; **Con** = control group; **EE** = energy expenditure; **Exp** = experimental group; **FB** = fitness breaks; **HR** = heart rate; **M** = mean; **MVPA** = moderate-to-vigorous physical activity; **RM** = repeated measures; **VPA** = vigorous physical activity; ↔ indicates no significant difference; > indicates significantly greater than; < indicates significantly less than.

push-up claps. Children's enjoyment of the FB and playtime was also measured. Physical activity increased in the FB for boys and girls, although higher physical activity levels were observed in boys.[53] Moreover, the FB encouraged the children to engage in MVPA for 50% of playtime. The authors concluded that the use of FB in primary schools would substantially contribute to the children's daily physical activity levels.

Whilst the FB breaks increased children's physical activity, the duration of the programme was 3 days and the novelty of undertaking the FB may account for some of the increases seen. Moreover, due to the nature and structure of the FB, it is likely that such an intervention requires continuous organisation and supervision of school staff. This could mean that it is less sustainable than environmental approaches such as playground markings, which appear to warrant less supervision and instruction for the children to use safely. Additionally, whilst there was no difference between the boys' and girls' enjoyment for playtime, girls' enjoyment of the FB was significantly lower than boys'. Boys may receive greater benefits from the FB, though further research is needed to address this.

Connolly and McKenzie[54] investigated the effects of a games intervention, implemented by playground supervisors, on elementary school children's physical activity levels. Children were more active during the games programme than standard playtime, and there were no significant sex differences between the children's self-reported physical activity. Additionally, there were no differences in the children's enjoyment of the games playtime and standard playtime. This highlights that a games playtime may have similar benefits for both boys and girls in terms of physical activity levels and enjoyment, but further research is needed. This approach is mainly limited by the need for high levels of child supervision by school staff. Moreover, novelty effects may explain some of the increases seen in the children's physical activity.

In the limited studies conducted to date, playground markings and FB intervention studies have stimulated short-term increases in physical activity levels of boys and girls. The main advantage of playground markings are that they give children of all ages the opportunity to engage in the activity of their choice, and through selecting enjoyable activities they are more likely to sustain their participation.[5,52] Since markings are not sex specific, this may explain in part why both sexes benefited from the markings. The main disadvantage is the cost involved, as schools consistently experience competing budgetary demands.

The advantages of the FB intervention are the opportunities for children to engage in a variety of activities that promote physical exertion using different parts of the body, and the development of different physical skills.[53] However, girls did not enjoy the FB as much as the boys, as its structure appealed more to the boys' competitive nature.[53] Enjoyment is a central facet to participation behaviours, and if girls do not experience a positive affective response,[58] they may lack motivation and avoid taking part in physical activity. Secondly, the size of the obstacle course used in the FB study would occupy a large proportion of available space in smaller playgrounds. This could affect the physical activity levels of other children on the playground due to a lack of play space. The effects on physical activity of reducing the scale of the obstacle course to suit smaller playground needs would need addressing in schools looking to use this approach as a playtime intervention.

6. Future Research Directions

Even with the observed benefits of the playground-based interventions, there are a number of key issues that future research could concentrate on to further knowledge of children's activity levels during playtime:

- The research has currently focused on the short-term benefits of the interventions, with the longest follow-up reported in the literature being 6 weeks. The extent of possible novelty effects of the playground markings and the FB on physical activity levels, and the medium- and long-term benefits of the interventions, warrant further attention.

- The types of markings or activities that are most effective in promoting physical activity are currently unknown. However, the school's playground culture or the area where they live might affect children's preferences for different activities. The size and design of the original playground would also have an impact on children's physical activity levels. Future research may need to consider matching playground markings or activities to child and schools needs in order to be effective in promoting physical activity.
- The effect of seasonal influences on children's physical activity has attracted some attention,[25,59] although further research is required.
- Current studies using playground interventions have assessed small numbers of children in only a couple of geographical areas in the UK and the US. This lack of evidence limits the ability to generalise the results across child populations as a whole. Larger population-based studies using similar interventions would increase the existing knowledge concerning the benefits of school-based interventions. It is acknowledged, however, that the cost of implementing playtime strategies might be a limiting factor.

The extent to which the monitoring of children's physical activity on 1 day is representative of their daily school playtime physical activity requires further investigation. This has been one of the main caveats of studies investigating school playtime physical activity levels. In addition, a number of studies that have reported children's physical activity during playtime have focused on one playtime. Monitoring all the available playtimes across the school day would determine playtime's contribution to physical activity and enable more direct comparisons of children's playtime activity across different studies.

The effect that the provision of equipment in the school playground has on children's physical activity and playground behaviour is currently under-researched. Zask et al.[48] found that the ratio of balls to pupils was significantly correlated with VPA, suggesting that supplying sufficient equipment during playtime can influence and encourage children's physical activity. Therefore, studies that supply equipment such as bats, balls and skipping ropes, for example, on one day and which restrict children's access to such equipment the following day could determine how beneficial such an intervention would be on children's physical activity and their behaviour.

The role that adults supervising playtime play in the promotion of physical activity has been largely neglected. In one study that addressed this issue, children complied with and maintained their physical activity participation following adult encouragement to be physically active during playtime.[45] However, since the confidence and the skills of these adults to give prompts could vary, the training supervisors could develop these skills and serve to expand their knowledge of children's games, which may increase the activity levels of children across the playground environment. In the UK, playground supervisors have undergone training programmes, although the extent to which the training benefits physical activity promotion has not been reported.

The influence that school size has on physical activity requires investigation. Zask et al.[48] found that physical activity was higher in small schools compared with large schools. Social inclusion may be stronger in small schools due to smaller numbers of children, so children who are less sporty than their peers are included in games, whilst in larger schools they may be excluded. This suggests that opportunities for social interaction may have an important influence on physical activity during playtime, and studies should look at the playground behaviour of children to further knowledge of underlying reasons for differences in children's playtime physical activity.

7. Conclusion

The limited school-based investigations that have been reported in the literature suggest that a number of factors affect children's physical activity levels during playtime. These factors include sex, age, prompts received, seasons, equipment provision, playground space, playtime duration and training. However, no studies to date have considered the impact of all these factors together. Whilst such studies would be complex, investigations that attempt such designs would provide a clearer understanding of the factors that contribute towards children's physical activity during playtime. These complex research designs would further enable physical activity promoters to detect the most effective approaches to stimulating activity during school playtime. More effective evidence- and school-based interventions, which aim to increase children's physically active play during playtime, are required.

Acknowledgements

The authors would like to thank the anonymous reviewers for their insightful comments on earlier drafts of this review. No sources of funding were used to assist in the preparation of this review. The authors have no conflicts of interest that are directly relevant to the content of this review.

References

1. Blair SN, Connelly JC. How much physical activity should we do? The case for moderate amounts and intensities of physical activity. Res Q Exerc Sport 1996; 67 (2): 193-205
2. Blair SN, Kohl HW, Paffenbarger RS, et al. Physical fitness and all-cause mortality: a prospective study of healthy men and women. JAMA 1989; 262: 2395-401
3. Riddoch CJ, Boreham C. Physical activity, physical fitness and children's health: current concepts. In: Armstrong N, van Mechelen W, editors. Pediatric exercise science and medicine. Oxford: Oxford University Press, 2000: 243-52
4. Taylor AH. Physical activity, anxiety and stress. In: Biddle SJH, Fox KR, Boutcher SH, editors. Physical activity and psychological well-being. London: Routledge, 2000: 10-45
5. Sallis JF, Patrick K. Physical activity guidelines for adolescents: consensus statement. Pediatr Exerc Sci 1994; 6 (4): 302-14
6. Harro M, Riddoch CJ. Physical activity. In: Armstrong N, van Mechelen W, editors. Pediatric exercise science and medicine. Oxford: Oxford University Press, 2000: 77-84
7. Cale LA, Almond L. Children's physical activity levels: a review of studies conducted on British children. Phys Educ Rev 1992; 15 (2): 111-8
8. Armstrong N, Welsman J. Young people and physical activity. Oxford: Oxford University Press, 1997
9. Gavarry O, Giacomoni M, Bernard T, et al. Habitual physical activity in children and adolescents during school and free days. Med Sci Sports Exerc 2003; 35 (3): 525-31
10. Riddoch CJ, Andersen LB, Wedderkopp N, et al. Physical activity levels and patterns of 9- and 15-year-old European children. Med Sci Sports Exerc 2004; 36 (1): 86-92
11. Bailey RC, Olson J, Pepper SL, et al. The level and tempo of children's physical activities: an observational study. Med Sci Sports Exerc 1995; 27 (7): 1033-41
12. Sallo M, Silla R. Physical activity with moderate to vigorous intensity in preschool and first-grade schoolchildren. Pediatr Exerc Sci 1997; 9 (1): 44-54
13. Pate RR, Long BJ, Heath G. Descriptive epidemiology of physical activity in adolescents. Pediatr Exerc Sci 1994; 6 (4): 434-47
14. Sleap M, Warburton P. Physical activity levels of 5-11 year-old children in England: cumulative evidence from three direct observation studies. Int J Sports Med 1996; 17 (4): 248-53
15. Marshall SJ, Biddle SJH, Sallis JF, et al. Clustering of sedentary behaviours and physical activity among youth: a cross-national study. Pediatr Exerc Sci 2002; 14 (4): 401-17
16. Dale D, Corbin CB, Dale KS. Restricting opportunities to be active during school time: do children compensate by increasing physical activity levels after school? Res Q Exerc Sport 2000; 71 (3): 240-8
17. Sarkin JA, McKenzie TL, Sallis JF. Gender differences in physical activity during fifth-grade physical education and recess periods. J Teach Phys Educ 1997; 17: 99-106
18. McKenzie TL, Sallis JF, Kolody B, et al. Long-term effects of a physical education curriculum and staff development program: SPARK. Res Q Exerc Sport 1997; 68 (4): 280-91
19. Kelder SH, Mitchell PD, McKenzie TL, et al. Long-term implementation of the CATCH physical education program. Health Educ Behav 2003; 30 (4): 463-75
20. McKenzie TL, Sallis JF, Prochaska JJ, et al. Evaluation of a two-year middle-school physical education intervention: M-SPAN. Med Sci Sport Exerc 2004; 36 (8): 1382-8
21. Stone EJ, McKenzie TL, Welk GJ, et al. Effects of physical activity interventions in youth: review and synthesis. Am J Prev Med 1998; 15 (4): 298-315
22. Hardman K, Marshall J. The state and status of physical education in schools in international context. Eur Phys Educ Rev 2000; 6 (3): 203-29
23. Blatchford P. Playtime in the primary school: problems and improvements. Berkshire: NFER-Nelson, 1989
24. Blatchford P, Baines E, Pellegrini AD. The social context of school playground games: sex and ethnic difference, and changes over time after entry to junior school. Br J Dev Psychol 2003; 21: 481-505
25. Stratton G. A preliminary study of children's physical activity in one urban primary school playground: differences by sex and season. J Sport Pedag 1999; 2 (1): 71-81
26. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise and physical fitness: definitions and distinctions for health-related research. Public Health Rep 1985; 100: 136-41
27. Welk GJ, Corbin CB, Dale D. Measurement issues in the assessment of physical activity in children. Res Q Exerc Sport 2000; 71 (2): 59-73
28. Biddle SJH, Sallis J, Cavill N. Young and active: physical activity guidelines for young people in the UK. London: Health Education Authority, 1998
29. Ridgers ND, Stratton G, Fairclough SJ. Assessing physical activity levels during recess using accelerometry. Prev Med 2005; 41 (1): 102-7
30. Boulton MJ. Participation in playground activities at middle school. Educ Res 1992; 34 (3): 167-81
31. Pate RR, Baranowski T, Dowda M, et al. Tracking of physical activity in young children. Med Sci Sport Exerc 1996; 28 (1): 92-6
32. Stratton G, Ridgers ND. Sporting playgrounds project: an overview. Br J Teach Phys Educ 2003; 24: 23-5
33. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. Sports Med 2001; 31 (6): 439-54

34. Puhl J, Greaves K, Hoyt M, et al. Children's Activity rating Scale (CARS): description and calibration. Res Q Exerc Sport 1990; 61 (1): 26-36
35. Janz KF. Use of heart rate monitors to assess physical activity. In: Welk GJ, editor. Physical activity assessments for health-related research. Champaign (IL): Human Kinetics, 2002: 143-61
36. Welk GJ. Use of accelerometry-based activity monitors to assess physical activity. In: Welk GJ, editor. Physical activity assessments for health-related research. Champaign (IL): Human Kinetics, 2002: 125-41
37. Nilsson A, Ekelund U, Yngve A, et al. Assessing physical activity among children with accelerometers using different time sampling intervals and placements. Pediatr Exerc Sci 2002; 14 (1): 87-96
38. Ott AE, Pate RR, Trost SG, et al. The use of uniaxial and triaxial accelerometers to measure children's 'free-play' physical activity. Pediatr Exerc Sci 2000; 12: 360-70
39. Rowlands AV. Field methods of assessing physical activity and energy balance. In: Eston RG, Reilly T, editors. Kinanthropometry and exercise physiology laboratory manual. Tests, procedures and data, volume one, anthropometry. London: Routledge, 2001: 151-70
40. Stratton G, Mota J. Girls' physical activity during primary school playtime: a validation study using systematic observation and heart rate telemetry. J Hum Movement Stud 2000; 38 (3): 109-21
41. Santos P, Silva P, Guerra S, et al. Gender differences in physical activity during recess time. Rev Port Ciên Des 2003; 3: S150-1
42. Mota J, Stratton G. Gender differences in physical activity at primary school recess in Portuguese Primary Schools. Rev Port Ciên Des 2000; 3: S150
43. Johns DP, Ha AS. Home and recess physical activity of Hong Kong children. Res Q Exerc Sport 1999; 70 (3): 319-23
44. Hovell MF, Bursick JH, Sharkey R, et al. An evaluation of elementary students' voluntary physical activity during recess. Res Q 1978; 49: 460-74
45. McKenzie TL, Sallis JF, Elder JP, et al. Physical activity levels and prompts in young children at recess: a two-year study of a bi-ethnic sample. Res Q Exerc Sport 1997; 68 (3): 195-202
46. Kraft RE. Children at play: behaviour of children at recess. J Phys Educ Recr Dance 1989; 60: 21-4
47. McKenzie TL, Marshall SJ, Sallis JF, et al. Leisure-time physical activity in school environments: an observation study using SOPLAY. Prev Med 2000; 30: 70-7
48. Zask A, van Beurden E, Barnett L, et al. Active school playgrounds: myth or reality? Results of the 'Move It Groove It' Project. Prev Med 2001; 33 (5): 402-8
49. Morgan CF, McKenzie TL, Sallis JF, et al. Personal, social and environmental correlates of physical activity in a bi-ethnic sample of adolescents. Pediatr Exerc Sci 2003; 15 (3): 288-301
50. Lindon J. Understanding children's play. Cheltenham: Nelson Thornes, 2001
51. Pellegrini AD. School recess and playground behaviour: developmental and educational roles. New York: SUNY Press, 1995
52. Stratton G. Promoting children's physical activity in primary school: an intervention study using playground markings. Ergonomics 2000; 43 (10): 1538-46
53. Scruggs PW, Beveridge SK, Watson DL. Increasing children's school time physical activity using structured fitness breaks. Pediatr Exerc Sci 2003; 15 (2): 156-69
54. Connolly P, McKenzie TL. Effects of a games intervention on the physical activity levels of children at recess. Res Q Exerc Sport 1995; 66 Suppl.: A-60
55. Stratton G, Leonard J. The metabolism of the elementary school playground: the effects of an intervention study on children's energy expenditure. Pediatr Exerc Sci 2002; 14 (2): 170-80
56. Stratton G, Mullan E. The effect of playground markings on children's physical activity levels. Rev Port Ciên Des 2003; 3: S137
57. Gabbard C. Enhance your elementary programme with a fitness break. J Phys Educ Recr Dance 1992; 63: 11-2
58. Weiss MR, Ferrer-Caja E. Motivational orientations and sport behaviour. In: Horn TS, editor. Advances in sport psychology. Champaign (IL): Human Kinetics, 2002: 101-83
59. Riddoch CJ, Mahoney C, Murphy N, et al. The physical activity patterns of Northern Irish schoolchildren aged 11-16 years. Pediatr Exerc Sci 1991; 3 (4): 300-9

Correspondence and offprints: *Nicola D. Ridgers*, Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Henry Cotton Campus, 15-21 Webster Street, Liverpool, L3 2ET, UK.
E-mail: n.ridgers@ljmu.ac.uk

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Preventive Medicine 42 (2006) 372–374
Preventive Medicine
www.elsevier.com/locate/ypmed

Day-to-day and seasonal variability of physical activity during school recess

Nicola D. Ridgers [a,c,*], Gareth Stratton [a,c], Emily Clark [a], Stuart J. Fairclough [b,c], David J. Richardson [a,c]

[a] Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Henry Cotton Campus, 15-21 Webster Street, Liverpool L3 2ET, UK
[b] School of Physical Education, Sport and Dance, Liverpool John Moores University, I.M. Marsh Campus, Barkhill Road, Liverpool L17 6BD, UK
[c] The REACH Group, Liverpool John Moores University, UK

Available online 28 February 2006

Abstract

Objective. Children's physical activity levels are difficult to establish on a day-to-day or season-to-season basis. Most studies have attempted to measure reliability in habitual settings. This study investigated the variability in children's physical activity during recess.

Methods. Fifteen boys and 19 girls (aged 6 to 11 years) from 2 schools in North West England wore heart rate monitors for 5 consecutive days in summer and winter terms to assess day-to-day and seasonal variability during school recess. Data were collected in 2004. Repeated measures ANOVA's and intraclass correlations (ICC) analysed the day-to-day and seasonal variability in children's moderate-to-vigorous (MVPA) and vigorous physical activity (VPA) data.

Results. There were no significant differences in children's MVPA and VPA across days and seasons. ICCs for MVPA across 2 days ranged from 0.75 to 0.85 in summer, and from 0.53 to 0.81 in winter. Three-day MVPA ICCs were 0.83 in summer and 0.71 in winter.

Conclusions. The results revealed no significant variation in children's recess physical activity levels across days and seasons. Whilst children were free to choose their recess activities in school, the results suggested that children were relatively consistent in their choices, limiting physical activity variability.

Keywords: Children; Recess; Physical activity variability; Seasons; Schools

Introduction

Many factors can influence children's physical activity behaviours and the stability they demonstrate over time (Baranowski and de Moor, 2000), complicating the assessment of physical activity (Sallis et al., 1995). These include seasonal factors and activity participation. The stability of children's habitual physical activity has received attention, though the stability of physical activity within certain contexts, to the best of our knowledge, has not been investigated. Stable behaviours demonstrated in different contexts would lead to shorter monitoring periods (Tudor-Locke et al., 2005). One such context is recess, which occurs on a daily basis (Stratton, 1999). However, the day-to-day and seasonal variability of children's physical activity during recess has not been reported. Therefore, the purpose of this study was to investigate the variability of children's physical activity during recess in the summer and winter, and to examine how many days of monitoring are needed to determine children's physical activity levels in recess.

Method

Participants and settings

Thirty-four children (15 boys, 19 girls) randomly selected from 2 primary schools in northwest England returned signed informed parental consent to participate in the study. The schools were located in the same geographical area of high social and economic deprivation in a large urban city.

All children participating in the study followed their normal daily school routine. Physical activity was monitored during morning and lunch recess for 5 consecutive days in the summer and winter term, respectively. The mean recess durations were 86 ± 11.8 and 80 ± 15.3 min in the summer and winter, respectively. The average temperatures were 19°C and 10°C for summer and winter recess. Throughout the study, small pieces of sports equipment such as skipping ropes and footballs were available. The research protocol received ethical approval from the University Ethics Committee.

* Corresponding author. Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Henry Cotton Campus, 15-21 Webster Street, Liverpool L3 2ET, UK. Fax: +44 151 231 5357.
E-mail address: n.ridgers@ljmu.ac.uk (N.D. Ridgers).

0091-7435/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.ypmed.2006.01.017

Instrumentation

The Polar Team heart rate telemetry system (Polar Electro Oy, Kempele, Finland) measured the children's physiological response to school recess. Heart rate was recorded every 5 s. Resting heart rate (RHR) was determined by averaging the 5 lowest recorded heart rate values recorded for each individual during each testing day (Janz, 2002). Heart rate reserve (HRR) values of 50 (HRR_{50}) and 75 (HRR_{75}) percent were used as threshold values to represent moderate-to-vigorous physical activity (MVPA) and vigorous-physical activity (VPA), respectively. Maximum heart rate was set at 200 beats min^{-1}.

Procedure

Seventeen children per school were randomly selected to participate in the study. Recess physical activity was monitored on five consecutive school days (Monday to Friday) in the summer (June 2004) and winter terms (November 2004). Measurements of body mass and stature (to the nearest 0.1 kg and 0.1 cm, respectively) were recorded using Seca scales (Seca Ltd., Birmingham, UK) and the Leicester Height Measure (Seca Ltd., Birmingham, UK) on the first day of testing in each school term prior to fitting the heart rate monitors. The monitors were attached to the children using an adjustable elastic chest strap at the start of each school day. The children were then asked to follow their normal daily routine. Children wore the monitors during the morning and lunch recess periods, and were removed at the end of the school day.

Statistical analysis

Due to student absence in the summer term, and weather disruption in the winter term, three complete consecutive days (Monday to Wednesday) were obtained and used for further analysis. Heart rate data were downloaded using the Polar Team System Interface and analysed using the Polar Precision Performance™ 3.0 Software (Polar Electro Oy, Kempele, Finland). Of the 34 children monitored in this study, 20 of the sampled children (10 boys, 10 girls) provided complete data sets (Monday to Wednesday in both terms) and were retained for analysis in SPSS version 12. The dependant variables were percentage of time spent in MVPA and VPA. The independent variables were season (summer, winter) and day (Monday, Tuesday, Wednesday). Boys and girls data were combined together to increase statistical power due to the small sample size. Intraclass correlations (ICC) determined whether the percentage of time children spent in MVPA and VPA was different across monitored days in both seasons. Values above 0.70 were considered as demonstrating acceptable reliability (Vincent, 1999). A 3 × 2 (day × season) repeated measures analysis of covariance (RM ANCOVA) analysed day and seasonal differences on the dependent variables (with BMI as the covariate). The alpha level was set at $P < 0.05$.

Results

The mean (SD) values for the children's anthropometric and physiological characteristics are shown in Table 1.

MVPA

ICC

In summer, the ICC ranged from 0.71 to 0.85 for 2 days, and 0.83 for 3 days. In winter, the ICC ranged from 0.53 to 0.81 for 2 days, and 0.71 for 3 days.

RM ANCOVA

There were no significant main effects for day, $F(2,34) = 0.48$; $P > 0.05$, or season, $F(1,17) = 0.17$; $P > 0.05$. There was a trend for physical activity levels to be higher in winter than summer, though this trend was not significant (Table 2). The day × season interaction was not significant ($P > 0.05$).

VPA

ICC

In summer, the ICC ranged from 0.42 to 0.57 for 2 days, and 0.59 for 3 days. In winter, the ICC ranged from 0.51 to 0.84 for 2 days, and 0.79 for 3 days.

RM ANCOVA

There were no significant main effects for day, $F(2,34) = 0.48$; $P > 0.05$, or season, $F(1,17) = 0.42$; $P > 0.05$. There was a trend for children to be more vigorously active in winter than summer, though this trend was not significant (Table 2). The day × season interaction was not significant ($P > 0.05$).

Discussion

The study found no significant daily variation in children's physical activity levels during recess. Whilst numerous social and environmental factors can influence recess variability, the results suggest that children's physical activity during recess is similar across days. Children can freely choose their recess activities, and the results suggest that children are consistent in their choices, possibly due to playground hierarchies that dictate activity choices (Blatchford, 1998), reducing the variability recorded.

There was a trend, albeit non-significant, for physical activity to be higher in winter than summer, supporting the findings of Stratton (1999) and contrasting habitual studies which report higher physical activity levels in the summer (Hagger et al., 1997; Loucaides et al., 2003). Recess seasonal variation may be attributable to a thermoregulatory need to keep warm during the winter, for children do not have the choice of

Table 1
Descriptives mean (SD) of complete and incomplete data

		Age (years)	Body mass (kg)	Stature (m)	Body mass index ($kg \cdot m^{-2}$)	MVPA (% recess time)	VPA (% recess time)
Summer	Complete data	7.8 (1.0)	28.6 (4.9)	1.32 (0.07)	16.3 (2.0)	24.5 (13.5)	6.4 (5.7)
	Incomplete data	7.4 (1.2)	30.1 (5.5)	1.32 (0.08)	17.3 (2.9)	23.5 (11.8)	6.0 (6.2)
Winter	Complete data	8.4 (1.1)	33.2 (6.4)	1.34 (0.07)	18.3 (2.6)	25.6 (14.6)	9.1 (9.4)
	Incomplete data	8.1 (1.1)	31.4 (5.5)	1.34 (0.08)	17.7 (3.1)	19.5 (13.7)	6.2 (6.9)

No significant differences between complete and incomplete data sets on all descriptives, $P > 0.05$.

Table 2
Percentage of time spent in MVPA and VPA during recess according to season and day mean (SD)

Season	Day	MVPA	VPA
Summer	1	22.5 (15.1)	6.7 (6.6)
	2	28.6 (17.9)	8.1 (10.6)
	3	22.6 (13.7)	4.4 (4.8)
Winter	1	25.6 (16.1)	9.9 (12.1)
	2	26.3 (21.2)	8.1 (11.3)
	3	25.1 (17.6)	9.4 (9.6)

No significant differences between days or seasons on MVPA and VPA, $P > 0.05$.

playing inside on cold days (Thomson, 2004). However, in light of the non-significant seasonal variation, future studies may not need to correct for seasonal effects when examining recess physical activity.

There is no consensus as to how many days of monitoring are needed to represent typical recess activity. For VPA alone, it appears that more than 1 day is required, and further studies are needed to establish the number needed for acceptable reliability. However, for MVPA, the present results suggest that 1 day of monitoring may be representative of typical activity during recess.

This study has several limitations. It used a small sample size and did not investigate gender differences, which may be a source of variability during recess. Secondly, the study used heart rate, which can be influenced by factors other than physical activity. Future studies should use objective measures such as accelerometry with larger samples to determine daily and seasonal variability during recess.

Conclusion

Studies may not need to correct for seasonal effects on children's physical activity during school recess. Furthermore, assessing children's physical activity levels during recess on 1 day may be representative of typical recess activity.

Acknowledgments

This project was funded by Liverpool City Council Department for Life-Long Learning and Sport England. We would like to thank Gary White of Liverpool Sport Action Zone, John Curley for assistance in the data collection, and all the children who participated in the study.

References

Baranowski, T., de Moor, C., 2000. How many days was that? Intra-individual variability and physical activity assessment. Res. Q. Exerc. Sport. 71, 74–78.

Blatchford, P., 1998. Social Life in School: Pupil Experiences of Breaktime and Recess from 6 to 16. Falmer Press, London.

Hagger, M., Cale, L., Almond, L., 1997. Children's physical activity levels and attitudes towards physical activity. Eur. Phys. Educ. Rev. 3, 144–164.

Janz, K.F., 2002. Use of heart rate monitors to assess physical activity. In: Welk, G.J. (Ed.), Physical Activity Assessments for Health-Related Research. Human Kinetics, Champaign, IL, pp. 143–161.

Loucaides, C.A., Chedzoy, S.M., Bennett, N., 2003. Pedometer-assessed physical activity in Cypriot children. Eur. Phys. Educ. Rev. 9, 43–55.

Sallis, J.F., Berry, C.C., Broyles, S.L., McKenzie, T.L., Nader, P.R., 1995. Variability and tracking in physical activity over 2 years in young children. Med. Sci. Sports. Exerc. 27, 1042–1049.

Stratton, G., 1999. A preliminary study of children's physical activity in one urban primary school playground: differences by sex and season. J. Sport. Ped. 2, 71–81.

Thomson, S., 2004. Just another classroom? Observations of primary school playgrounds. In: Vertinsky, P., Bale, J. (Eds.), Sites of Sport: Space, Place, Experience. Routledge, London, pp. 73–84.

Tudor-Locke, C., Burkett, L., Reis, J.P., Ainsworth, B.E., Macera, C.A., Wilson, D.K., 2005. How many days of monitoring predict weekly physical activity in adults? Prev. Med. 40, 293–298.

Vincent, W.J., 1999. Statistics in Kinesiology. Human Kinetics, Champaign, IL.

Available online at www.sciencedirect.com
ScienceDirect
Preventive Medicine xx (2007) xxx–xxx
Preventive Medicine
www.elsevier.com/locate/ypmed

Long-term effects of a playground markings and physical structures on children's recess physical activity levels

Nicola D. Ridgers [a,c,*], Gareth Stratton [a,c], Stuart J. Fairclough [b,c], Jos W.R. Twisk [d,e]

[a] *Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Henry Cotton Campus, 15-21 Webster Street, Liverpool L3 2ET, UK*
[b] *Centre for Physical and Outdoor Education, Liverpool John Moores University, I.M. Marsh Campus, Barkhill Road, Liverpool, L17 6BD, UK*
[c] *The REACH Group, Liverpool John Moores University, UK*
[d] *Department of Clinical Epidemiology and Biostatistics, VU University Medical Centre, Amsterdam, The Netherlands*
[e] *Department of Methodology and Applied Biostatistics, Institute of Health Services, Vrije University, Amsterdam, The Netherlands*

Abstract

Objective. The aim of the study was to investigate the impact of a playground redesign intervention across time on children's recess physical activity levels using combined physical activity measures and to evaluate the potential influence of covariates on the intervention effect.

Method. Fifteen schools located in areas of high deprivation in one large city in England each received £20,000 through a national £10 million Sporting Playgrounds Initiative to redesign the playground environment based on a multicolored zonal design. Eleven schools served as matched socioeconomic controls. Physical activity levels during recess were quantified using heart rate telemetry and accelerometry at baseline, 6 weeks and 6 months following the playground redesign intervention. Data were collected between July 2003 and January 2005 and analyzed using multilevel modeling.

Results. Statistically significant intervention effects were found across time for moderate-to-vigorous and vigorous physical activity assessed using both heart rate and accelerometry.

Conclusions. The results suggest that a playground redesign, which utilizes multicolor playground markings and physical structures, is a suitable stimulus for increasing children's school recess physical activity levels.

Keywords: Children; School; Multilevel modeling; Recess

Introduction

Physical activity is an integral component of a healthy lifestyle (Strong et al., 2005). Concern has been expressed that a large proportion of children are insufficiently active to gain health benefits (Andersen et al., 2006). One appropriate and convenient setting for the promotion of physical activity to children is the school environment (Wechsler et al., 2000). Physical education and recess provide the two main opportunities for elementary school-based physical activity. The sustainability and effectiveness of physical education interventions have been documented (McKenzie et al., 1997b), yet little data detail the impact of longitudinal recess-based interventions on activity levels (Ridgers et al., 2006b).

Recess-based interventions have used environmental interventions such as playground markings (Stratton, 2000; Stratton and Mullan, 2005), obstacle courses (Scruggs et al., 2002) and equipment provision (Verstraete et al., 2006) to increase activity on the premise that exposure to supportive physical environments can facilitate physically activity behaviors. Short-term increases in physical activity levels have been reported; however, to the best of our knowledge, no data currently exist which evaluate the longer-term effectiveness of such interventions on recess physical activity levels. The evaluation of the effectiveness and sustainability of recess interventions is required, identifying whether short-term increases are sustained or influenced by novelty effects, as this information could be critical in utilizing recess as a physical activity promotion context.

* Corresponding author. Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Henry Cotton Campus, 15-21 Webster Street, Liverpool, L3 2ET, UK. Fax: +44 151 231 4353.
E-mail address: n.ridgers@ljmu.ac.uk (N.D. Ridgers).

0091-7435/$ - see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.ypmed.2007.01.009

Please cite this article as: Ridgers, N.D. et al. Long-term effects of a playground markings and physical structures on children's recess physical activity levels. Prev. Med. (2007), doi:10.1016/j.ypmed.2007.01.009

This study forms part of a longitudinal project that is investigating the impact of a playground intervention on children's recess physical activity levels. Physical activity was measured objectively using heart rate and accelerometry to investigate the impact on the intervention on both physiological and mechanical stress. The purpose of study was twofold: (a) to investigate the effect of a playground intervention on children's recess moderate-to-vigorous (MVPA) and vigorous physical activity (VPA) engagement over time, and (b) to evaluate the potential influence of covariates on the intervention effect.

Methods

Participants and settings

Two hundred and thirty-two boys and 238 girls recruited from 26 elementary schools from one large city in the North West England returned signed parental informed consent to participate in the study. All schools were located within one Local Authority that was involved in a national £10 million Sporting Playgrounds' Initiative. Funding was allocated to Local Authorities situated in areas of high social and economic deprivation in order to improve the playground environment of schools in their locality. The schools in this study were located in one of the most deprived areas in the country (Noble et al., 2004).

Intervention

Fifteen schools (130 boys, 126 girls) each received £20,000 to redesign the playground environment based on the sporting playground zonal design. This involved dividing the playground into three specific color-coded areas: (a) a red sports area, (b) a blue multi-activity area and (c) a yellow quiet play zone. The markings were relevant to the physical activity behavior and social behaviors desired for each area (Stratton and Ridgers, 2003). The physical structures that the school received included soccer goal posts, basketball hoops and fencing around the red sports area and seating in the yellow quiet area (Stratton and Ridgers, 2003). The remaining eleven schools (102 boys, 112 girls) served as socioeconomic matched controls and did not receive any playground markings through the national initiative. Small pieces of sports equipment such as soccer balls, jump rope and tennis balls were available for use in all school playgrounds throughout the duration of the study. Schoolteachers supervised morning and afternoon recess, while lunchtime assistants supervised lunch recess.

Instrumentation

Children's physical activity levels during recess were quantified using heart rate (HR) telemetry and accelerometry. Combined measures were partly used to account for the physiological and biomechanical variance associated with HR and accelerometry respectively but also to assess mechanical (accelerometry) and physiological (HR) strain. Mechanical strain suggests that the musculoskeletal system is being stressed whereas physiological strain stresses the cardiorespiratory system. Combining methods would enable the study to report against two aspects of health promotion respectively and independently in a field setting. The Polar Team System (Polar Electro Oy, Kempele, Finland) HR monitor was used to measure the children's physiological response to recess. HR was recorded every 5 s. The children's resting HR (RHR) was determined by averaging the lowest 5 recorded HR values during each phase of data collection. HR reserve (HRR) values of 50% (HRR_{50}) and 75% (HRR_{75}) were used as the threshold values to represent MVPA and VPA respectively (Stratton, 1996). Maximum HR was set at 200 beats min^{-1} (Stratton, 1996). The percentage time each child spent at or above HRR_{50} and HRR_{75} during recess was calculated and used in subsequent analyses.

The ActiGraph (Model 7164, MTI Health Services, Florida, USA) is a uni-axial accelerometer that measures vertical acceleration of human motion. The epoch time length was set at 5 s (Nilsson et al., 2002). Activity cut points of 163–479, 480–789 and ≥790 counts per five-second epoch were used to determine the amount of time children spent in moderate, high and very high intensities respectively (Nilsson et al., 2002). MVPA was defined as the summed total time spent in each activity intensity level during recess. The summed total time spent in high and very high intensity activity represented VPA. Total percentage time spent engaged in MVPA and VPA during recess was calculated and used in the subsequent analyses.

Procedure

Children recruited into the study were randomly allocated to wear either one or two physical activity monitors, which was stratified by gender. All children wore an HR monitor (n=470), while 298 children (149 boys, 149 girls) additionally wore an accelerometer. Monitors were worn on one school day at each measurement point. Baseline measures were collected between July 2003 and March 2004. Intervention phase data were collected 6 weeks and 6 months following the redesigning of the intervention schools' playgrounds, which occurred between March 2004 and July 2004. Control school data were collected at baseline, and during the two follow-up measurement periods. Seasonality was not controlled for during this study as previous research conducted in a subgroup of schools participating in the project indicated that there were no significant day to day or seasonal differences in recess physical activity levels (Ridgers et al., 2006a). Monitors were fitted at the start of the morning school timetable following a familiarization period and worn during morning, lunch and, where applicable, afternoon recess. Children were then asked to follow their normal daily routine. Monitors were removed at the conclusion of the school day and the data were immediately downloaded.

At follow-up 1 (6 weeks), HR and accelerometry data were collected from 80% and 87% of the available sample in this phase of the project respectively. Children who did not withdraw from the study but who did not record data due to school absence or monitoring problems were recorded as missing data at that point. At follow-up 2 (6 months), HR and accelerometry data were collected from 84% and 92% of the available sample respectively. Despite some missing data, all longitudinal data collected from the children were used in subsequent analyses. Multilevel modeling is robust against missing data points and can estimate intervention effects over time while using data from children with incomplete follow-up (Quené and van den Bergh, 2004).

Data analyses

HR data were analyzed using the Polar Precision Performance™ 3.0 Software (Polar Electro Oy, Kempele, Finland). Accelerometer data were analyzed using the ActiSoft Analysis Software Version 3.2 (MTI Health Services, Florida, USA). Independent t-tests were conducted to examine differences in HR baseline physical activity levels for children wearing one or two physical activity monitors and to examine differences between the intervention and control children at baseline for age, stature, body mass and body mass index (BMI). Descriptive data were analyzed using the Statistical Package for the Social Sciences version 12 (SPSS Inc., Chicago, IL, USA).

Multilevel modeling was used to determine the effects of the playground redesign intervention across time. A three-level data structure was used, where the three levels of analysis were the timing of the follow-up measurement (level 1), pupil (level 2) and school (level 3). Data were analyzed using MLwiN 1.10 software (Institute of Education, University of London, UK). MVPA and VPA assessed using HR and accelerometry following the intervention were the outcome variables. Baseline values for MVPA, VPA, BMI, age and recess time (continuous variables) and gender (dichotomous variable) were identified a priori as potential covariates. Two analyses were conducted on MVPA and VPA for each method to examine the effect of the intervention over time. The crude analysis determined the effect of the intervention over time while controlling for baseline physical activity and time. The adjusted analysis determined the intervention effect when the covariates were added to the model (Twisk, 2006). To evaluate the influence of covariates on the intervention effect, effect modification was assessed by constructing interaction terms between the intervention group and all covariates. Separate analyses were conducted for MVPA and VPA measured using each method. Regression coefficients in the model were assessed for significance using the Wald statistic. Statistical significance was set at $p<0.05$, and at $p<0.10$ for interaction terms. Interaction

Please cite this article as: Ridgers, N.D. et al. Long-term effects of a playground markings and physical structures on children's recess physical activity levels. Prev. Med. (2007), doi:10.1016/j.ypmed.2007.01.009

Table 1
Descriptive baseline anthropometric data (collected in North West England between July 2003 and March 2004) for boys and girls in the intervention and control schools (mean, SD)

School	Boy		Girl	
	Int	Con	Int	Con
Age (years)	8.4 (1.9)*	7.9 (1.4)*	8.1 (1.7)	8.1 (1.5)
Stature (m)	1.33 (0.08)	1.31 (0.09)	1.31 (0.09)	1.29 (0.11)
Body mass (kg)	31.9 (7.8)	30.3 (8.6)	30.6 (8.4)	30.3 (9.7)
Body mass Index (kg^{-2})	17.8 (2.8)	17.3 (2.9)	17.4 (2.9)	17.7 (3.3)

Key: Int = Intervention group; Con = Control group.
* Significant inter-group difference: control < experimental group, $p<0.05$.

terms have less power, explaining why the significance level is set slightly higher (Twisk, 2006).

Results

Exploratory analyses

Independent *t*-tests on HR baseline physical activity levels for children wearing either a HR monitor or both a HR monitor and accelerometer revealed no significant differences in MVPA or VPA during recess between the two groups for boys and girls ($p>0.05$).

The descriptive (mean, SD) anthropometric characteristics of the children at baseline are displayed in Table 1. Intervention boys were older than control boys at baseline ($p<0.05$). No other significant differences were found between the groups, and between boys and girls, for the remaining variables ($p>0.05$).

Main analyses

Table 2 shows summary statistics (raw scores) for children's physical activity levels at baseline, 6 weeks and 6 months post-intervention. Table 3 shows the effect of the intervention on both MVPA and VPA across time assessed using HR and accelerometry from the multilevel modeling analysis.

HR

A statistically positive intervention effect across time was found for both MVPA ($p<0.05$) and VPA ($p<0.05$; Table 3).

Table 3
Average change in recess physical activity levels (% recess) across two follow-up measurements (6 weeks and 6 months) from baseline in intervention children compared to control children following a playground redesign intervention

Outcome measure	Crude model[1]		Adjusted model[2]	
	β (95% CI)	p	β (95% CI)	p
Heart rate				
MVPA	4.52 (0.19, 8.85)	0.041 *	4.03 (0.15, 7.91)	0.042 *
VPA	2.36 (−0.11, 4.83)	0.061	2.43 (0.06, 4.80)	0.045 *
Accelerometry				
MVPA	5.68 (1.41, 9.96)	0.009 **	4.53 (0.59, 8.47)	0.025 *
VPA	2.47 (0.75, 4.19)	0.005 **	2.32 (0.71, 3.93)	0.005 **

Data collected in North West England between July 2003 and January 2005.
Note: Reference category for intervention effect is control school. Regression coefficients (β) reflect the average differences in physical activity levels during recess assessed using heart rate telemetry and accelerometry over the two follow-up measurements (6 weeks and 6 months post-intervention) from baseline. A positive β value indicates a positive intervention effect on the physical activity levels of intervention children compared to control children during recess over time (6 weeks and 6 months post-intervention). The β value reflects the percentage increase in activity levels during recess of the intervention group compared to the control group. [1]Crude model: adjusted for baseline value of physical activity measure and time. Since follow-up measures were conducted at irregularly spaced intervals, time was included in the crude model to account for this. [2]Adjusted model: model further additionally adjusted for gender, and baseline BMI, age and recess time available. CI = confidence intervals. MVPA = moderate-to-vigorous physical activity. VPA = vigorous physical activity.
* $p<0.05$.
** $p<0.01$.

Table 2
Uncorrected means (SD) for physical activity levels during recess (% recess) assessed using heart rate and accelerometry at baseline, and 6 weeks and 6 months post-intervention for boys and girls in both the intervention and control schools

PA measure	Gender	Baseline		6 weeks		6 months	
		Int	Con	Int	Con	Int	Con
MVPA							
HR	Boy	29.3 (17.2)[a]	37.1 (18.5)[a]	35.4 (18.7)	36.7 (18.4)	37.9 (20.3)	36.6 (19.3)
	Girl	23.5 (16.6)	27.3 (15.3)	29.1 (19.1)[b]	25.1 (16.5)[b]	28.4 (16.7)	24.2 (15)
ACC	Boy	30.8 (11.7)	33.7 (13.2)	38.1 (15.3)	34.6 (12.9)	37.1 (14.5)	32.2 (12.1)
	Girl	21.9 (9.9)[a]	27 (10.4)[a]	28.2 (12.8)	23 (9.7)	26.8 (11.8)	22.1 (7.7)
VPA							
HR	Boy	9.6 (10.2)[a]	13.5 (12.6)[a]	11.6 (10.8)	13.6 (13.5)	14.2 (14.2)	13.9 (12.7)
	Girl	6.9 (7.6)	8 (7.1)	10.4 (12.2)	6.7 (8.1)	8.9 (9.4)	6.8 (8.4)
ACC	Boy	4.5 (4.1)[a]	7 (5.7)[a]	10.2 (6.9)	9.1 (6.6)	10.7 (8.3)	8.1 (6.3)
	Girl	2.9 (3.6)[a]	6.5 (4.9)[a]	5.9 (5.3)	5.3 (3.4)	5.8 (5.2)	4.9 (3.3)

Data collected in North West England between July 2003 and January 2005.
Key: Int = intervention group; Con = control group; MVPA = moderate-to-vigorous physical activity; VPA = vigorous physical activity; HR = heart rate; ACC = accelerometry.
[a] Significant inter-group difference: control > experimental group, $p<0.05$.
[b] Significant inter-group difference: control < experimental group, $p<0.05$.

Please cite this article as: Ridgers, N.D. et al. Long-term effects of a playground markings and physical structures on children's recess physical activity levels. Prev. Med. (2007), doi:10.1016/j.ypmed.2007.01.009

Intervention school children engaged in 4% and 2.4% more MVPA and VPA respectively during recess than control school children (adjusted scores). A positive interaction term was found between the intervention and recess duration for both MVPA and VPA ($p<0.05$), indicating that the intervention effect was stronger with increasing recess duration. In addition, inverse interaction terms were found between the intervention and baseline MVPA and VPA ($p<0.05$ and 0.10 respectively), indicating that the intervention effect was stronger for children who were less active at baseline. All other interaction terms (with time, gender, age and BMI) showed p-values >0.10.

Accelerometry

A statistically positive intervention effect across time was found for both MVPA ($p<0.05$) and VPA ($p<0.05$; Table 3). Intervention school children engaged in 4.5% and 2.3% more MVPA and VPA respectively during recess than control school children (adjusted scores). An inverse interaction between the intervention and age was found for MVPA ($p<0.05$), indicating that the intervention effect was stronger for the younger children. In addition, a positive interaction was found between the intervention and recess duration for MVPA ($p<0.10$), indicating that the intervention effect was stronger with increasing recess duration. A positive interaction was found between the intervention and time for VPA ($p<0.05$), suggesting that the intervention effect strengthened longitudinally across time. All other interaction terms showed p-values >0.10.

Discussion

The aim of this study was to evaluate the effects of a playground redesign intervention on a large sample of children's recess MVPA and VPA using combined measures over time and to evaluate the potential influence of covariates on the intervention effect. This builds on previous recess interventions that have evaluated short-term effects using single measures of physical activity.

This study indicated that the playground intervention was effective in increasing children's recess MVPA and VPA over time. Previous studies have reported that playground-based interventions have increased recess physical activity in the short-term following an intervention (Scruggs et al., 2002; Stratton, 2000; Stratton and Mullan, 2005; Verstraete et al., 2006). However, no comparable data currently exist concerning the longer-term effects of interventions within the recess context, nor do the short-term studies acknowledge the hierarchical nature of this type of investigation. While the increases in recess physical activity observed in this longitudinal study are smaller, the general lack of intervention by time interactions indicates that the provision of playground markings and physical structures is a suitable stimulus for increasing and sustaining increases across time. This is of note as previous research has suggested that increases in children's physical activity have not been maintained across time (Dishman and Buckworth, 1996).

Individual- and group-level variables affect children's behavior during recess. One such variable is recess duration, which interacted with the intervention effect in this study. Specifically, the intervention effect on MVPA and VPA was stronger with higher daily recess duration. Previous research has indicated that activity decreases as recess time proceeds (McKenzie et al., 1997a). This study suggests that longer daily recess periods allowed children to engage in more physical activity following the intervention, which may be explained in several ways. Firstly, the children may have had more time to take advantage of the increased activity opportunities during recess (Zask et al., 2001). Secondly, longer recess durations may allow time for the initial organization of games and activities while reducing the impact these social interactions could have on activity levels. Physical education research has suggested that up to one quarter of lessons can be accounted for by the organization of teams, activities and games rules (McKenzie et al., 1997b), and it is possible that organizing games during recess may also account for some of the time available.

The playground intervention effect was stronger for children who engaged in less MVPA and VPA at baseline. This is significant from a public health perspective as less active children often remain less active than their more active peers (Pate et al., 1996). Furthermore, physical inactivity has been linked to obesity in youth (Strong et al., 2005). Recess interventions could be important for the promotion of physical activity as children spend time outdoors on the playground, they increase their access to facilities and may decrease their perceived barriers to activity engagement as a number of activities were offered in the specific zones within well resourced playgrounds. These determinants have been identified as having consistent relationships with physical activity (Sallis et al., 2000). However, in this study, this finding was only found for HR monitoring. Thus our data suggest that the strain placed on the cardiorespiratory system increased, while mechanical stress may not have been greatly influenced. Future recess studies should implement direct observation to discern what activities these children engaged in both at baseline and follow-up. This would help clarify these findings further.

Several limitations exist with this study. The first is the number of missing data at both follow-up measurement points, particularly for HR, which were largely attributable to technical difficulties and child absence from school on the testing day. However, it should be noted that multilevel modeling analyses can handle missing data while estimating the effects of the intervention using their data at baseline and 6 weeks (Quené and van den Bergh, 2004). A second limitation is that combining HR and accelerometry to quantify physical activity has produced differing results in this study. This could also be considered a strength as combining measures has enabled the assessment of both physiological and mechanical strain, highlighting that playground activities stress the body in different ways leading to differing findings.

Conclusion

This study utilized multiple methods in a large sample of children to analyze the 6 months effects of a playground

Please cite this article as: Ridgers, N.D. et al. Long-term effects of a playground markings and physical structures on children's recess physical activity levels. Prev. Med. (2007), doi:10.1016/j.ypmed.2007.01.009

redesign intervention, building on previous recess intervention studies that have determined the effects of interventions in smaller sample sizes over shorter follow-up periods (Ridgers et al., 2006b). The results indicate that playground markings and physical structures are an effective method for significantly increasing children's recess physical activity levels in the longer-term. From a public health perspective, it is noteworthy that children who were less active at baseline benefited more from the intervention than their more active peers. In conclusion, increases observed in this study were sustained over time and not attributable to the novelty effect of the intervention.

Acknowledgments

This research project was funded by Liverpool City Council Department for Life-Long Learning and Sport England. Gary White of Sport Action Zone, John Curley, Adam Hale, Ruth McLoughlin and Emily Clark for data collection assistance and all children who participated in the study.

References

Andersen, L.B., Harro, M., Sardinha, L.B., Froberg, K., Ekelund, U., Brage, S., et al., 2006. Physical activity and clustered cardiovascular risk in children: a cross-sectional study. Lancet 368, 299–304.

Dishman, R.K., Buckworth, J., 1996. Increasing physical activity: a quantitative synthesis. Med. Sci. Sports Exercise 28, 706–719.

McKenzie, T.L., Sallis, J.F., Elder, J.P., Berry, C.C., Hoy, P.L., Nader, P.R., et al., 1997a. Physical activity levels and prompts in young children at recess: a two-year study of a bi-ethnic sample. Res. Q. Exerc. Sport 68, 195–202.

McKenzie, T.L., Sallis, J.F., Kolody, B., Faucette, F.N., 1997b. Long-term effects of a physical education curriculum and staff development program: SPARK. Res. Q. Exerc. Sport 68, 280–291.

Nilsson, A., Ekelund, U., Yngve, A., Sjöström, M., 2002. Assessing physical activity among children with accelerometers using different time sampling intervals and placements. Pediatr. Exerc. Sci. 14, 87–96.

Noble, M., Wright, G., Dibben, C., Smith, G.A.N., McLennon, D., Antilla, G., et al., 2004. Indicies of Deprivation 2004. Report to the Office of the Deputy Prime Minister. Neighbourhood Renewal Unit, London.

Pate, R.R., Baranowski, T., Dowda, M., Trost, S.G., 1996. Tracking of physical activity in young children. Med. Sci. Sports Exercise 28, 92–96.

Quené, H., van den Bergh, H., 2004. On multi-level modeling of data from repeated measures designs: a tutorial. Speech Commun. 43, 103–121.

Ridgers, N.D., Stratton, G., Clark, E., Fairclough, S.J., Richardson, D.J., 2006a. Day-to-day and seasonal variability of physical activity during school recess. Prev. Med. 42, 372–374.

Ridgers, N.D., Stratton, G., Fairclough, S.J., 2006b. Physical activity levels of children during school playtime. Sports Med. 36, 359–371.

Sallis, J.F., Prochaska, J.J., Taylor, W.C., 2000. A review of correlates of physical activity of children and adolescents. Med. Sci. Sports Exercise 32, 963–975.

Scruggs, P.W., Beveridge, S.K., Watson, D.L., 2002. Increasing children's school time physical activity using structured fitness breaks. Pediatr. Exerc. Sci. 15, 156–169.

Stratton, G., 1996. Children's heart rates during physical education lessons: a review. Pediatr. Exerc. Sci. 8, 215–233.

Stratton, G., 2000. Promoting children's physical activity in primary school: an intervention study using playground markings. Ergonomics 43, 1538–1546.

Stratton, G., Mullan, E., 2005. The effect of multicolor playground markings on children's physical activity levels during recess. Prev. Med. 41, 828–833.

Stratton, G., Ridgers, N.D., 2003. Sporting playgrounds project—an overview. Br. J. Teach. Phys. Educ. 24, 23–25.

Strong, W.B., Malina, R.M., Blimkie, C.J., Daniels, S.R., Dishman, R.K., Gutin, B., et al., 2005. Evidence based physical activity for school-age youth. J. Pediatr. 146, 732–737.

Twisk, J.W.R., 2006. Applied Multilevel Analysis. Cambridge Univ. Press, pp. 62–107.

Verstraete, S.J.M., Cardon, G.M., De Clercq, D.L.R., De Bourdeaudhuij, I.M.M., 2006. Increasing children's physical activity levels during recess in elementary schools: the effects of providing game equipment. Eur. J. Public Health 16, 415–419.

Wechsler, H., Devereaux, A.B., Davis, M., Collins, J., 2000. Using the school environment to promote physical activity and healthy eating. Prev. Med. 31, S121–S137.

Zask, A., van Beurden, E., Barnett, L., Brooks, L.O., Dietrich, U.C., 2001. Active school playgrounds—myth or reality? Results of the "Move It Groove It" project. Prev. Med. 33, 402–408.

Please cite this article as: Ridgers, N.D. et al. Long-term effects of a playground markings and physical structures on children's recess physical activity levels. Prev. Med. (2007), doi:10.1016/j.ypmed.2007.01.009

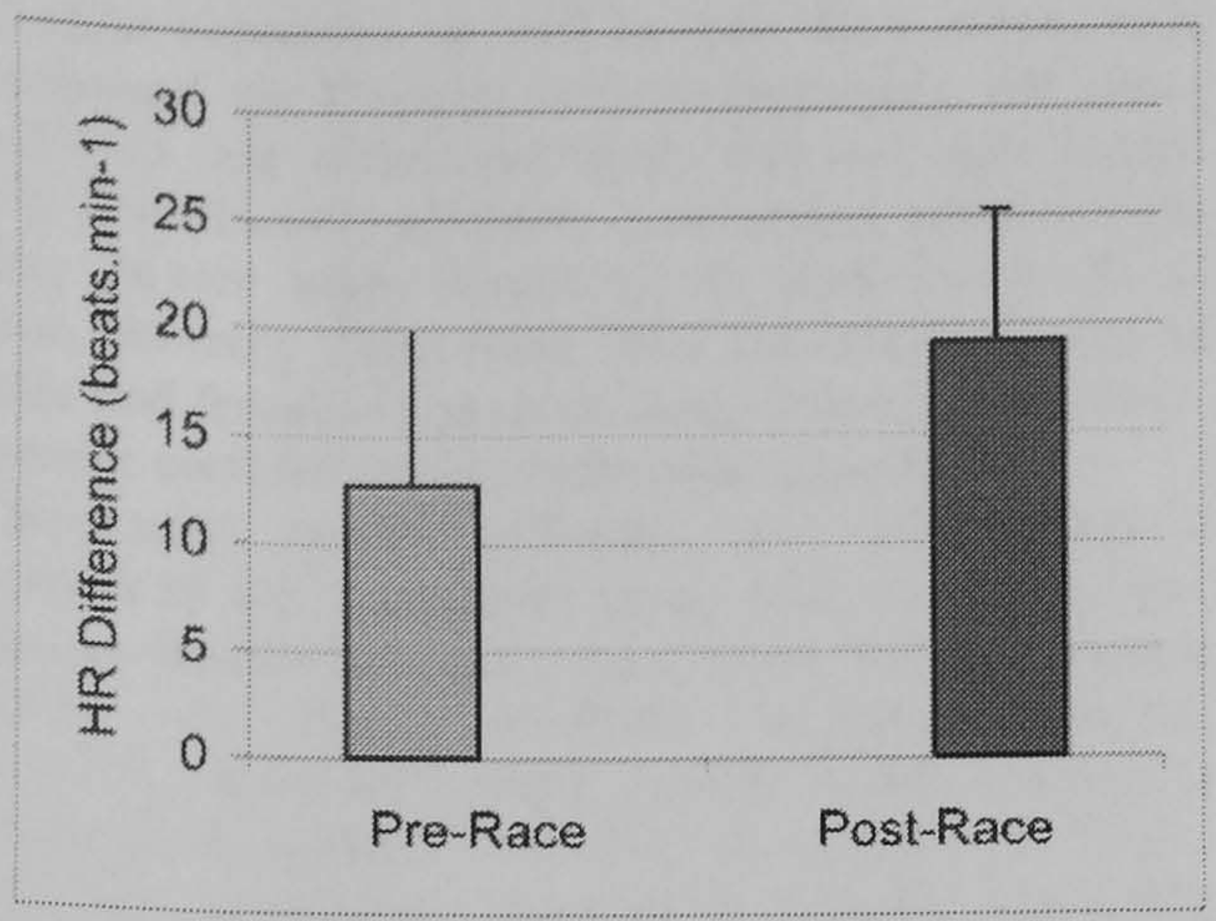


Fig. 2. The heart rate (HR) difference between supine and standing postures pre and post race.

$P > 0.05$) and cardiac output (1.02 ± 1.39 l·min^{-1}, $P < 0.05$).

Despite a significant reduction of SBP during post-exercise orthostasis, only one participant reported experiencing presyncopal symptoms, and none experienced a syncopal episode. There were no differences in measurements between pre race and 24 h post race.

Prolonged exercise was associated with significant orthostatic systolic hypotension. This relationship appears to result from a marked decrease in stroke volume that may be partially due to significant dehydration and reduction in central blood volume. The orthostatic systolic hypotension post race is only partially offset by a greater increase in heart rate. The current results suggest regulatory adaptations within the cardiovascular system following completion of a marathon may predispose a greater incidence of presyncopal and syncopal episodes.

Physical activity during playtime: Examining seasonal and sex differences

N. Ridgers[1], G. Stratton[1], E. Clark[1], S. Fairclough[2], & D. Richardson[1]

[1]*Research Institute for Sport and Exercise Sciences and* [2]*School of Physical Education, Sport and Dance, Liverpool John Moores University, Liverpool, UK*

School playtime offers an opportunity for children to engage in physical activity during the school day. Physical activity in playgrounds may significantly contribute to daily recommendations of one hour's accumulated moderate-to-vigorous physical activity (MVPA; Biddle *et al.*, 1998: *Young and active: Physical activity guidelines for young people in the UK.* London: Health Education Authority). Across the school year, children's physical activity levels may be affected by the weather and the condition of the playground environment (Stratton, 1999: *Journal of Pedagogy, 2,* 71–81). The aim of this study was to examine whether physical activity differed between boys and girls and across seasons.

Thirty-four children (15 boys and 19 girls) aged 5–10 years from two schools participated in the study approved by the university's ethics committee. The children's physical activity during school playtime was measured using heart rate telemetry, with heart rate recorded every 5 s. The children wore the monitors for 5 consecutive days in June (summer term) and November (winter term). Heart rate thresholds of 50–74% heart rate reserve (HRR) and 75% HRR represented MVPA and vigorous physical activity (VPA) respectively. The children's percentage of playtime engaged in MVPA and VPA were calculated for each day and subsequently averaged to obtain MVPA and VPA values for summer and winter. A 2 × 2 (season × sex) analysis of variance with repeated measures on season was used to compare differences in the children's physical activity.

Boys engaged in more MVPA ($P < 0.1$) during school playtime than girls. The boys and girls spent 30% and 22% of playtime engaged in MVPA respectively. There was no significant difference between the boys' and girls' VPA ($P > 0.05$). No main effect for season was seen for MVPA or VPA ($P > 0.05$). The season × sex interactions for MVPA and VPA were not significant ($P > 0.05$). Overall, boys engaged in 24½ and 23 min and girls engaged in 19 and 16½ min of MVPA during the summer and winter terms respectively.

The results suggest that children engage in similar levels of MVPA during playtime in the summer and winter terms. Vigorous physical activity tended to be higher in winter than summer, suggesting that vigorous physical activity may be associated with children's thermoregulatory need to keep warm during playtime in colder weather (Stratton, 1999) and could be linked to less restrictive clothing worn during the summer months. Boy's physical activity levels were higher than those of the girls in both seasons, and playtime observations indicated that boys' games tended to dominate the play space, whereas girls' mode of activity was generally of low to moderate intensity. This study suggests that children use playtime to engage in similar levels of physical activity across the seasons. In conclusion, studies may not need to correct for seasonal effects on children's physical activity during school playtime.

atrial (A) peak diastolic filling velocities in both the left and right ventricles, as well as their E:A ratios, were determined via Doppler echocardiography. All structural data (left ventricular mass, left and right ventricular end-diastolic volume) were scaled allometrically using fat-free mass measured by dual-energy X-ray absorptiometry. Data were then correlated to age in males and females separately using Pearson's product moment correlation and regression equations.

Structural results indicated that males have a decrease in left ventricular mass with increasing age, whereas female left ventricular mass did not change (males: $r = -0.34$, $P < 0.05$; females: $r = 0.07$, $P > 0.05$). Although a slight decline in left ventricular end-diastolic volume was seen in males ($r = -0.14$, $P > 0.05$), the decline observed in females was much greater ($r = -0.26$, $P < 0.05$). Males demonstrated a slight, non-significant increase in right ventricular end-diastolic volume with age ($r = 0.17$, $P > 0.05$), but no such change was seen in females ($r = -0.03$, $P > 0.05$). Systolic functional data revealed a comparable lack of change in ejection fraction in both sexes (males: $r = 0.07$; females: $r = 0.02$, both $P > 0.05$); however, there was a small decrease in stroke volume in males ($r = -0.16$, $P > 0.05$) and to a larger extent in females ($r = -0.31$, $P < 0.05$). Doppler results showed similar trends in both males and females with declines in both mitral and tricuspid early (mitral: $r = -0.41$ in males, $r = -0.49$ in females; tricuspid: $r = -0.69$ in males, $r = -0.59$ in females, all $P < 0.05$) and E:A ratios (mitral: $r = -0.71$ in males, $r = -0.73$ in females; tricuspid: $r = -0.53$ in males, $r = -0.53$ in females, all $P < 0.05$).

In males both left ventricular mass and left ventricular end-diastolic volume decrease with age, whereas in females left ventricular mass does not change despite a decrease in left ventricular end-diastolic volume. For the mass to remain constant, this reduction in volume would imply that wall thickness increases. This is supported by previous autopsy data (Olivetti *et al.*, 1995: *Journal of the American College of Cardiology*, *26*, 1068–1079) and is likely connected to an age-associated loss of cardiomyocytes in both males and females with a more adequate reactive hypertrophy seen in females. The increase in right ventricular data seen in males does not correspond to previous autopsy data, although this could be due to the difficulty in imaging the right ventricle with echocardiography in an older population. Changes in right ventricular diastolic early and atrial filling velocity concurs with left ventricular data in this study and as previously reported in the literature.

In conclusion, two-dimensional echocardiographic data concur with previous MRI data (Hees *et al.*, 2002) in which left ventricular mass decreases in males but not in females. This, together with the decreases observed in left ventricular volume in males and to a larger extent in females, contradicts earlier echocardiographic investigations. Changes in right ventricular volume are worthy of further investigation.

The physical activity levels of normal and overweight girls and boys during primary school recess: The Liverpool Sporting Playgrounds Project

G. Stratton, N. Ridgers, S. Fairclough, & D. Richardson

Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK

The physical activity and adiposity of children is currently a major public health concern primarily because of the consistent upward trend in overweight in this age group. There is sound evidence that overweight children are less active than their normal weight counterparts (Trost *et al.*, 2001: *International Journal of Obesity and Related Metabolic Disorders*, *25*, 822–829). There are no reported data on the physical activity of overweight and obese children in sustainable settings where physical activity is an obvious choice behaviour such as playgrounds. The purpose of this investigation was to assess whether there were any differences in physical activity levels of overweight girls and boys in primary school playgrounds.

Three hundred and seventy-seven children were monitored for physical activity using heart rate telemetry (Polar Electro Oy, Kempele, Finland). Heart rate reserves of 50 and 75% maximal heart rate were equivalent to moderate to vigorous physical activity (MVPA) and vigorous physical activity (VPA) respectively. A body mass index (BMI) was derived from measures of body mass and height and overweight was defined as the 85th percentile (Cole *et al.*, 2001: *British Medical Journal*, *320*, 1–6)

The results are reviewed in Table I. A significant main effect was found for sex ($F_{1,376} = 8.47$; $P < 0.004$) and the BMI group × sex interaction ($F_{1,372} = 9.47$; $P < 0.002$) for the percentage of playtime spent in

Table I. Results (mean ± *s*).

		Normal weight		Overweight	
Boys	Total % MVPA day	35.4	18.57	29.4	18.16
	Total %VPA day	13.0	11.38	9.7	11.64
Girls	Total % MVPA day	23.8	16.99	29.6	16.84
	Total %VPA day	7.4	8.03	9.2	7.70

MVPA. Similar significant differences were found for the percentage of recess time spent in VPA between girls and boys ($F_{1,376} = 8.03$; $P < 0.005$) and the BMI × sex interaction ($F_{1,372} = 5.67$; $P < 0.02$). There were no significant main effects for the percentage of recess time spent in MVPA or VPA for BMI ($P > 0.05$).

Normal weight boys were the only group to take advantage of activity opportunities during school recess time. Overweight boys and all girls did not achieve the same levels of activity and this may be due to the types of games played, space used and social dynamics of the primary school play area. These results are important to consider when designing health-promoting playgrounds for girls and boys, as this study suggests that current school playgrounds only serve to promote activity in normal weight boys leaving other groups disadvantaged.

Reproducibility of peak $\dot{V}O_2$ achieved during cycle ergometry in normoxia and hypoxia

C. Thake & M. Price

School of Science and the Environment, Coventry University, Coventry, UK

Incremental cycle exercise protocols to determine peak physiological responses are generally considered to be reliable (Kohrt *et al.*, 1987: *Medicine and Science in Sports and Exercise, 19*, 51–5). However, to the authors' knowledge no data regarding the reproducibility of peak physiological responses during cycle ergometry in hypoxic conditions have been reported and no published guidelines for exercise testing in simulated hypoxic environments are available. Furthermore, the mode of gas delivery differs between normobaric (via a mask or mouthpiece) and hypobaric (ambient air) experimental models and may contribute to the reproducibility of physiological data. The aim of this study was to determine the reproducibility of peak physiological responses during incremental cycle ergometry in normoxia and hypoxia.

Ten moderately trained individuals (age 26.1 ± 6.9 years, height 1.79 ± 0.07 m, body mass 72.5 ± 7.3 kg, body fat 10.8 ± 2.3%) volunteered to undertake repeat incremental exercise tests until volitional exhaustion (Cheng *et al.*, 1992: *International Journal of Sports Medicine, 13*, 518–522) in normoxic (room air, $n = 8$) and normobaric hypoxic ($F_IO_2 = 14\%$, equivalent to 3000 m, $n = 8$) conditions in a single blind randomized crossover design. Cycling commenced at a workload of 80 W for 5 min and was increased by 50 W every 5 min. When heart rate was equal to or exceeded 160 beats · min^{-1}, 50 W increments were made every 2.5 min until volitional exhaustion. A cadence of 80 rev · min^{-1} was maintained throughout. Inspired volume ($\dot{V}_{I\ ATPS}$) was measured (Harvard Dry Gas Meter, Cranlea UK) down stream of a 1000 litre gas reservoir. The F_EO_2 and F_ECO_2 were sampled continuously (Servomex 1400) via an expiratory mixing box. Minute ventilation ($\dot{V}_{E\ STPD}$), peak oxygen uptake ($\dot{V}O_{2peak}$) and respiratory exchange ratio (RER) were subsequently calculated. Heart rate (Polar Accurex) and arterial saturation (SpO_2; Nonin Model 8500) were monitored continually. Differences between peak physiological responses were analysed using paired *t*-tests and the test–retest variability (technical error of measurement, TEM) of each measure was determined (Bland & Altman, 1986: *The Lancet, i*, 307–310).

Peak physiological responses measured in normoxia and hypoxia are given in Table I. Although different between normoxia and hypoxia ($P < 0.001$), $\dot{V}O_{2peak}$ test–retest values were not significantly different in either normoxia (4.09 ± 0.62 and 4.06 ± 0.56 l · min^{-1}) or hypoxia (3.37 ± 0.47 and 3.37 ± 0.47 l · min^{-1}). The TEM for $\dot{V}O_{2peak}$ was 3.2 ± 0.9 and 2.8 ± 1.1% respectively. Test–retest data showed highly significant correlations ($r = 0.98$ and 0.97 for normoxia and hypoxia, respectively; $P < 0.0001$) and were within acceptable limits ± 2 standard deviations of the mean

Table I. Test–retest peak physiological responses in normoxia and normobaric hypoxia ($n = 8$, mean ± s).

	Normoxia		Normobaric hypoxia	
	Test 1	Test 2	Test 1	Test 2
$\dot{V}O_{2peak}$ (l · min^{-1})	4.09 ± 0.62	4.06 ± 0.56	3.37 ± 0.47	3.37 ± 0.47
Peak heart rate (beats · min^{-1})	182 ± 15	184 ± 12	178 ± 13	180 ± 11
$\dot{V}_{E\ STPD}$ peak (l · min^{-1})	113.4 ± 13.8	112.3 ± 12.2	113.5 ± 11.1	114.4 ± 9.9
RER	1.22 ± 0.15	1.22 ± 0.14	1.31 ± 0.08	1.33 ± 0.08
SpO_2 (%)	94 ± 4	96 ± 2	76 ± 4	77 ± 5
Peak power (W)	334 ± 34	331 ± 37	275 ± 45	275 ± 45