Energy Expenditure and Enjoyment of Active Video Games Vs. Other Activities in 10-12 Year Old Boys

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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LIST OF ABBREVIATIONS

BMI	body mass index
%BF	body fat percent
CVD	cardiovascular disease
EE	energy expenditure
HR	heart rate
HR_{peak}	peak heart rate
% HR_{peak}	percentage of peak heart rate
LPL	lipoprotein lipase
MET	metabolic equivalent expressed in the Ainsworth Compendium ($\dot{V}O_2$/ 3.5mLO_{2STPD}.kg^{-1}.min^{-1}) MET_{meas} metabolic equivalent measured ($\dot{V}O_2$ / measured RMR)
MSFT	multi-stage fitness test
NEAT	non-exercise activity thermogenesis
RMR	resting metabolic rate
$\dot{V}O_2$	oxygen consumption
$\dot{V}O_{2\,peak}$	peak oxygen consumption
% $\dot{V}O_{2\,peak}$	percentage of peak oxygen consumption

ABSTRACT

Children are becoming more inactive and are spending a significant proportion of their time participating in screen-time sedentary behaviours. New generation active video games may provide an opportunity to convert traditional sedentary screen-time into active screen-time. The aims of this thesis were to: 1) determine the metabolic costs of different activities; 2) determine whether experience and fitness influence the metabolic costs of active video games; and 3) determine children's enjoyment of active video games. Accordingly, this thesis is presented as two papers.

Twenty-six boys' (11.4 ± 0.8 yr) participated in the study. Each performed sedentary activities (resting, watching television and sedentary gaming), active video games (Nintendo® Wii Bowling, Boxing, Tennis, Skiing and Step Aerobics), traditional physical activities (walking and running) and a maximal fitness test. During all activities oxygen uptake ($\dot{V}O_2$) and heart rate were measured and energy expenditure (EE) calculated. The active video games resulted in a significantly higher EE compared to rest (63-190%, p<0.05). No significant differences in EE were found between the most active video games (Wii Boxing and Wii Step) and walking. The intensities of the active video games were low (≤ 3 $METS_{meas}$). There was no evidence to suggest that gaming experience or aerobic fitness influenced EE during active video game play.

Using the same sample, the aim was to determine the participants' enjoyment of active video games sedentary activities and physical activities. Participants' enjoyment was measured using the Physical Activity Enjoyment Scale immediately after the activities. The percentages of children that enjoyed each activity were: walking (39%), television (58%), running (60%), PS3 (73%), Wii Boxing (88%), Wii Tennis (77%), Wii Fit (75%) and Wii Bowling (89%). The active video games were the most enjoyable activities irrespective of participants' weight status, fitness and experience.

The metabolic costs of active video games suggest that they may be suitable for future interventions which are aimed at decreasing time spent in sedentary behaviour. However, as they are low intensity activities, active video game play time should not be accumulated as part of the 60-minutes of daily moderate to vigorous physical activity that is currently recommended for children.

CHAPTER 1. INTRODUCTION

The public health crisis of physical inactivity is reaching epidemic proportions (Biddle, Gorely, & Stensel, 2004). It has been estimated that 1.9 million deaths per year are attributed to physical inactivity (World Health Organisation, 2002). Physical inactivity, defined as engaging in minimal physical activity and failing to achieve even the most basic of activity guidelines (Kolt, Schofield, Schofield, McLachlan, & Mackay, 2006), is a major contributor to the global burden of chronic health disease. World Health Organisation (WHO) data suggests that there is a significant proportion of the global population who are classified as inactive (World Health Organisation, 2003). Alarmingly, it is apparent that physical inactivity does not pertain to the adult population alone (Biddle et al., 2004). An increasing amount of data is indicating that a significant proportion of children are inactive too (Duncan, Al-Nakeeb, Woodfield, & Lyons, 2007b; Vincent, Pangrazi, Raustorp, Michaud Tomson, & Cuddihy, 2003). Of equal concern is data which shows that children are spending a significant proportion of their days involved in sedentary behaviour (Andersen, Crespo, Bartlett, Cheskin, & Pratt, 1998; Christakis, Ebel, Rivara, & Zimmerman, 2004; Robinson et al., 1993). Sedentary behaviour, defined as activity which requires low levels of energy expenditure (EE) and minimal bodily movement (Kolt et al., 2006), may be contributing to chronic health diseases in children (Hamilton, Hamilton, & Zderic, 2007). Chronic health diseases such as type 2 diabetes, hypertension and obesity, which were once classified as 'adult' diseases, are now prevalent in children (Rosenbloom, Joe, Young, & Winter, 1999).

There are a number of contributing factors to childhood physical inactivity and sedentary behaviour including; a decline in physical education and physical activity offered by schools, changes in urbanisation and transport and the increase in the amount of time children spend participating in sedentary leisure based activities (Hamlin & Ross, 2005). Additionally, media rich home environments promote activities such as watching television, playing computer games and playing video games. Sedentary leisure based activities screen-based activities form a significant part of a child's leisure time (Meier, Hager, Vincent, Tucker, & Vincent, 2007). In New Zealand, 64.1% of children aged 5-14 years watch two or more hours of television per day (Ministry of Health, 2008). There have been several interventions proposed to try and decrease the amount of time children spend partaking in sedentary activities. Such interventions include making sedentary activities contingent on exercise (Faith et al., 2001), using reinforcement to discourage sedentary activities (Epstein, Paluch, & Raynor, 2001; Epstein et al., 1995) and setting television ‘budgets’ (Ford, McDonald, Owens, & Robinson, 2002). While these interventions have been effective in reducing sedentary behaviour, a disadvantage of them is that it may be difficult to get children to “buy” into these ideas. For interventions like this to work long-term they need to be accepted by the target audience. In this case, inactive children who are attracted to electronic media may not be motivated to be involved in such interventions. It is also possible that they may view physical activity as a punishment if their desired behaviour, electronic media, is contingent on the less desirable behaviour, physical activity. This is clearly a challenging position for health and physical activity promoters.

Although most of the sedentary behaviour research has focussed on television viewing, home-based video games are another sedentary behaviour which may be indirectly contributing to obesity and health diseases in children. In 2005 Sony alone sold approximately 91 million PlayStation®2 consoles worldwide (Borusiak, Bouikidis, Liersch, & Russell, 2008). Traditionally, these games have been equally as sedentary as watching television. However, recently the gaming world has been revolutionised with the introduction of interactive video games such as Nintendo® Wii Sports and PlayStation® EyeToy. These games offer the opportunity for players to actively play the games requiring part- and whole-body movement. Therefore, compared to traditional sedentary-style games, it seems plausible that there may be benefits in encouraging children to play active video games at least in terms of increasing daily EE.

Several attempts have been made to determine the EE whilst playing active video games (Graves, Stratton, Ridgers, & Cable, 2007; Lanningham-Foster et al., 2006; Maddison, Mhurchu, Jull, Prapavessis, & Rodgers, 2007). However, there are some limitations to these studies, and gaps in the literature, which could be addressed. For example, small sample sizes (n = 11-13; Graves et al., 2007; Graves et al. 2008) and large age ranges (Graves, Ridgers, & Stratton, 2008) have been used in some studies making it difficult to generalise the results to other populations. It has also been suggested that experienced players may differ in their movement patterns compared to novice players (Maddison et al., 2007). Therefore, it may be important to determine whether variables such as experience and fitness influence EE. As lack of fun has been shown as a barrier to physical activity (Hamlin & Ross, 2005) it may be important to determine the extent to which children enjoy playing active video games. Also, determining the relative intensity of active video games will assist in establishing whether they can help children to meet daily physical activity guidelines. Finally, direct comparisons between the EE of active video games and other activities such as walking and running have not been made. Therefore, this is an area which needs to be further explored to determine whether active video games can be used as intervention to decrease sedentary behaviour and physical inactivity.

Determining the acute physiological and metabolic effects of walking, running, traditional screen-based leisure activities and active video games will not only help to determine whether active video games offer a "healthier" version of screen-based leisure; but will also aid in quantifying metabolic equivalents ($METS_{meas}$) of these activities. In physical activity research, diaries and proxy reports are commonly used to estimate daily EE based on MET values determined from previous studies which are included in the compendium of physical activities (Ainsworth et al., 2000). This compendium is well-established for adults however an equivalent compendium of activities for youth and children is limited (Harrell et al., 2005). It has been suggested that the EE of a broader spectrum of children's activities needs to be measured using indirect calorimetry (Arvidsson, Slinde, Larsson, & Hulthen, 2007).

Statement of the Problem

Active video games may provide a viable opportunity for children to increase their daily EE and reduce the time they spend participating in sedentary pursuits. Currently there is little information available on the physiological responses to active video games and no research on the differences in EE between novice and experienced players exists. In addition, it has not been determined whether fitter, more active children expend less energy during active video games. For active video games to work as an effective intervention children need to find them appealing and enjoyable. Finally, it has been suggested that an accurate compendium of physical activities specifically for children needs to be compiled using indirect calorimetry. There is clearly a need to conduct further empirical research in this area addressing these issues in order to determine whether active video games offer a viable opportunity to increase physical activity levels and EE in children.

Aim of Thesis

The aims of the thesis are:

1. To determine EE during different activities in children by objectively quantifying and comparing the metabolic costs of several activities including; resting, walking, running, watching television and playing a range of commercially available non-active and active video games.

2. To determine whether relationships exist between the metabolic costs of active video games and variables such as playing experience and fitness.

3. To determine the perceived enjoyment of children's activities including; resting, walking, running, watching television and playing a range of video games.

Significance of the Research

The significance of the research is to;

1. Provide objective evidence on whether active video games can be used as an effective intervention to increase daily physical activity in children.

2. Add to the body of work on the quantification of the metabolic costs of activities for children. Indirect calorimetry will be used to ensure valid and reliable results.

CHAPTER 2. CHILDREN, PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR: IS THERE A WAY FORWARD? A REVIEW OF THE LITERATURE

Introduction

Childhood physical inactivity is increasing at an exponential rate (Biddle, 2007) with a significant proportion of children failing to achieve minimum daily physical activity guidelines (Duncan et al., 2007b; Vincent et al., 2003). In 2003 approximately one third of New Zealand children were classified as either overweight or obese[1] (Ministry of Health, 2003). Despite widespread evidence showing that physical activity is important for short- and long- term health, physical inactivity is still increasing. Although this is concerning, even more alarming is the amount of time that children are spending in sedentary activities (Andersen et al., 1998; Christakis et al., 2004; Robinson et al., 1993).

Whilst the proportion of children who choose to participate in sedentary activities continues to increase, those that are involved in public health recognise that there is a crucial need to develop practical and sustainable interventions and strategies to encourage children to decrease the amount of time they are spending being sedentary. Recently several research groups have proposed a paradigm in which interventions have been designed with the aim of reducing sedentary behaviours. Hamilton and colleagues (2007) believe that reducing sedentary behaviour may not have a simple inverse relationship with increasing physical activity. They propose that there are physiological mechanisms which are offset by reducing time spent being sedentary and increasing time spent in non-exercise physical activity.

The aim of this review is to systematically examine the current body of literature on a) the physiological consequences of inactivity; b) physical activity patterns and sedentary behaviour patterns in children; and c) the interventions used to decrease time spent in sedentary behaviour. Literature on these issues will be examined and critiqued in order to provide an evidence-based overview of the topic area. Due to the depth of

[1] The Ministry of Health used cut-offs by Cole et al. (2000) to define overweight and obesity in children (Appendix 1).

information available in this field the literature in this review will be limited to literature pertaining to children, specifically those less than 12 years of age. Furthermore, physical activity interventions will not be explored in this review as the emphasis of the review will be on exploring sedentary behaviour interventions.

The Benefits of Physical Activity

Before exploring the physiological effects of inactivity and sedentary behaviour, a brief summary of the benefits of physical activity will be highlighted. It is important to note that physical activity and exercise are different concepts. Physical activity can be defined as bodily movement produced by skeletal muscles which results in EE whereas exercise is a subset of physical activity. Exercise is a planned, structured and repetitive activity usually with the goal of maintaining or improving physical fitness. (Caspersen, Powell, & Christenson, 1985). There have been a number of benefits associated with physical activity (Krekoukia et al., 2007; Meyer, Kundt, Lenschow, Schuff-Werner, & Kienast, 2006; Ondrak & Morgan, 2007). For example, studies have provided evidence to show that regular involvement in physical activity reduces the incidence of type 2 diabetes in children and adolescents (Schmitz et al., 2002). Additionally, scientific research has proposed that physical activity can be a successful moderator of blood pressure (Ewart, Young, & Hagberg, 1998; Hansen, Froberg, Hyldebrandt, & Neilsen, 1991; Sorof & Daniels, 2002), obesity (Goran, Reynolds, & Linquist, 1999; Meyer et al., 2006; Woo et al., 2004), cholesterol (Meyer et al., 2006; Woo et al., 2004) and triglycerides (Meyer et al., 2006; Raitakan et al., 1994) in children.

Physical activity also helps with bone development. Critical phases of bone development occur during childhood. During this period lifestyle factors play a significant role on an individuals capability to reach their genetic potential for peak bone mass (Molgaard, Thomsen, & Michaelsen, 2001). Research findings show that active lifestyles, weight bearing activities and good nutrition all contribute to the development of healthy bones (French, Fulkerson, & Story, 2000; Ondrak & Morgan, 2007). Vigorous physical activity in particular has been strongly associated with higher bone mineral content in children (Rowlands, Ingledew, Powell, & Eston, 2004).

As well as helping to improve children’s physical health, physical activity can also improve their mental health. There is evidence to show that those who participate in physical activity benefit from it both psychologically and socially (Scully, Kremer, Meade, Graham, & Dudgeon, 1998). People who are regularly active are less likely to suffer from depression, are more likely to have a higher self esteem and they tend to enjoy the social experiences that go hand-in-hand with the activities they do (Paluska & Schwenk, 2000). Studies found confirm that children who participate in physical activity are less likely to suffer from psychological illnesses and emotional distress (Biddle et al., 2004; Penedo & Dahn, 2005).

The literature reviewed above suggests that there are many positive benefits of physical activity. These findings are well documented and have been extensively researched. Therefore, in this review a more in-depth focus will be given to the physiological consequences on inactivity.

Physiological Consequences of Physical Inactivity

In comparison to the benefits of physical activity, which have been extensively studied, the physiological consequences of physical inactivity are an emerging paradigm. This area of research has been prompted by the recognition that the global population is becoming increasingly inactive. Epidemiological studies indicate that the greatest disease and mortality rates are in the least active people (Hamilton, Hamilton, & Zderic, 2004). It has also been proposed that the physiological mechanisms of inactivity and the benefits of activity may not be inversely related (Hamilton et al., 2007). Although there is extensive research on the mechanisms of exercise physiology there is little research available on the mechanisms of inactivity physiology. The paradigm of inactivity physiology proposes that physical inactivity can lead to significant negative effects on many specific cellular processes important for disease-related proteins (Hamilton et al., 2004).

Before examining the negative consequences of physical inactivity it is important to understand the concepts of EE and non-exercise activity thermogenesis (NEAT).

Energy expenditure (EE)

Energy expenditure (EE) and physical activity remain two separate yet interrelated constructs. Physical activity is described as a behaviour and is typically classified in terms of frequency and durations, whereas EE refers to the energy cost or intensity of a given activity (Lamonte & Ainsworth, 2001). Total daily EE is quantified by calculating the sum of resting metabolic rate (RMR), the thermic effect of food and activity thermogenesis. Activity thermogenesis can be further separated into two constituents; exercise and NEAT. It has been suggested that RMR accounts for 50-60% of total daily EE, the thermic effect of food accounts for 10-15% of total daily EE, and activity thermogenesis accounts from 15% in highly sedentary individuals (Figure 2.1) to 50% in active individuals total daily EE (Levine, 2004; McManus, 2007).

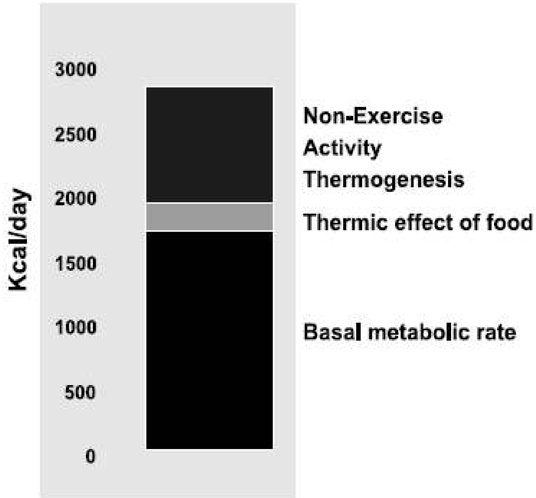

Figure 2.1. Components of daily EE in sedentary adults (Levine, 2004, p. 676). Being sedentary suggests that exercise is not undertaken during a day. Therefore, a typical healthy person who participates in exercise will have another section to the bar chart indicating their EE from exercise thermogenesis.

Activity thermogenesis is the most variable component of the energy balance equation. Non-exercise activity thermogenesis, an element of activity thermogenesis, comprises of energy expended during activities of daily living such as; walking, standing, sitting, playing and fidgeting (Levine, 2002; McManus, 2007). Levine (2002) suggests that the NEAT is the most predominant component of activity thermogenesis. Non-exercise activity thermogenesis is therefore a major contributor to inter- and intra-variations of EE in human beings.

Measuring energy expenditure using metabolic equivalents

Metabolic equivalent (MET) values can be used to predict the intensity of physical activities (Ainsworth et al., 2000). Physical activity research relies on using

MET values provided in the compendium of physical activities (Ainsworth et al., 2000) to determine EE values from activity diaries, proxy reports and other subjective measures of activity. However, controversy remains over whether the MET values in the adult compendium are suitable to use for research with children (Harrell et al., 2005; Spadano, Must, Bandini, Dallal, & Dietz, 2003a). In adults, in the Ainswoth compendium, it is assumed that 1 MET is equal to 1 kcal. $kg^{-1}.h^{-1}$ (or 4.186 $kJ.kg^{-1}.h^{-1}$) (Spadano et al., 2003a). However, research using indirect calorimetry has indicated that children have higher resting MET values than adults (Hsu et al., 2003). The higher resting MET values reported in children are a result of children's higher resting metabolic rate (RMR). Research in this area suggests that the decline in RMR during growth is likely due to a decrease in the proportion of some of the more metabolically active organs and tissues as well as changes in body composition (Hsu et al., 2003). Therefore, it is possible that the energy costs of completing tasks may also be higher in children (Harrell et al., 2005) but the ratio of EE to resting metabolic rate (RMR) may still be the same. The implication of this is that Ainsworth et al.'s (2000) compendium of physical activities may not always be appropriate to use for estimating the energy costs of children's activities. A further challenge is that several activities that children may partake in on a regular basis have not, for obvious reasons, been included in the adult compendium.

Harrell et al. (2005) have attempted to develop a compendium of the EE of Physical Activity in Youth. In their study 295 youth aged 8-18 years, with at least 10 boys and 10 girls in each age group, were measured while performing a number of different day-to-day activities that children carry out. Participants were measured using indirect calorimetry at rest for 15-minutes and for 10-minutes during 14 different activities. A key finding from their study indicated that RMR was not significantly different between genders; however RMR declined as age increased. Therefore, younger children were found to have higher RMR than older children. Furthermore, age-adjusted metabolic equivalents (A-AME) were calculated by dividing the $\dot{V}O_2$ of the activity by the $\dot{V}O_2$ at rest. MET values were also calculated for each activity by dividing the $\dot{V}O_2$ of the activity by the common denominator 3.5 $ml.kg^{-1}.min^{-1}$. Significant differences were found between the A-AME and MET values highlighting that using the universal 3.5 $ml.kg^{-1}.min^{-1}$ to represent 1 MET in children will typically lead to an underestimation of EE in children. This finding provides evidence that further research is needed to provide a comprehensive compendium of activities for children. Overall, there is currently a limited amount of research quantifying the energy cost of various physical activities in children (Spadano, Must, Bandini, Dallal, & Dietz, 2003b; Torun, 1989). Arvidsson et al. (2007) believe there is a need to create a comprehensive compendium of physical activities for children using indirect calorimetry.

Non-exercise activity thermogenesis (NEAT)

Recently there has been an increase in NEAT related research with much of this research focussing on the physiology of energy balance (Levine, 2002). There are now a number of research groups that advocate that individuals who are at risk of metabolic diseases should increase the amount of daily time they spend participating in NEAT activities. Although the role of NEAT in paediatric obesity has not yet been examined, it has been proposed that NEAT may play a key role in modulating weight gain in children (McManus, 2007).

It is well known that individuals who do not participate in enough physical activity are at increased risk of metabolic syndrome, type 2 diabetes, CVD and obesity (Hamilton et al., 2007). Hamilton et al. (2004) have proposed that the risk of developing these diseases may be exacerbated by spending more time sitting and performing less non-exercise physical activity. In adults, research suggests that sedentary time predicts metabolic syndrome and its components independent from exercise (Hamilton et al., 2007). Therefore, this suggests that decreasing the amount of time individuals spend participating in sedentary activities may be an area that needs to be increasingly focussed on in the future.

The inactivity paradigm proposed by Zderic and Hamilton (2006) suggests that the physiological mechanisms of physical inactivity should be compared to low intensity physical activities that commonly occur during daily living. This type of research will be valuable in helping to determine whether encouraging people to replace sedentary behaviours with light activities is worthwhile. To date, the research which has been conducted within this paradigm suggests that light activities provide modulating effects on a number of risk factors for disease including the regulation of lipoprotein lipase (LPL) and the metabolic syndrome (Zderic & Hamilton, 2006).

Physical Activity and Sedentary Behaviour in Children

As the number of children who are physically inactive continues to increase there is a greater need to monitor habitual activity patterns of children. Experts believe that it is necessary to set physical activity guidelines for children to ensure that children are meeting the daily requirements of physical activity in order to stay healthy. Additionally, to develop effective interventions and strategies it is necessary to determine how active and how sedentary children are. This section will review the physical activity and sedentary behaviour guidelines and determine whether children are meeting these guidelines.

International physical activity and sedentary behaviour guidelines

Long standing assumptions have been that physical activity guidelines are the same for children as they are for adults (Welk, Corbin, & Dale, 2000). However, recently research has suggested that there is a need to develop guidelines specific to the physical activity needs for children. This has encouraged a number of countries to develop physical activity guidelines for children and youth.

Despite New Zealand having physical activity guidelines in place for adults since 1996, it was not until December 2007 that physical activity guidelines were introduced for children and adolescents (SPARC, 2008). These guidelines are displayed in Table 2.2. Countries with similar physical activity guidelines for children include Australia, America, Canada and the United Kingdom. Their physical activity guidelines are all relatively similar to New Zealand's as they each suggest that children should be participating in 60-minutes of moderate to vigorous physical activity per day (Table 2.2). All of these countries, excluding the United Kingdom, have also put guidelines in place which have been developed to encourage children to decrease their daily screen-time (Table 2.2).

Table 2.2. Physical activity and screen-time recommendations for children

Country	Age (years)	Physical Activity Recommendations	Screen-Time Recommendations
New Zealand (SPARC, 2008)	5-18	60 minutes of moderate to vigorous activity per day.	Limit screen-time to < 2 hours per day.
Australia (Commonwealth Department of Health and Aging, 2004)	5-12	At least 60 minutes (and up to several hours) of moderate to vigorous activity per day.	Limit screen-time to < 2 hours per day especially during daylight hours.
	12-18	60 minutes of moderate to vigorous activity per day.	Limit screen-time to < 2 hours per day.
United States (Council on Sports Medicine and Fitness and Council on School Health, 2006)	6-12	Children and adolescents should participate in at least 60 minutes of moderate intensity activity per day. Activity may be accumulated in small increments throughout the day.	Limit screen-time to < 2 hours per day.
Canada (Public Health Agency of Canada, 2002)	6-14	Increase time spent on physical activity starting with 30 minutes more per day.	Reduce "non-active" time spent on television, video, computer games and surfing the internet starting with 30 minutes less per day.
United Kingdom (Department of Health, 2004)	Not defined	Children and young people should achieve a total of at least 60 minutes of at least moderate intensity physical activity each day. At least 2 x per week this should include activities to improve bone health, muscle strength and flexibility.	None.

Pedometer based guidelines

Pedometers are an objective measure of physical activity and are now widely available in most countries. In New Zealand, pedometers have been endorsed by companies such as McDonald's who issued pedometers to 100,000 school children in their "My Greatest Feat" campaign (McDonald's, 2008). For adults, 10,000 steps per day is the accepted daily step count guideline for reducing the risk of becoming overweight (Tudor-Locke & Bassett, 2004). However, concerns have been raised over whether 10,000 steps per day are enough for children (Tudor-Locke & Bassett, 2004). Few studies have been undertaken to try and establish evidenced based guidelines and recommendations on the number of steps that should be taken by children each day. In this regard, Tudor-Locke et al. (2004) aimed to establish criterion referenced standards for physical activity related to healthy body composition in children. They used pedometers and body mass index (BMI) cut-off points to determine their reference points. Children in this study included 995 girls and 959 boys aged 6-12 years from America, Australia, and Sweden. Tudor-Locke et al.'s (2004) findings supported the hypothesis that children need be achieving a much higher step count per day than adults. Their findings proposed that 6-12 year old girls and boys should be doing 12,000 and 15,000 steps a day, respectively, in order to maintain a healthy body composition. However, a weakness of this study was that children's steps were only measured during weekdays with weekend step counts not included in the analysis. This may have lead to an overestimation in step counts as other studies have indicated that children are more active during weekdays than they are during weekends (Duncan, Schofield, & Duncan, 2006).

Research shows that percentage of body fat (%BF) is more strongly associated with step counts in children than BMI or waist circumference measures (Duncan et al., 2006). Therefore, Duncan et al. (2007a) calculated recommended daily step counts for children based on %BF. They also included weekend step counts in their analysis as an attempt to overcome one of the weaknesses found in Tudor-Locke et al.'s (2004) study and included children from multiple ethnic groups that live in New Zealand. The results suggested that girls and boys should be doing 13,000 and 16,000 steps per day, respectively. For both genders the recommended daily step counts were 1,000 higher than Tudor-Locke et al.'s (2004) previous study.

Current physical activity levels of children

There have been a number of observational studies performed with the purpose of trying to establish how active children are using pedometer step counts as the outcome measure (Table 2.3). Rowlands et al. (1999) conducted one of the first studies which looked at pedometer step counts in children aged 8-10 years from North Wales. The mean steps taken were 16,035 and 12,729 for boys and girls, respectively. This shows that the children were meeting the recommended daily step counts proposed by Tudor-Locke et al. (2004) and Duncan et al. (2007a). In addition to step counts they measured accelerometer counts, heart rate (HR), aerobic fitness and skin-folds. Their data showed that those who did the least number of steps were more likely to have a higher level of fatness and to be less fit. Thus, suggesting that physical inactivity is linked to increased levels of body fat in children. A weakness with Rowlands et al.'s (1999) study is that they did not keep the amount of days the pedometer was worn consistent. Another limitation of their cross-sectional study was that their data does not show whether physical inactivity causes increased body fat or whether increases in body fat cause children to be inactive.

Table 2.3 **A collection of studies looking at pedometer step counts in children**

Author	Sample	Age	Design	Country	Boys mean daily steps	Girls mean daily steps	Difference between boys and girls steps	Main findings
Loucaides (2003)	n = 232	11-12	Measured 5 days in winter / 5 days in summer; children recorded total steps when school finished and total steps in evening.	Greece	Summer 17,624 ± 5,035 Winter 15,480 ± 4,153	Summer 13,607 ± 4,396 Winter 11,160 ± 2,694	Summer 29.4% Winter 38.4%	Boys step counts higher in winter (38.4%)* and summer (29.4%)* than girls. Overall, step counts 13%* higher in summer than winter. Step counts higher after school than during school in winter (36% and 26% for boys and girls, respectively)* and summer (49% and 45% for boys and girls, respectively)*.
Cox et al. (2006)	n = 91	5-11	Measured school based and out of school steps for 3 days.	New Zealand	15,606 ± 4,601	13,031 ± 3,079	19.8%	Boys were 19.8% more active than girls*. Older children comprised 78.8% of the most active group and younger children comprised of 74.2% of the least active group*. A higher proportion of steps out of school (52.4%) than during school (47.6)*.

Duncan et al. (2006)	n = 1115	8.3 ± 1.7	Measured steps for 3 weekdays and 2 weekend days	New Zealand	Weekdays 16,133 ± ,864 Weekends 12,702 ± 5,048	Weekdays 14,124 ± 3,286 Weekends 11,158 ± 4,309	Weekdays 14.2% Weekends 13.9%	Weekend step count lower than weekday for boys (27.0%) and girls (26.7%)*. Boys more active than girls (14.2% and 13.9% on weekdays and weekends, respectively)*.
Duncan et al. (2007b)	n = 208	9.3 ± 0.9	Measured steps for 4 days (2 weekend, 2 weekdays).	New Zealand	12,263 ± 3,789	11,748 ± 3,310	4.4%	Boys are 4.4% more active than girls*. Children 33.8% more active on weekdays than weekends*
Rowlands et al. (1999)	n = 34	9.5 ± 0.7	Measured steps for 3-6 days (mean 4.93).	N/A	16,035 ± 5,999	12,729 ± 4,026	26.0%	Activity positively correlated with fitness (r=0.59)* and negatively correlated with fatness (r=-0.42)*.

Vincent et al. (2003)	n = 1954	6-12	Measured steps of American,	America	12,554 -13,872	10,661-11,383	~ 19%	Swedish children more active than Australian (7.3 -
			Swedish and Australian	Australia	13,864-15,023	11,221-12,322	~22%	22.2%) and American (12.9 – 32.3%)*
			children for 4 weekdays.	Sweden	15,673-18,346	12,041-14,825	~30%	No significant differences in step counts across age groups. American children had higher BMI's* - over 33% of all American children were classified as overweight compared to less than 16.8% of all Australian and Swedish children.

Where * = significant difference, $p<0.05$

Since Rowlands et al.'s (1999) study, several other researchers have reported the step counts that children take each day (Cox et al., 2006; Duncan et al., 2006; Duncan et al., 2007b; Loucaides et al., 2003; Vincent et al., 2003). The mean daily step counts for boys and girls ranged approximately between 10,600 and 17,600 (Table 2.3). The findings between the studies are somewhat inconsistent as depicted by the relatively large differences in the mean daily step counts. Some of these differences may be due to the methodological designs of the different studies. For example, the number of days in which the pedometers were worn ranged between 3 and 5 days, only some studies included a weekend day in their data collection (e.g. Duncan et al., 2006; Duncan et al., 2007b) and different methods were used to report total step counts. However, from the studies reviewed there is convincing evidence to suggest that boys are more active than girls (Cox et al., 2006; Duncan et al., 2006; Duncan et al., 2007b; Vincent et al., 2003). This conclusion was reached in all of the studies which compared activity levels between genders. The studies reported that boys took between 4% to 38% more steps per day than girls. In the majority of the studies this was the only method used to measure physical activity. However, Duncan et al. (2006) and Vincent et al. (2003) tried to triangulate their physical activity measures by including a physical activity diary to be completed while fitted with the pedometer.

Loucaides et al. (2003) have suggested that the pedometer might be one of the best measures to use for comparing international differences in physical activity. In the literature one study was found which compared the differences in the daily steps of children between countries (Vincent et al., 2003). The aim of this study was to assess differences in physical activity levels and BMI's of children from the United States, Australia and Sweden. The main findings from this study indicated that American children were the least active and Swedish children the most active (Table 2.3). America also had the highest BMI scores as well as the greatest number of children who were classified as overweight. The ranges indicate that American and Australian children are failing to meet the recommended daily step count guidelines proposed by Duncan (2007a). Although the study was able to provide useful data from a number of countries there are some weaknesses with the study. For example, the pedometers were only worn during weekdays, no means or standard deviations were reported between step counts and no comparisons were made between genders.

It should also be noted that the data sets do not necessarily reflect the overall variations between countries as the children measured may not be representative of the population (Duncan et al., 2006).

It is important to examine some of the other significant findings from the pedometer studies which may impact on children's physical activity patterns. For example, it has been found that there are differences between during and after school step counts, weekday and weekend step counts and summer and winter step counts (Cox et al., 2006; Duncan et al., 2006; Loucaides et al., 2003). There is evidence to show that children who accumulated the highest mean daily steps spent a larger proportion of their time out of school accumulating them (Cox et al., 2006; Loucaides et al., 2003). If this is the case then there is an increasing need to try and encourage children to voluntarily participate in physical activity out of school hours. Duncan et al. (2006) reported that the amount of steps taken during the weekdays was consistently higher than the amount of steps taken during weekends. Weekend activity decreased with age and increased with socioeconomic status. Finally, Loucaides et al. (2003) found that step counts taken in summer were significantly greater than step counts taken during winter. In fact, their results suggest that during winter children are failing to meet the recommended daily step counts proposed by both Duncan et al. (2007a) and Tudor-Locke et al. (2004). Therefore, future research interventions should perhaps be aimed to increase physical activity during the times when children are least active.

To summarise, the literature suggests that children are less active than they should be. Based on pedometer step counts it has been established that girls are less active than boys and children are less active during weekends and winter. Therefore, strategies are needed to address these issues.

Children and sedentary behaviour patterns

As well as determining physical activity levels of children, it is also important to understand their sedentary behaviour patterns. Sedentary behaviour is believed to be one of the significant contributors to the increase in chronic health diseases (Healy et al., 2008). It has been argued that time spent in sedentary behaviour should be considered a distinct entity from exercise (Hamilton et al., 2007). Hamilton et al. (2007) argue that inactivity may produce serious health problems that cannot simply be explained by exercise deficiency. However, compared with physical activity, the research on sedentary behaviour is still in its infancy (Biddle, 2007).

The complexity of sedentary behaviour has only recently begun to be realised, yet it is often oversimplified in both research and in media representations of the research (Biddle (2007). This can be seen by the various definitions and measures of sedentary behaviour within the literature (Biddle, 2007). The most commonly used measure of sedentary behaviour is television viewing time (Christakis et al., 2004; Jordan, Hersey, McDivitt, & Heitzler, 2006). However, several authors have recently noted that sedentary time extends far beyond television viewing which is just one of the many activities that individuals participate in on a daily basis (Hardy, Bass, & Booth, 2007; Marshall, Biddle, Sallis, McKenzie, & Conway, 2002). For example, other sedentary behaviours may include doing homework, reading for pleasure, playing a musical instrument, sedentary hobbies and crafts and travelling in a vehicle. However, there are few studies available that have analysed total time spent in sedentary behaviour.

Television viewing time is the most commonly measured sedentary behaviour partly because it has been reported to be the most frequent sedentary activity that children partake in (Meier et al., 2007). Indeed, the aim of a number of studies has been to assess the total amount of time children spend engaging in television viewing (Andersen et al., 1998; Christakis et al., 2004; Jordan et al., 2006; Robinson et al., 1993). However, the amount of time children spend watching television varies substantially between studies. Christakis et al. (2004) tried to ascertain the amount of time American children under 11 years spend engaging in total media time. They concluded that the children in their study spent just over 2-hours per day in media activities. Another study used self-report measures to calculate the amount of time adolescent girls spend watching television (Robinson et al., 1993). In this study it was found that the mean amount of time spent watching television per day was 2.5-hours which equates to 17.5-hours per week. In a study involving over 6,000 children it was found that 67% of children watched at least 2-hours of television per day and 26% of the children watched more than 4-hours of television per day (Andersen et al., 1998).

Children that watched greater than 4-hours of television per day had significantly greater body fat ($p<0.001$) and greater BMI ($p<0.001$) than those that watched television less than 2-hours per day. Finally, in a recent study conducted by Jordan et al. (2006) it was found that 63% of the school aged children had a television in their rooms and reported watching more than three hours of television per day. All of these studies indicate that many children are watching more television than the recommended two hours of television per day (Commonwealth Department of Health and Aging, 2004; Department of Health, 2004; SPARC, 2008).

In addition to simply determining the amount of time children spend watching television, there is also a growing amount of literature available which has aimed to determine the patterns and correlates of sedentary behaviour (for example, DuRant & Baranowski, 1994; Granich, Rosenberg, Knuiman, & Timperio, 2008; Jordan et al., 2006; Marshall et al., 2002). One of the correlates which have been frequently studied is the relationship between physical activity and sedentary behaviour. However, there is conflicting evidence in the research regarding this relationship. For example, DuRant and Baranowski (1994) found that children who were most active tended to watch less television and for shorter durations. Whereas, Robinson et al. (1993) found that among adolescent girls television viewing time only appeared to have weak associations with physical activity (r=0.22, p=0. 70) or change in physical activity over time. However, the major limitation of this study, and other studies (DuRant & Baranowski, 1994; Granich et al., 2008; Jordan et al., 2006), was that both physical activity and television viewing data were collected using self-report measures. This may account for some of the differences found between studies in the amount of time spent in these activities.

Another correlate which has been studied is caloric intake and eating while watching television. This has been explored as it has been proposed that television viewing is often accompanied by eating. It has been estimated that 20-25% of total daily energy intake is consumed in front of the television (Matheson, Killen, Wang, Varady, & Robinson, 2004). Unfortunately, the foods eaten are often high calorie foods which have poor nutritional value (Temple, Giacomelli, Kent, Roemmich, & Epstein, 2007). In a recent meta-analysis by Gorely et al. (2004), it was found that television viewing was associated with in-between meal snacking. However, there were no associations found between television viewing and total caloric intake. The extent to which television watching contributes to obesity is controversial (Hancox & Poulton, 2006). In a study involving 971 adolescent girls, Robinson et al. (1993) found that television viewing time appeared to have no association with adiposity (BMI; r=0.30, p=0.62). However, in a longitudinal study that involved 976 New Zealand children, it was found that time spent watching television is a significant predicator of BMI and overweight in childhood (Hancox & Poulton, 2006).

Children's television watching behaviour may be a consequence of parental behaviour including what parents perceive is an acceptable volume of television watching for their children. Jordan et al. (2006) were interested in assessing parent reactions to the recommendation of limiting television hours to 2-hours per day. While parents generally perceived this to be a reasonable time limit, children, particularly those within the 9 to 10 year old age group, thought that the 2-hours were not long enough. It is interesting to note that among the reported barriers to reducing television time was the notion that the parents would not have enough time to complete their own daily chores since they would need to be spending a lot more time keeping their children occupied (Jordan et al., 2006).

Whilst television viewing has been the focus of sedentary behaviour research in children to date, there are other sedentary activities which may be significantly contributing to children's total sedentary time, especially other electronic media activities e.g. video games. During 2005, Sony alone sold 91 million PlayStation®2 consoles (Borusiak et al., 2008). In 2006, revenues from the gaming industry exceeded US$24.5 billion and sales are expected to reach US$55 billion by the end of 2008 (Alpert, 2007). In a recent study it was found that children who played video games spent on average one hour on weekdays and one and a half hours on weekends playing video games (Cummings & Vandewater, 2007). It was also found that boys were more likely to play video games than girls and that on the weekends, for every hour boys played video games, they spent 8 minutes less in sports and active leisure activities (Cummings & Vandewater, 2007). This is a concerning trend.

Interventions to Reduce Sedentary Behaviour

Reducing the amount of time spent in front of the television or computer is considered to be one of the most modifiable environmental influences of obesity (DeMattia, Lemont, & Meurer, 2007). There have been several randomised controlled trials testing the effective ways of doing this (refer to Table 2.4 for a collection of these studies and their summaries). For example, there have been studies which have made television viewing contingent on exercise (Faith et al., 2001; Roemmich, Gurgol, & Epstein, 2004), whereas other studies have focused on reinforcing decreased sedentary behaviour (Ford et al., 2002).

School based interventions

Schools have been a popular setting for implementing sedentary behaviour interventions. There have been several studies found within the literature which have aimed to reduce sedentary behaviour among children via the school curriculum (Gortmaker et al., 1999b; Robinson, 1999). In Robinson et al.'s (1999) study, two schools took part involving 192 children (aged 8.9 ± 0.6 years). One school acted as the control and the other school received the intervention which consisted of eighteen 30-50 minute lessons incorporated into the standard curriculum. These lessons focussed on challenging children to reduce the amount of time they spent watching television by teaching them ways to become 'intelligent' viewers. This intervention proved effective with children in the experimental group having significant decreases compared to the control group in several anthropometric measures including: BMI (-0.75%), tricep skinfold thickness (-6.4%) and waist-to-hip ratio (-1.2%). In addition, there were also significant decreases in the amount of time the experimental children spent watching television (-64%) and eating meals in front of the television (-17%) compared to the control group. Robinson et al.'s (1999) results indicated that that this type of intervention may be effective in reducing adiposity in children. However, one of the limitations of this study was that no data was collected to determine whether the health lessons taught by the school teachers were delivered per the study design.

Gortmaker et al.'s (1999b) 2-year intervention study was similar in design to Robinson et al.'s (1999). Their study, which involved 10 schools and 1286 students aged 11.7 ± 0.7 years, included an interdisciplinary intervention programme. The aim of the programme was to encourage students to decrease television viewing, decrease consumption of high-fat foods, increase fruit and vegetable intake, and increase moderate and vigorous physical activity. Key messages were addressed in different subjects across the school curriculum (e.g. languages, maths and science) during 16 core lessons over the year (32 lessons in total). The 5 control schools' curriculum was carried out as per normal. A significant finding from this intervention was that obesity prevalence among female students in the control schools increased (2.2%) and decreased in intervention schools (-3.3%). Although no changes were found in physical activity, children in the intervention schools television watching decreased by 0.58 and 0.40 hours per day for girls and boys, respectively. However, whilst school-based interventions are effective in decreasing television viewing time, no changes in physical activity have been observed indicating that other sedentary activities replace television viewing. Or, the lack of detectable change in physical activity might have been due to the insensitive instruments used to measure physical activity. In both Robinson et al.'s (1999) and Gortmaker et al.'s (1999) studies physical activity was measured using self-report measures which may have lead to inaccurate estimations of actual physical activity.

Overall, school-based interventions are proving successful. Despite there being a lot been done within the school environment, there is now a need to target reducing sedentary behaviour within the home environment, given that studies have shown that after school and weekends are when children are least active. Studies using contingent approaches and reinforcement theory have been the most commonly adopted approaches to reducing sedentary behaviour at home.

Contingent interventions

Making sedentary behaviours contingent on physical activity has proved successful in increasing physical activity but the evidence on whether sedentary behaviour is reduced is conflicting (Faith et al., 2001; Roemmich et al., 2004). Faith et al. (2001) aimed to decrease sedentary behaviour by making television viewing contingent on pedalling a stationary cycle ergometer. In their study each minute of pedalling 'earned' two minutes of television time. The control group had access to a cycle ergometer but television viewing time was chosen freely by them. It was found that the intervention group spent significantly more time per week on the cycle ergometer than the control group (64.4 minutes vs. 8.3 minutes, *p*=0.04). The intervention group also spent significantly less time per week watching television compared to the control group (1.6 hours vs. 21.0 hours *p*=0.006). These differences in viewing time and activity levels had an effect on anthropometric measurements with body fat percentage decreasing by 5.1% in the intervention group between pre- and post- test measures. Thus, suggesting that the intervention was successful at both increasing physical activity and reducing sedentary behaviour.

Roemmich et al. (2004) also made sedentary behaviour contingent on exercise. In their study, open-loop feedback was used to encourage children to reduce sedentary behaviour. Children wore accelerometers to determine how active they were during a week. The amount of time children in the experimental group were allowed to spend watching television during the week depended upon how active they had been the previous week. These children were able to view their activity counts on a daily basis. The control group also wore accelerometers but were unable to view their activity counts. They were told to be active for 60-minutes a day. Results showed that children in the experimental group significantly increased their amount of physical activity (24%). The experimental group also decreased the amount of time they spent watching television (18%), however this decrease was not significant compared to the control group. Another finding from this study suggested that the change in time spent watching television was directly related to the change in BMI z-score (*r*=0.69, *p*=0.02).

Both of the studies indicated that physical activity can be increased by making sedentary behaviour contingent on physical activity. However, the conflicting results on the reduction of sedentary behaviour show that further research is needed to clarify whether contingent interventions are effective in reducing long term sedentary behaviour. There were also limitations with both studies. Firstly, although children reduced the amount of time they spent watching television in Faith et al.'s (2001) study, there were no measures to identify what children did with the time. Therefore, as aforementioned, it is possible that some of the participants simply swapped television watching with another sedentary behaviour e.g. reading. Both studies also relied on a small samples (n=10-13) of obese children which means that the results cannot be generalised to other populations. Finally, consideration needs to given as to whether this type of design would work in practice. In reality it might be considerably difficult, and unrealistic, to get both children and parents to 'buy' into the idea of having a television powered by a cycle ergometer. This is important to consider because if interventions are not acceptable to the target population it is difficult to develop long term behaviour change.

Behavioural interventions

Several behavioural interventions have been developed using counselling (Ford et al., 2002) and reinforcement (Epstein et al., 2001; Epstein et al., 2008; Epstein et al., 1995). Ford et al. (2002) compared two different interventions with the aim of reducing the amount of time children spend watching television, playing video games and watching videos. The first group received counselling which included a discussion on the general problems associated with excessive media use. The second group received counselling and a behavioural intervention. The behavioural intervention included helping parents to identify a) how much time their children spent watching television, b) choosing a weekly media 'budget' with their child and c) helping the child stick to their budget. Despite there being a decrease in the amount of time spent watching television and videos and playing video games (behavioural group -13.7 ± 26.1; counselling group -14.1 ± 16.8) no statistically significant changes were found for either group. However, the behavioural intervention group reported a statistically significant increase (2.5 hours per week, 56.8%) in the amount of time spent in organised physical activity suggesting that the behavioural intervention might be a viable approach to use in the future. However, there are several limitations to this study. Firstly, the instruments used to collect the self-report measures were not specifically identified. There are also validity and reliability issues surrounding the use of self-report measures. Finally, the sample was made up of a small sample of low-income, African-American children only. Therefore, this limits the ability to generalise the results of this study to other populations.

Another popular method which has been used to reduce sedentary behaviour is using reinforcement. Epstein and colleagues have done a number of studies in this area (Epstein, Paluch, Gordy, & Dorn, 2000; Epstein et al., 2001; Epstein et al., 2008;

Epstein et al., 1995) and have found that reinforcement has had a positive affect on changing children's behaviours. In their earlier study (Epstein et al., 1995) compared the effects of reinforcing children for increasing physical activity, reducing time spent being sedentary, and the combination of both on child weight control. Fifty-five families participated in the trial. Those (parents and children) participating in the study attended weekly meeting treatments for 4-months, followed by two monthly meetings and measurement at the end of year one. The reinforcers used were 1) parental praise; and 2) another reinforcer which was agreed on in a contract made between each parent and their child. Results of the study indicated that reinforcing decreased sedentary behaviour only was most effective in decreasing the percentage of overweight children (-20% vs. -17% for sedentary behaviour and physical activity and -14% for physical activity). The sedentary behaviour group also had the greatest reduction in energy intake. Therefore, it is unclear whether the change in percent overweight children was caused by the decrease in sedentary behaviour, a decrease in energy intake or a combination of the two. In a similar study Epstein et al. (2000) aimed to compare the influence of targeting decreases in sedentary behaviour vs. increases in physical activity in obese children aged 10.5 ± 1.2 years. They did not find any significant differences between the groups but they did report a significant decrease in body fat (-2%) and percent overweight children (-12.9%) across both of the groups at the end of the intervention.

More recently, Epstein et al. (2001) chose to evaluate the gender differences at targeting increased physical activity or targeting a combination of increased physical activity and decreasing sedentary behaviour. Research has consistently reported that girls are less active than boys. Obese girls and boys, in the increase physical activity group, benefited equally from the intervention. However, in the combined intervention boys benefited more than girls with the decrease in percent overweight 14.8% greater in the boys group compared to the girls group. This suggests that interventions may need to consider different gender responses.

Table 2.4. Randomised controlled trials aimed at reducing sedentary behaviour

Author	Subject Characteristics	Mean age (years)	Intervention	Control	Main Findings
School Based / Community Interventions					
Gortmaker et al. (1999) 2-years	n = 10 schools	11.7 ± 0.7	5 schools (n = 645 children) An interdisciplinary school based intervention programme focussed on encouraging students to decrease television viewing, decrease consumption of high-fat foods, increase fruit and vegetable intake, and increase moderate and vigorous physical activity.	5 schools (n = 641 children) Usual curriculum.	Obesity increased by 2.2% in control schools and decreased by 3.3% in intervention schools*. TV decreased by 0.58 hr/d and 0.40 hr/day in girls and boys respectively. No significant changes in PA.
Gortmaker et al. (1999a) 2-years	n = 14 schools	9.2 (no SD)	6 schools. Included in the school curriculum was a focus on encouraging students to decrease television viewing, decrease consumption of high-fat foods, increase fruit and vegetable intake, and increase physical activity and decreasing television viewing.	8 schools. Usual curriculum.	Compared to the control group, the intervention group increased their servings of fruit and vegetables per day (26.2%)*, decreased their daily consumption of high fat foods (-1.4%)* and decreased the amount of time they spent watching television (-13.6%). There was no evidence to suggest that PA increased.

Robinson (1999) 1-year	n = 2 schools	8.9 ± 0.6	1 school (n = 100) Received an 18-lesson, 6-month classroom curriculum to reduce TV, videotape and videogame use.	1 school (n = 92) Usual curriculum.	BMI, skinfolds, waist-to-hip ratio, TV viewing, video game use & eating in front of TV decreased by 0.75%*, 6.4%*, 1.2%*, 64%*, 221%* and 17.0%* more in the intervention group, respectively. No change seen in fitness levels.
Robinson et al. (2003) 12-weeks	n = 61 girls	9.5 ± 0.9	12-week dance programme after school. 5 home visits to encourage reducing SB.	Health education.	Compared to the control group, the intervention's group BMI decreased by 0.9%*, self-reported moderate to vigorous PA increased by 4.2%* and SB decreased by 19%*.
Simon et al. (2004) 6-months	n = 8 schools	11.6 ± 0.6	4 schools (n = 479 children) School based programme to encourage decreased SB and increased PA. Activities were offered during school breaks and after school.	4 schools (n = 475 children) Usual curriculum.	In the intervention girls and boys leisure organised PA increased by 24%* and 12%*, respectively; whereas girls and boys in the control group increased theirs by 2% and -1%. High SB decreased by -7%* and -3%* in the intervention group and increased by 4% and 14% in the control group for girls and boys, respectively.

Contingent Interventions					
Faith et al. (2001) 12-weeks	n = 10 obese children	10.2 ± 1.5	TV viewing contingent on pedalling a stationary cycle ergometer. 1min of pedalling = 2min of TV.	Cycle ergometer in home but TV viewing was not contingent on pedalling.	81.1%* more cycling and 92.4%* less TV viewing than control group. 2.7%* decreased BF%.
Roemmich et al. (2004) 6-weeks	n = 13 families	11 ± 0.5	Received a contingent reward of TV time after PA goals had been met. Accelerometers were used to give PA feedback.	Wore accelerometers but no feedback was given.	24%* increase in PA, 18% decreased TV viewing time. Change in BMI related to change in TV viewing (r=0.69) *. No significant differences found between groups.
Behavioural Interventions					
Epstein et al. (1995) 1-year	n = 55 families	10.1(no SD)	Reinforced decreased SB (Grp 1).	Reinforced decreased SB and increased PA (Grp 2). Reinforced increased PA (Grp 3.).	Group 1 had a greater decrease in % overweight (20% vs. 17%[2] vs. 14%[Grp3])* and BF% (5% vs. 2%[2] [3])*. All groups fitness levels increased from baseline measures.*

Epstein et al. (2000) 2-years	n = 90 obese children	10.5 ± 1.2	Decreased SB was reinforced by parents.	Increased PA was reinforced by parents.	No significant differences between groups. BF% decreased by ~2%* and percent overweight decreased by 12.9%* across groups.
Epstein et al. (2001) 6-months 1-year follow up	n = 56	10.4 ±1.2	Weekly family meetings with contingent rewards for meeting goals for reduced SB and increased PA. Gender differences were determined.	Same as the intervention group but contingent rewards for increasing PA only. Gender differences were determined.	No significant differences between genders in the increase PA group. Boys BMI decreased more than girls (-1.76 vs. -0.27)* in the combined group suggesting that there may be gender differences in modifying inactivity.
Epstein (2008) 2-years	n = 70 >75th BMI percentile	6.0 ± 1.3	Weekly budget was set for TV, computers and associated behaviours. Budgets reduced by 10% from baseline per month until the budget had been reduced by 50%. Children were reinforced by parental praise, researchers praise, a star chart, and they earned $0.25 for each hour per week under budget ($2.00 maximum).	Children had free access to TV and earned $2.00 per week regardless of their behaviour change.	No change in PA. TV time decreased ~50%* more in the intervention group when compared to the control group.

Ford et al. (2002) 4-weeks	n = 28 families	9.5 ± 1.4	Received counselling and a behavioural intervention that included an electronic TV time manager.	Received counselling only.	There was a 56.8%* increase in time spent in organised PA. No significant differences found in TV, videotape & video game use.

* = significant difference M = male, F = female, BF% = body fat percentage, SB = sedentary behaviour, TV = television, PA = physical activity

Limitations of the sedentary behaviour studies

Overall, there have been a number of limitations found with the interventions aimed at reducing screen-time. The main limitations that have been identified include; small sample sizes, homogenous samples and self-report measures. Self-report and proxy report measures have been the main methods used to measure time spent in sedentary behaviour. Although plenty of studies have assessed the validity and reliability of physical activity measures, there has been little attempt made to validate sedentary measures.

Also, a number of the studies only collected information on the amount of time children spent in screen-based leisure time. Therefore, the activities substituted for screen-time was unable to be reported. This means that total sedentary time was not reported. It also seems pertinent to point out that a number of these interventions would be difficult to sustain long term. In order to reduce sedentary behaviour effectively interventions need to develop long term behavioural changes (Jason & Brackshaw, 1999).

Summary of sedentary behaviour interventions

Overall, studies which have been designed to decrease sedentary behaviour seem to be yielding promising results. These studies indicate that sedentary behaviour interventions can significantly decrease time spent watching television, decrease body fat and in some cases increase physical activity. More interventions are needed within this paradigm focusing on decreasing other popular sedentary activities such as video game play.

Active video games

Previous interventions which have aimed to reduce sedentary behaviour have mainly done so by focusing on reducing the amount of time children spend partaking in screen-based activities. However, it seems unrealistic to try to completely eliminate television and screen use from children as it has become apparent that children are reluctant to give up these activities (Jordan et al., 2006). Video gaming companies have found an opportunity to develop and promote 'healthy' video games. With the revenues in the gaming industry soaring (Alpert, 2007), 'healthy' video games may be a partial solution to reducing sedentary behaviour. There are several commercially available active video game consoles on the market including Nintendo® Wii, EyeToy (PlayStation® 2, Sony) Dance UK (PlayStation® 2, Sony) and Dance Dance Revolution (XBOX®, Konami Digital Entertainment). These video game consoles require and encourage gamers to perform movement in order for their onscreen character to move. For example, during the Nintendo® Wii Sports games the player holds the Wii Remote and uses it like a tennis racquet, a bowling ball, a golf club and a baseball bat (Appendix 7). Therefore, during a game such as tennis, the way in which the gamer swings the remote will determine where the onscreen character hits the ball (Appendix 7). EyeToy has a web camera which allows the onscreen character to mimic the gamers' movements. Dance UK and Dance Dance Revolution both have mats on which the player dances in time to the movements on the screen.

Active-video games have the potential to decrease sedentary behaviour and research is emerging to support their efficacy. In America, it has been reported that physical educators are gradually introducing students to interactive video games via the physical education curriculum (Trout & Christie, 2007). For example, in the State of West Virginia active video games were purchased for 765 public schools' physical education programmes (Trout & Christie, 2007). Educators have suggested that active video games not only encourage activity but they can also aid as an educational tool as some of the games have been fitted with devices to measure variables such as HR and caloric expenditure (Trout & Christie, 2007).

Trout and Christie (2007) acknowledged that these games were bought without there being reliable research available supporting the benefits of such games. However, recently, the explosion of health promoting video games into the market has lead to a surge of research in the area. There have been several papers published looking at the potential benefits that active video games have to offer (Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006; Maddison et al., 2007; Ni Mhurchu et al., 2008; Straker & Abbott, 2007). Typically, these studies have quantified the energy expended whilst playing a variety of games (Table 2.5).

In one of the earliest studies published on active video gaming, the effects of active video games were compared to traditional video games (Lanningham-Foster et al., 2006). Each child's EE was measured using indirect calorimetry. Measurements were taken while resting, playing a traditional seated video game, walking on a treadmill at 1.5 miles.h^{-1} and watching television, and while playing two active video games. It was found that EE increased significantly from resting values during all other conditions. The active video games that were played were EyeToy and Dance Dance Revolution which resulted in increased EE (13.21 ± 4.20 SD kJ.kg^{-1}.h^{-1} and 17.26 ± 4.28 SD kJ.kg^{-1}.h^{-1}, respectively) by 110% and 167%, respectively, compared to rest. However, RMR was measured after 5-hours of fasting and a snack was given to the children between completing the resting measures and beginning the intervention. The order of video games was not randomised between subjects and details of the EyeToy game played were not clearly stated.

In a similar study by Maddison et al. (2007) a number of these methodological limitations were overcome. Like Lanningham-Foster et al. (2006), Maddison et al. (2007) used indirect calorimetry to measure children under several conditions including resting (seated), inactive video game (seated) and playing five active games in a randomised order. The active video games were played for 5-8 minutes and included; EyeToy Knockout, Homerun, Groove, AntiGrav and Dance UK (PlayStation® 2, Sony). Outcome measures included HR, activity counts and EE. Results indicated that EE, activity counts and HR were significantly greater during the active video games than at rest or during traditional video games. For example, energy expended during Knockout, Homerun, Dance UK, Groove and AntiGrav increased 400%, 354%, 277%, 123% and 177% from rest, respectively. These data suggests active games have the potential to contribute to a child's daily physical activity.

Straker and Abbott (2007), like Maddison et al. (2007) and Lanningham-Foster (2006), used EyeToy (Cascade, PlayStation® 2, Sony, Tokyo, Japan) as the chosen active video game in their study. Participants also watched a DVD. Straker and Abbott's (2007) results indicated that the energy cost of playing the active video game (Cascade, EyeToy, PlayStation® 2, Sony, Tokyo, Japan) was 226% higher than watching a DVD. Additionally, the authors noted that the oxygen cost of EyeToy

(26.54 $ml.kg^{-1}.min^{-1}$) is comparable to stair-walking at 5.6 $km.hr^{-1}$ (24.6 $ml.kg^{-1}.min^{-1}$), climbing (30.6 $ml.kg^{-1}.min^{-1}$) and rope skipping (35.3 $ml.kg^{-1}.min^{-1}$). However, it should be noted that the oxygen cost of stair-walking, climbing and rope skipping were not measured within the study but were compared to those measurements observed by Harrell et al. (2005). To allow a more accurate comparison in future studies, it would be better if researchers considered measuring the EE of activities that children regularly partake in, such as walking and running, and compare the energy values of these activities to active video games in the same subjects.

It is generally difficult to compare the differences in EE between studies due to the wide range and varying differences in the active video games used. However, Maddison et al. (2007) and Lanningham-Foster et al. (2006) used relatively similar dance games in each of their studies. The games, Dance UK and Dance Dance Revolution, both involve players moving around on a "dance mat" in time with visual and musical cues. It is interesting to note that despite using relatively similar dance games Maddison et al. (2007) and Lanningham-Foster et al. (2006) observed substantially different increases in EE. For example, Maddison et al (2007) found that EE increased by 277% when children played Dance UK. Whereas, Lanningham-Foster (2006) found that Dance Dance Revolution only increased EE by 167% from rest. It is likely that small differences between the two dance games resulted in such varied responses which suggest that consideration of specific individual games for specific gaming consoles is required to maximize EE.

More recently, two papers by Graves and colleagues have been published on the energy expended during Nintendo® Wii video games (Graves et al., 2008; Graves et al., 2007). The first study (Graves et al., 2007) compared the differences in EE between traditional video games (XBOX® 360) and three active video games including: Wii Bowling, Wii Tennis and Wii Boxing (Nintendo® Wii). Their results indicated that EE was at least 134%-149% greater during active gaming than during sedentary gaming. However, they used the Intelligent Device for EE and Activity (IDEEA) system to measure EE. This system is worn around the waist and indirectly measures EE (Graves et al, 2007). However, Graves et al. (2007) suggested that the IDEEA may have been a limitation to their study as the system does not detect arm movements well. This is a significant problem as such gaming largely comprises of upper body movements. Therefore, EE may have been underestimated in Graves et al. (2007) study. Furthermore, the study was limited by the small sample size (n=11). Therefore, these results cannot be applied to the broader population.

In their second study, however, Graves et al. (2008) overcame some of the limitations that were present in their first study. For example, they used indirect calorimetry to measure EE whilst playing the Wii Sport games (Bowling, Tennis and Boxing). Graves et al. (2008) also aimed to examine the contribution of upper limb and total body movement to adolescents' EE whilst playing active video games on the Nintendo® Wii. It was found that when compared to rest, EE increased significantly during active gaming. For example, EE was 117%, 139%, 218% higher during Wii Bowling, Wii Tennis and Wii Boxing, respectively. Additionally, it was found that the physiological cost of upper-body orientated active video games was increased when both upper-limbs were encouraged. Although this study was more methodologically robust than the earlier study it was limited by the small sample size (n=11) and the large age range of the subjects (11-17 years). EE decreases with age (Harrell et al., 2005). Therefore, having such a broad range of subjects may have influenced results.

In addition to simply describing the EE of active video games some studies have sought to determine whether other factors may influence EE during active video game play. For example, body size may be influential in the amount of energy expended. Unnithan, Houser and Fernhall (2006) compared the differences in energy expended between overweight and non-overweight children while playing Dance Dance Revolution. They found that absolute energy expenditure was significantly greater in obese children than in normal weight children (overweight, 4.6 ± 1.3 and non-overweight 2.9 ± 0.7, $p \leq 0.05$). However, when values were adjusted for fat free mass EE was not statistically significant between the two groups. Lanningham-Foster et al.'s (2006) also compared the physiological responses of overweight and lean children while participating in the various activities. Lanningham-Foster et al. (2006) hypothesised that lean children would expend more energy than overweight children. However, although they found that EE differed significantly (when adjusted for body weight) between the two subgroups during resting (lean, 7.1 ± 1.3 $kJ.kg^{-1}.h^{-1}$,overweight, 5.9 ± 0.8 $kJ.kg^{-1}.h^{-1}$, $p<0.02$), sitting and watching television(lean, 8.4 ± 1.7 $kJ.kg^{-1}.h^{-1}$ and overweight, 7.1 ± 1.3 $kJ.kg^{-1}.h^{-1}$, $p<0.03$), and sitting and playing the traditional video game (lean, 8.4 ± 1.7 $kJ.kg^{-1}.h^{-1}$ and overweight, 7.1 ± 0.8 $kJ.kg^{-1}.h^{-1}$, $p<0.05$) no significant differences in EE were found during walking and watching television or during the activity promoting video game between the two groups. Although weight status does not seem to impact the energy expended during active video gaming, fitness might. It is possible that fitter children have less acute physiological and metabolic responses compared to unfit children. Therefore, this may be an additional variable to study during future research.

Another variable that may impact the amount of energy expended while playing active video games is 'gaming experience'. Maddison et al. (2007) noted that a potential limitation of their study was that they only collected EE data of those who considered themselves to be novice active video game players i.e. they all had some previous experience playing electronic games. It is possible that experienced active video game players may differ in the way they approach the game in terms of movements, thus, potentially altering their EE. There appears, however, to be only one study in the literature which compares the energy expended by experienced and novice gamers (Sell, Lillie, & Taylor, 2008). In this study experienced (n=12) Dance Dance Revolution players and novice (n=7) players were compared during a 30 minute game of Dance Dance Revolution. Their results indicated that experienced players expended 38% more relative energy than inexperienced players (0.13 $kcal.kg^{-1}.min^{-1}$ vs. 0.08 $kcal.kg^{-1}.min^{-1}$, respectively, $p<0.05$,). Additionally, their study indicated that experienced players enjoyed the game significantly more than their inexperienced counterparts. However, as this study only used a small sample (n=19) of male college students (21.8 ± 3.5 years) it is difficult to generalise these results to other populations. Furthermore, it is possible that differences between the energy expended of experience vs. non-experienced may be game specific.

It has been noted that for interventions to foster long term behavioural changes and in order for them to be sustainable they must appeal to their target audiences (Motl et al., 2001). Therefore, an additional area that may need to be explored is the appeal of active video games. If children enjoy activities they are more likely to want to do them. Future interventions designed to help combat the obesity epidemic should include an element of "fun" in them. Therefore, enjoyment should be an area explored in future studies. Whilst initial attempts have been made to quantify and compare EE of active video games and other activities of children, further studies are needed to determine whether the energy expended during these "active" video games is of a suitable intensity for health benefits. For example, comparisons should be made with other types of children's activities such as walking and running.

To advance knowledge generated from the aforementioned descriptive studies, intervention studies are now needed to determine the mid- to long-term health effects of playing these games regularly. In this regard, only one intervention study can be found in the active video gaming literature (Ni Mhurchu et al., 2008). The aim of the study was to evaluate the effect of active video games on children's (n=20) physical activity levels. Specifically, the researchers were seeking to determine how often and how long children played active games for, and what impact did active video games have on children's physical activity. All of the participants recruited for the study owned a PlayStation® 2 gaming console. Participants were randomised to either receive an active video game upgrade package (n=10) or to a control group (n=10) during the 12-week intervention study. Results from this 12-week study showed that children who had the opportunity to play active video games played fewer video games overall (54 vs. 98 minutes per day, p=0.06) and participated in more physical activity overall (as measured by an accelerometer) compared to the control group (mean difference at 6 weeks = 194 counts/ min, p=0.04, at 12 weeks = 48counts/min p=0.6. Children in the active video games group had decreased waist circumferences compared to controls (-1.4cm; p = 0.04). Overall, the results of this study are promising and further research should be conducted to explore the effectiveness of active video games to increase activity levels and subsequently improve the health of children.

Trout and Christie (2007) have noted that any strategy for increasing or promoting physical activity is worth exploring. Similarly, McManus (2007) has noted that innovative solutions are needed to encourage children to increase NEAT. After briefly reviewing the literature on physical activity in children McManus (2007) concludes that converting screen-time into activity is likely to be a feasible and appealable way of increasing children's activity. Likewise, Floriani and Kennedy (2008), in their review which explored recent updates on the area of physical activity promotion, concluded that opportunities for finding active alternatives to sedentary behaviours such as television and videogames need to be further explored. Therefore, it seems plausible that active video games may have an important role in helping with the obesity epidemic in the future. However, further research is needed before such games can be used as an activity promoting tool.

Table 2.5. Acute studies published showing children's increase in energy expenditure from rest during active video game play

Author	Subjects	Age (years ± SD)	Measurement of EE	Percentage Increase in EE from Rest (%)			
				Sedentary Activities	Upper Body Games	Lower Body Games	Combined Upper- and Lower- Body Games
Graves et al. (2007)	n = 11 45% female	14.6 ± 0.5	IDEEA	Sedentary video game (54%)	Wii Bowling (134%)*		Wii Tennis (149%)* Wii Boxing (144%)*
Graves et al. (2008)	n = 13 46% female	15.1 ± 1.4	Indirect Calorimetry	Sedentary video game (38%)	Wii Bowling (117%)*		Wii Tennis (139%)* Wii Boxing (218%)*
Lanningham-Foster et al. (2006)	n = 25 0% female	9.7 ± 1.6	Indirect Calorimetry	Watching television seated (19%)* Sedentary video game (21%)*		Watching television whilst walking on a treadmill (133%)*	DDR (167%)* EyeToy (110%)*

Maddison et al. (2007)	n = 21 48% female	12.4 ± 1.1	Indirect Calorimetry	Sedentary video game (24%)		EyeToy Dance UK (277%)* EyeToy Groove (123%)*	EyeToy Knockout (400%)* EyeToy Homerun (354%)* EyeToy AntiGrav (177%)*
Straker & Abbott (2007)	n = 20 40% female	9-12	Indirect Calorimetry	Handheld (-5%) Gamepad (5%) Keyboard (8%)	Wheel (18%)		EyeToy Cascade (226%)*

Where * indicates statistical significance $p<0.05$; and EE indicates energy expenditure

Summary and Recommendations

This review has provided an overview of current publications concerning children's physical activity, physical inactivity and sedentary behaviour. It is clear that the percentage of children that are inactive and sedentary is increasing and there is a concomitant increase in the number of obese children and other health risk factors. Alternative approaches aimed at reducing time spent in sedentary behaviour appear to be equally, if not more, effective than increasing physical activity. However, a number of these interventions have methodological weaknesses and it is questionable as to whether they would work in practice as children highly value screen-time and are reluctant to eliminate or reduce this pastime. It has been found that children who are most active spend a larger proportion of their non-school time engaged in physical activity. This indicates that there is a need for future interventions to be designed to encourage children to be active at home. Furthermore, children are less active in winter than in summer thus suggesting that an indoor physical activity intervention may be beneficial. Consequently, there is a need for home based, indoor interventions which are aimed at reducing physical inactivity activity.

It seems that many researchers agree that unique and novel interventions are necessary if the obesity crisis is to be alleviated. Therefore, it is pertinent that non-traditional interventions are explored. One approach that has recently been advocated is promoting the use of active video games which can be used to increase daily EE by replacing sitting-based screen-time activities (e.g. television, traditional non-active video games) with activity based screen-time. Studies to date have quantified EE whilst playing various active video games. However further research is needed to address the methodological limitations of these studies. Additionally, consideration of the effect of variables such as experience levels and enjoyment and direct measures of fitness on the energy expended during active video games may provide some additional useful information as to whether active video games may be a useful long term intervention for all or specific groups of children.

CHAPTER 3. ENERGY EXPENDITURE DURING NINTENDO® WII ACTIVE VIDEO GAMES: HOW DOES IT COMPARE TO OTHER SEDENTARY AND PHYSICAL ACTIVITIES?

Abstract

Background: Activity promoting video games may provide a unique opportunity to convert traditional sedentary pursuits into physical activity. **Purpose:** 1) To determine whether active video games increase energy expenditure (EE) significantly above resting levels; 2) to determine whether the increases in EE are influenced by gaming experience or fitness; and 3) to determine the relative intensity of active video games. **Method:** Twenty-six boys aged 11.4 ± 0.8 years were measured using indirect calorimetry while resting, participating in two sedentary activities (television and inactive gaming), five active video games (Wii Boxing, Wii Tennis, Wii Bowling, Wii Step and Wii Ski) and two physical activities (walking and running). Subjects were divided into beginners, intermediate, and experienced Wii Sport gamers and into high and low aerobic fitness groups). Heart rate (HR), EE and oxygen uptake ($\dot{V}O_2$) were compared to rest and between activities. Gaming intensity was also determined. **Results:** No significant differences in EE were found between resting and sedentary activities. EE increased significantly from rest during all active video games (63-190%, $p<0.05$) and physical activities (184-442%, $p\leq0.001$). The most active video games (Wii Boxing, 411 $J.kg^{-1}.min^{-1}$ and Wii Step, 350 $J.kg^{-1}.min^{-1}$) were not significantly different from walking (403 $J.kg^{-1}.min^{-1}$). However, EE was significantly less than running (768 $J.kg^{-1}.min^{-1}$, $p\leq0.001$) during all activities. No significant differences were found in EE between novice, beginner or experienced gamers or between gamers with high vs. low fitness. **Conclusion:** Active video games may be beneficial substitutes for sedentary pursuits but should be played in conjunction with traditional physical activity.

Introduction

Currently, there are a number of children failing to achieve the minimum daily physical activity guidelines (Spinks, Macpherson, Bain, & McClure, 2007). Of equal concern, is that the amount of time children spend in sedentary pursuits is quantitative (Andersen et al., 1998; Jordan et al., 2006; Robinson et al., 1993). For those working in the public health domain this is becoming increasingly disturbing as sedentary behaviour and decreased physical activity are independently associated with chronic health problems including obesity (Goran et al., 1999), type 2 diabetes (Krekoukia et al., 2007; Schmitz et al., 2002) and cardiovascular diseases (Chu, Rimm, Wang, Liou, & Shieh, 1998; Meyer et al., 2006; Woo et al., 2004). These lifestyle diseases cost countries, such as New Zealand, millions of dollars a year (Ministry of Health, 2002; World Health Organisation, 2003). Therefore, there is a critical need to develop interventions aimed at decreasing the burden of inactivity.

One of the most frequently observed sedentary activities that children partake in is screen-based activities including: television viewing, playing video games and playing on computers (Meier et al., 2007). Research suggests that children spend 2.5 to 4 hours per day participating in screen-based activities (Andersen et al., 1998; Robinson et al., 1993). More specifically, in New Zealand, 41.7% of boys aged 5-14 years watch more than 4-hours of television over weekends and 26.6% watch more than 10-hours of television during the week (Ministry of Health, 2003). Replacing traditional sedentary screen-time with “active” screen-time may be a useful way to encourage children to increase total daily EE and reduce the amount of time they are spending being physically inactive.

Opportunities to convert traditional sedentary screen-time to active screen-time may exist via the recent entry of revolutionised “active video games” into the gaming market. These games utilise cameras and motion sensors which allow the gamer to physically perform a variety of actions such as swinging a tennis “racquet”, throwing balls and running on the spot. Several studies have already determined the energy expended (Table 2.5) during active video games such as the PlayStation® 3 EyeToy

(Lanningham-Foster et al., 2006; Maddison et al., 2007) and the Nintendo® Wii Sports (Graves et al., 2008; Graves et al., 2007). Although these studies have provided useful information in terms of quantifying the EE of active video games it would be useful to determine the relative intensity of active video games as well as directly compare them to other children's activities such as walking and running.

The majority of the active video gaming studies have mainly provided descriptive data on the energy expended during games (Graves et al., 2008; Graves et al., 2007; Maddison et al., 2007; Straker & Abbott, 2007). However, Lanningham-Foster et al. (2006) compared EE during active video games between lean and obese children. Their results showed that EE, when adjusted for body weight, was not significantly different between the groups. Another study compared EE during a dancing video game between two groups of gamers, experienced and inexperienced gamers (aged 21.8 ± 3.8 years). Results indicated that experienced gamers expended 54% (p=0.05) more energy during the game (Sell et al., 2008). No similar studies have been done using either EyeToy games or Wii Sports games, which both involve substantially different movements to the dance type games. Thus, the experience of gamers may either lead to playing at a lower intensity due to economy of movement or it may enable gamers to play at a higher intensities.

The purpose of this study was to: 1) determine EE during a selection of Nintendo® Wii active video games and to compare the EE to walking and running; 2) determine whether the metabolic costs of activities were influenced by experience and/or fitness; and 3) determine the relative intensity of active video games.

Methodology

Experimental design

A cross-sectional, repeated measures design was employed for this study. The acute physiological and metabolic effects of active video games were quantitatively measured in order to determine EE at resting and during other sedentary and physical activities. Secondary outcomes of the study were to 1) determine if differences in the metabolic costs of activities between novice, intermediate and experienced active video game players existed; and 2) determine the relationship between aerobic fitness and EE during active video games. The dependent variables were $\dot{V}O_2$, HR and EE. The independent variables included ten different activities including: resting, walking, running, watching television, playing a sedentary video game and playing five different active video games.

Outline of procedures

Participants attended three testing sessions during which they performed different tasks (Table 3.1). During session 1, height, body mass, resting $\dot{V}O_2$, resting metabolic rate (RMR) and resting HR were measured. Participants then completed the walking and running activities followed by a Maximal MultiStage 20 Meter Shuttle Run Fitness Test (MSFT) to assess cardiovascular fitness. The session was concluded by allowing the subjects to familiarise themselves with the range of video games for a total of 20-minutes. During sessions 2 and 3 participants RMR was measured at the beginning of the sessions. Following this, one sedentary activity (watching teleision or playing PlayStation® 3) and two or three active video games were chosen at random for participants to play. Sedentary activities always preceded the active video games in order to ensure that the sedentary games were not initiated with the individual already in an elevated physiological state. Participants were given a 3-minute break between all activities.

Table 3.1. Outline of the testing sessions

Testing Session 1	Testing Session 2	Testing Session 3
Baseline height & weight	Resting measures	Resting measures
Resting measures	Sedentary activity 1	Sedentary activity 2
Walking at a self-selected pace	Active video game 1	Active video game 4
Running at a self-selected pace	Active video game 2	Active video game 5
Multistage Fitness test	Active video game 3	
Games familiarisation		

Participants

Twenty-six healthy boys aged 10-12 years (11.4 ± 0.8) were recruited for the study via personal contacts, local schools and community advertisements. Participants' mean body mass and height was 41.9 ± 9.2 kg and 146.4 ± 6.9 cm, respectively. A summary of all participants baseline characteristics are shown in Table 3.2. Exclusion criteria included children who were not healthy (e.g., those suffering from coughs and colds), injured, had asthma or were not able to exercise at moderate to high intensities. Written informed consent and assent was provided from parents/guardians and participants, respectively. Ethical approval for the study was granted by the Auckland University of Technology Ethics Committee (Appendices 2-5). Participants were divided into three groups, beginner, intermediate or experienced, based on their prior Wii Sports gaming experience. Experienced gamers were classified as children who played Wii Sports games once a week or more often. Intermediate gamers were those who had spent at least five hours playing Wii Sports games before but did not play on a regular basis (i.e. < once per week). Finally, beginner gamers were classified as those that had never played Wii Sports games prior to the study.

Testing protocols

Baseline measures

Participants' baseline height (Mentone Stadiometer, Moorabbin, Australia) and body mass (Seca 770, Germany) were recorded during the first testing session using standard anthropometric techniques. Participants were requested to eat the same amount as well as the same type of food during the 24-hours before each test. A food diary (Appendix 6) detailing what they ate during the 24-hours prior to each testing session was completed by each child and checked for consistency.

Aerobic fitness

The MSFT (Léger, Mercier, Gadoury, & Lambert, 1988) was used to assess aerobic fitness. The MSFT is an incremental shuttle run test to exhaustion during which the speed of running starts at a pace of 8.0 $km.hr^{-1}$ and is progressively increased by 0.5 $km.hr^{-1}$ every minute. The MSFT is both a valid and reliable predictor of fitness in children (Barnett, Chan, & Bruce, 1993; Léger et al., 1988; Winsley, 2003). The test was carried out in an indoor sports stadium. The 3-minute walking and 3-minute running activities (see section below) were completed before the fitness test and therefore used as the warm up. Prior to beginning the MSFT a verbal explanation of the test was given to the participant. Participants were asked to complete as many shuttles as they could while keeping in time with the audible beeps. The researcher completed the first four stages with each child in order to ensure that they paced themselves and turned correctly. A HR monitor (Polar S810, Kempele, Finland) was worn around participants' chest so that peak HR (HR_{peak}) could be determined. Peak oxygen consumption ($\dot{V}O_{2\,peak}$) was predicted using the equation y=31.025 + 3.238 x - 3.248a + 0.1536.ax. Where y= $\dot{V}O_{2\,peak}$ ($ml.kg^{-1}.min^{-1}$), x=maximal speed reached ($km.h^{-1}$) and a=age (years). This has been shown to be a valid (r = 0.71) and reliable (r = 0.89) equation to predict $\dot{V}O_{2\,peak}$ from the MSFT in children (Léger et al., 1988; Winsley, 2003). Leger et al. (1988) found in their study that sex, weight and height were not significant predictors of $\dot{V}O_{2\,peak}$.

Gaming and physical activities

Ten activities typically undertaken by children were assessed over three testing sessions on separate days. The activities included: resting, walking, running, watching television, playing a sedentary video game and playing five active video games. All of the activities, with the exception of walking and running, were carried out in a temperature controlled room (20-24°C, 60% humidity). This was checked using a barometer. To replicate a home environment, the room was fitted with a couch, table and cushions.

Resting. Resting metabolic and physiological measures, including $\dot{V}O_2$ and EE, and HR were recorded at the beginning of each testing session while participants lay in a supine position on a bed with their head resting on a pillow. Participants were encouraged to relax, but not sleep, and to move as little as possible. Children were required to rest on the bed for 15 minutes in order to reach a true physiological resting state (Harrell et al., 2005). Resting measures were collected on three separate days for each child, thus enabling the coefficient of variation to be determined. The coefficient of variation for RMR was 2.1%. Food diaries (Appendix 6) were used to ensure that subjects ate the same amount as well as the same type of food before each testing session. Subjects were also advised to avoid vigorous exercise the day before testing. In all situations oxygen uptake was measured at standard temperature and pressure dry (STPD).

Self-paced walking and running. The walking and running activities were performed in an indoor sports stadium. Participants were instructed to walk around a 50m circuit for 3-minutes at a pace they would typically walk to school at. Following a 3-minute rest participants were instructed to run around the same 50m circuit for 3-minutes at a pace they could maintain for the duration of the time. Participants had a 3-minute rest before completing the MSFT.

Screen-based activities. Children participated in seven screen-based activities including two sedentary activities and five active video games. During the sedentary screen-based activities (watching television and playing a sedentary video game) participants were required to sit comfortably on the couch. A 10-minute ‘G’ rated DVD (SpongeGuard on Duty, Nickelodeon, Australia) was chosen for the participants to watch. The traditional video game (Need for Speed ProStreet, Electronic Arts, Australia) was played on a PlayStation® 3 console (PlayStation®, Sony Computer Entertainment, New Zealand). Five active video games (Boxing, Tennis and Bowling, Wii Sports, Nintendo®, Australia; and Step and Ski, Wii Fit, Nintendo®, Australia) were played for 8-10 minutes on a Wii console (Wii, Nintendo®, Australia). The active video games included in the study were chosen to represent a range of activity levels which required upper, lower or combined upper and lower body movements. All participants played all games in the same standardised environment. The order in which the active video games were played was randomised. Detailed descriptions of the games can be found in Appendix 7.

Measurement of $\dot{V}O_2$

During all activities, except MSFT, a portable gas analysis system (MetaMax 3B, Cortex Biophysik, Leipzig, Germany) was used to measure $\dot{V}O_2$ and carbon dioxide output (CO_2) to determine metabolic rate and EE. The MetaMax has been shown to be a valid and reliable calorimetry device (Larsson, Wadell, Jakobsson, Burlin, & Henriksson-Larsén, 2004; Medbe, Mamen, Welde, Von Heimburg, & Stokke, 2002). Prior to testing, a two point calibration (at room temperature, using ambient air, and using a manufactured gas [BOC, Auckland] of known quantities, O_2 14.82%, CO_2 4.80%, N_2 80.38%) was performed in accordance with the manufacturer’s instructions. A bi-directional digital turbine flow meter was used to measure the volume of air inspired and expired. The turbine was calibrated prior to each testing session using a 3-L volume syringe (Hans Rudolph, Kansas City, Missouri).

Data analysis

For the active video games mean values for each variable from the 5th to 8th minutes were used for data analysis. This period was chosen to best reflect the steadiest state reached during the game and means were used to eliminate any outliers. For the walking and running activities the mean $\dot{V}O_2$ and HR in the final 30 seconds of each task were used for data analysis. Finally, the means of resting data for each participant was derived from calculating the mean of the final five minutes of resting during all three sessions. EE was calculated from $\dot{V}O_2$ data using the constants of 1L O_2 = 4.9 kcal and 1 J = 0.000239 kcal (McArdle, Katch, & Katch, 1996). EE was expressed both in absolute and relative (as a ratio of body mass) terms. $METS_{meas}$ were calculated by dividing the $\dot{V}O_2$ measured during each of the activities by resting $\dot{V}O_2$.

Statistical analysis

All data was analysed in SPSS version 14.0. The assumption of normal distribution was tested using the Kolmogorov-Smirnov test. Parametric tests were used as data was found to be normally distributed. For all variables, the means and standard deviations (SDs) of the data were calculated. Data for $\dot{V}O_2$, HR and EE ($J.kg^{-1}.min^{-1}$) were analysed using a repeated measures analysis of variance (ANOVA). Mauchly's Test of Sphericity was used to test for homogeneity of covariance. Independent paired samples t-tests were used as post-hoc tests to determine where the significant differences were. An analysis of covariance (ANCOVA) was also used, with weight as the covariant, to determine differences in EE (J.min) as a regression-based approach to normalise EE data is more suitable than the ratio method (Poehlman & Toth, 1995). Mixed model repeated measure ANOVA was used to determine the influence of experience and fitness in EE. Relationships between measures were also explored using Pearson Product Moment Correlation Coefficients (*r*). For all statistical tests the alpha level was set at $p<0.05$ to determine statistical significance.

Results

Baseline characteristics

A summary of all participants baseline characteristics are shown in Table 3.2.

Table 3.2. Participants' baseline characteristics (n=26)

Measure	Mean ± SD	Range
Age (years)	11.4 ± 0.8	10.0-12.4
Body Mass (kg)	41.9 ± 9.2	27.9-57.3
Height (cm)	146.4 ± 6.9	131.0-156.0
BMI (kg/m^2)	19.4 ± 3.6	14.2-27.6
Peak MSFT Speed ($km.h^{-1}$)	9.9 ± 0.9	8.1-11.6
Predicted $\dot{V}O_{2\,peak}$ ($ml.kg^{-1}.min^{-1}$)	43.5 ± 4.8	36.0-50.6
HR_{peak} ($b.min^{-1}$)	200 ± 9.1	181-218

Energy expenditure and metabolic data

The mean $\dot{V}O_2$, HR, EE and MET_{meas} data for each activity are presented in Table 3.3.

Table 3.3. **Energy expenditure, oxygen uptake, heart rates and metabolic equivalents during different activities** (means ± SDs).

Activity	**EE** (J. min^{-1})	**EE** (J.kg^{-1}. min^{-1})	**% Increase from Rest**	$\dot{V}O_2$ (ml.kg^{-1}.min^{-1})	**% of** $\dot{V}O_{2\ peak}$	**MET_{meas}**	**HR** (b. min^{-1})	**% Increase from Rest**	**% of HR_{peak}**
Rest	$5571 \pm 486^{*\ddagger}$	$142 \pm 39^{*\ddagger}$		$6.9 \pm 1.1^{*\ddagger}$	16 ± 3	1.00 ± .00	$79 \pm 13^{*\ddagger}$		40 ± 6
Television	$5935 \pm 1359^{*\ddagger}$	$142 \pm 32^{*\ddagger}$	0	$6.9 \pm 1.6^{\dagger*\ddagger}$	16 ± 3	1.04 ± .25	$83 \pm 13^{\dagger*\ddagger}$	5	42 ± 6
PS3	$6369 \pm 1918^{*\ddagger}$	$150 \pm 46^{*\ddagger}$	6	$7.5 \pm 2.0^{\dagger*\ddagger}$	17 ± 5	1.12 ± .30	$85 \pm 15^{\dagger*\ddagger}$	8	43 ± 7
Wii Tennis	$11521 \pm 2257^{\dagger*\ddagger}$	$289 \pm 78^{\dagger*\ddagger}$	104	$14.1 \pm 3.8^{\dagger*\ddagger}$	32 ± 9	2.16 ± .53	$106 \pm 22^{\dagger\ddagger}$	35	52 ± 11
Wii Bowling	$12552 \pm 2787^{\dagger*\ddagger}$	$277 \pm 56^{\dagger*\ddagger}$	95	$20.0 \pm 4.9^{\dagger*\ddagger}$	30 ± 6	3.03 ± .56	$107 \pm 13^{\dagger\ddagger}$	35	53 ± 7
Wii Boxing	$16830 \pm 3907^{\dagger\ddagger}$	$411 \pm 100^{\dagger\ddagger}$	190	$20.2 \pm 5.0^{\dagger*\ddagger}$	48 ± 11	3.05 ± .59	$140 \pm 27^{\dagger\ddagger}$	77	72 ± 14
Wii Step	$13843 \pm 3701^{\dagger\ddagger}$	$350 \pm 149^{\dagger\ddagger}$	147	$17.0 \pm 4.9^{\dagger\ddagger}$	40 ± 11	2.43 ± .43	$122 \pm 18^{\dagger\ddagger}$	54	62 ± 9
Wii Ski	$9204 \pm 2658^{\dagger*\ddagger}$	$230 \pm 90^{\dagger*\ddagger}$	63	$11.3 \pm 3.2^{\dagger*\ddagger}$	27 ± 8	1.65 ± .59	$113 \pm 22^{\dagger\ddagger}$	43	58 ± 10
Walking	$17058 \pm 4390^{\dagger\ddagger}$	$403 \pm 97^{\dagger\ddagger}$	184	$19.6 \pm 4.7^{\dagger\ddagger}$	46 ± 12	2.99 ± .83	$115 \pm 29^{\dagger\ddagger}$	46	58 ± 8
Running	$31818 \pm 8054^{\dagger*}$	$768 \pm 200^{\dagger*}$	442	$37.4 \pm 9.8^{\dagger*}$	89 ± 20	5.60 ± 1.4	$173 \pm 21^{\dagger*}$	119	87 ± 10

Where statistically significant ($p \leq 0.05$) from; † Rest, * Walking, ‡ Running

When using body mass as a covariate, EE did not increase significantly when watching television or playing PS3, compared to RMR. However, EE increased significantly (11 521 to 31 818 J.min^{-1}; 63% to 190%) from RMR during all other activities (Table 3.3). The statistical significance of the increases in EE can be found in Appendix 8. The ski game was the least active of the 'active' activities with only a 63% (230 ± 90 J.kg^{-1}.min^{-1}; *p*=0.013) increase in EE from rest. The active video game which yielded the greatest increase (190%; $p \leq 0.001$) in EE from rest was boxing (411 ± 100 J.kg^{-1}.min^{-1}) followed by step (147%; 350 ± 149 J.kg^{-1}.min^{-1}; $p \leq 0.001$). The energy expended during these two games was not significantly different from the energy expended during walking (403 ± 97 J.kg^{-1}.min^{-1}) but was significantly lower than EE during running (768 ± 200 J.kg^{-1}.min^{-1}; $p \leq 0.001$). The $METS_{meas}$ for all activities are displayed in Table 3.3. Mean velocity achieved during self-paced walking and self-paced running was 4.5 ± 0.4 km.hr^{-1} and 8.7 ± 1.2 km.hr^{-1}, respectively. Figure 3.1 shows an example of a participant's $\dot{V}O_2$ during video games versus $\dot{V}O_2$ at rest.

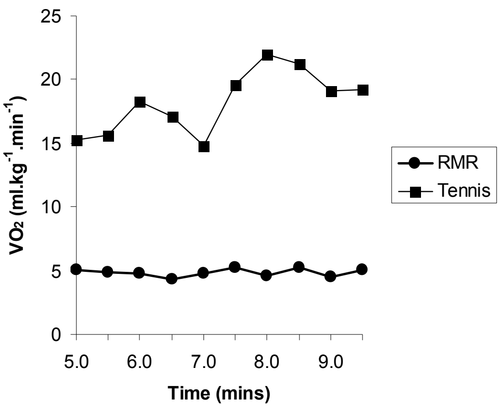

Figure 3.1a. Wii Tennis

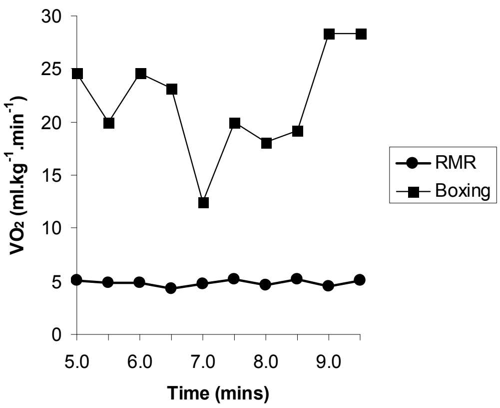

Figure 3.1b. Wii Boxing

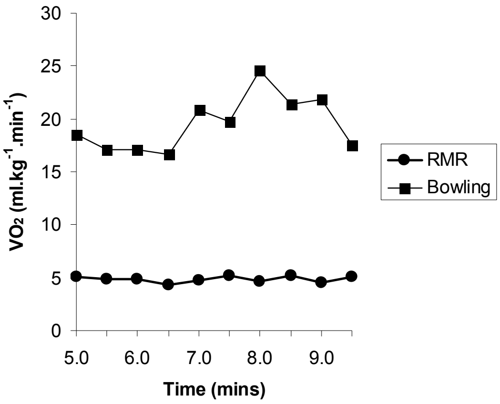

Figure 3.1c. Wii Bowling

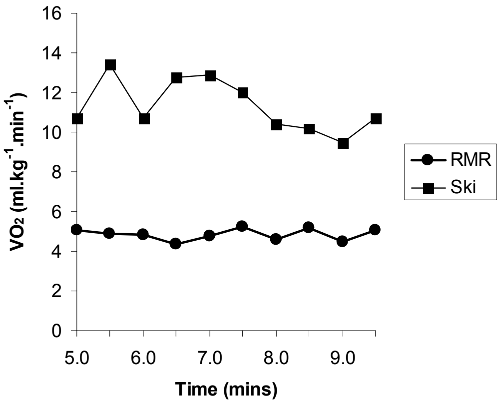

Figure 3.1e Wii Fit

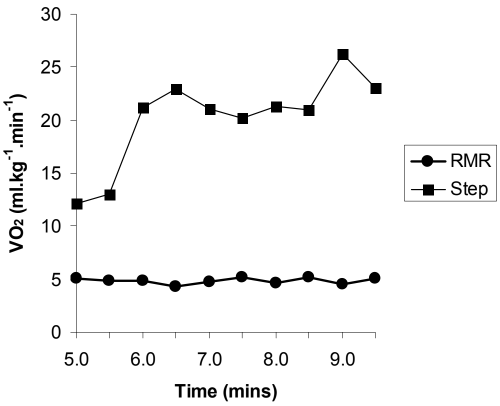

Figure 3.1d. Wii Step

Figure 3.1. An example of a participant's $\dot{V}O_2$ (ml.kg^{-1}.min^{-1}) during Nintendo® Wii active video games compared to the participants resting metabolic rate.

In some instances, HR followed a different trend to EE (Table 3.3). Compared to rest, HR increased significantly during all activities ($p \leq 0.05$). HR increased by 33%-75% during active video game play. The active video game in which HR increased the most (75%) was Wii Boxing, whereas, the active video game in which the smallest increase (33%) in HR occurred was Wii Bowling. No significant differences were found between the HRs during active video games and HR during walking (Appendix 8). Heart rate, as a percentage of HR_{peak}, was relatively low during active video game play (42%-72% HR_{peak}). Similarly, oxygen consumption, as a percentage of $\dot{V}O_{2\,peak}$, during active video games was also relatively low (27%-48% $\dot{V}O_{2\,peak}$; Table 3.3).

Influence of level of experience on energy expenditure

There were no significant differences found in baseline characteristics of each of the groups, classified by experience (beginner (n=11), intermediate (n=7), experienced (n=9)). Pearson correlations and mixed model repeated measure ANOVAs indicated that experience had no significant effects on metabolic data.

Influence of fitness on energy expenditure

Participants were classified into low (n=13 $\dot{V}O_{2\,peak}$ < 43.0 ml.kg^{-1}.min^{-1}) and high fitness (n=13; $\dot{V}O_{2\,peak}$ > 43.0 ml.kg^{-1}.min^{-1}) groups. Baseline characteristics for each group are displayed in Table 3.4. The low fitness group had significantly greater weight and BMI scores than the high fitness group ($p<0.05$). However, mixed model repeated measure ANOVA indicted that there were no significant differences between the groups $\dot{V}O_2$, EE or HR responses during sedentary and active video games.

There were some significant relationships between measures. Specifically, correlations existed between $\dot{V}O_{2\,peak}$ and $\dot{V}O_2$ at rest (r = 0.46, $p<0.05$), and between $\dot{V}O_{2\,peak}$ and EE (J.kg^{-1}.min^{-1}) at rest (r = 0.46, $p<0.05$).

Table 3.4. Baseline characteristics of high and low fitness groups

Measure	Low Fitness (n=13)	High Fitness (n=13)
Age (years)	11.6 ± 0.7	11.2 ± 0.8
Weight (kg)	47.4 ± 9.3	37.1 ± 6.2*
Height (cm)	147.1 ± 6.1	145.8 ± 7.7
BMI (kg/m^2)	21.9 ± 3.9	17.4 ± 1.7**
MSFT Speed Reached (km.h^{-1})	9.1 ± 0.4	10.6 ± 0.5**
Predicted $\dot{V}O_{2\,peak}$ (ml.kg^{-1}.min^{-1})	39.0 ± 1.8	47.4 ± 2.4**
HR_{peak} (b.min^{-1})	200 ± 11	200 ± 8

Where: $^{*}p < 0.05$, $^{**}p < 0.001$

Discussion

Energy expenditure of active video games

Results of this study indicated that EE increased significantly (63-190%; 89-270 J.kg.min^{-1}) from rest during active gaming. This finding supports previous similar studies (Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006; Maddison et al., 2007; Mellecker & McManus, 2008). It was also found that EE during all the active video games were significantly higher compared to playing a traditional video game or watching television. Data from previous studies supports this trend (Table 3.5; Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006; Maddison et al., 2007; Mellecker and McManus, 2008). Although similar trends have been seen within the active gaming literature, the extent to which EE increases during activity promoting video games has differed substantially between studies. During the least active video games in the present study (Wii Skiing, Wii Bowling and Wii Tennis), EE increased less (~63%, 95%, 104%, respectively) than the least active video games measured in other studies. For example, the smallest increases in EE were found during EyeToy Groove, 123% (Maddison et al., 2007), EyeToy Nicktoons Movin', 110% (Lanningham-Foster et al., 2006), Nintendo® Wii Bowling, 134% (Graves et al., 2007) and 116% (Graves et al., 2008). Similarly, the most active games (Wii Step and Wii Boxing) increased less than three of the most active games measured by Maddison et al. (2007). Their study indicated that Dance UK, Homerun and Knockout all increased EE more than 275% from rest with the EE from the most active game, Knockout, increasing 400% from rest. However, EE has generally been found to increase less than 220% during the most active games from other studies (Table 3.5; Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006).

Table 3.5. Percentage increases in energy expenditure from rest whilst watching television, playing non-active video games and playing active video games.

Author	Watching Television	Non active game	Active video games
Graves et al. (2007)	n/a	54%	134-149%
Graves et al. (2008)	n/a	38%	117-218%
Lanningham-Foster et al. (2006)	19%	21%	110-167%
Maddison et al. (2007)	n/a	23%	123-400%
Present study	0%	6%	63-190%

The relatively small increases in EE found during some of the Nintendo® Wii activities (e.g. Wii Skiing, Wii Bowling, Wii Tennis) may have occurred due to the nature of different activity promoting games. For example, in the dance games, such as those in Maddison et al.'s (2007) study, participants are required to keep in time with the dance moves on the screen. Similarly, several of the EyeToy games require children to continuously perform activities using both their arms and legs. Whereas during Nintendo® Wii Tennis and Wii Bowling only relatively small movements of the wrist are required to "swing" the racquet and bowl and during Wii Skiing minimal shifts in balance are required. Using larger muscle groups and continually shifting one's weight distribution, such as during the dancing and EyeToy games, is likely to be more metabolically demanding (Levine, Vander Weg, Hill, & Klesges, 2006) than the smaller movements that are required to play Nintendo® Wii Bowling, Wii Tennis or Wii Skiing. This suggests that the design of activity promoting video games should be considered for future interventions. An additional reason why the Nintendo® Wii video games may have increased EE relatively less in our study is because RMR in our study was higher (~ 20%) than reported in previous studies.

This is the first study to directly compare the EE of active video games to the EE of physical activities such as walking and running in the same subjects. It was found that during the most active video games, Wii Boxing and Wii Step, EE was not significantly different to self-paced walking (Table 3.3). However, EE during all of the active video games was significantly less than EE during self-paced running which suggests that the most active video games are still performed at a relatively low intensity compared to traditional forms of exercise. Although no other study to date has made direct comparisons between EE during the video game activities and physical activities, some studies (e.g. Graves et al. (2008); Maddison et al. (2007)) compared active video games to METS. Metabolic equivalent values have been derived for adults (Ainsworth et al., 2000) and children (Harrell et al., 2005) for a range of activities. Graves et al. (2008) compared Wii Bowling, Wii Tennis and Wii Boxing to actual versions of each of the games in Ainsworth et al.'s (2000) compendium of physical activities and noted that the actual sports involved a substantially greater amount of EE. However, the MET values in the compendium are based on adult data therefore may not be appropriate to compare children's data to as children have higher RMRs than adults (Harrell et al., 2005; Spadano et al., 2003a). More appropriately, Maddison et al. (2007) used the equation from the compendium for children and youth (Harrell et al., 2005) to calculate $METS_{meas}$ from their data. Using METS the intensity of activities can be described as light (≤ 3 METS), moderate (3-6 METS) or vigorous (≥ 6 METS). Maddison et al. (2007) concluded that two of the active video games in their study could be classified as light intensity exercise and the remaining video games could be classified as moderate intensity games. Using the same criteria as Maddison et al. (2007) all of the active video games in this study would be classified as light intensity activities (≤ 3 METS).

Intensity of active video games

Although an estimate of the intensity of the activities can be determined using $METS_{meas}$ values, a key strength of this study is that it was possible to express the intensity of each activity as a percentage of predicted $\dot{V}O_{2\,peak}$ and actual HR_{peak} since these measures were determined for each participant. One advantage of this is that it can be determined whether active video games are played at a sufficient intensity to improve and maintain cardiovascular fitness based on standardised exercise prescription guidelines. The most active games, Wii Step and Wii Boxing, were played at 40% and 48% of predicted $\dot{V}O_{2\,\text{peak}}$ and 52% and 75% of actual HR_{peak}, respectively. A review by Baquet et al. (2003) concluded that children need to participate in activities that are higher than 80% maximal HR in order to elicit changes in $\dot{V}O_{2\,\text{peak}}$. Therefore, it would seem that these active video games may not be appropriate for improving, or maintaining, cardiovascular fitness.

Heart rate, but not $\dot{V}O_2$, during the sedentary video games was significantly greater than resting HR. This suggested that the increase in HR was not proportional to the increase in $\dot{V}O_2$. A similar disassociation between HR and $\dot{V}O_2$ was seen in a study in which Unnithan et al. (2006) measured the energy cost of obese and lean adolescents playing a dance simulation video game. They reported the mean percentage of $\dot{V}O_{2\,\text{peak}}$ of the game to be 34.6% and 33.4% for obese and lean children, respectively, whereas the mean percentage of HR_{peak} was reported to be relatively higher, 64.8% and 64.5%, respectively. Similar results were reported by Tan et al. (2002) in their study. During the active video game (Dance Dance Revolution) junior college students were playing at 70% of HR_{max} and 44% of $\dot{V}O_{2\,\text{reserve}}$. These studies indicate that a disassociation between $\dot{V}O_2$ and HR exits across different video games and irrespective of age, fitness and body weight. The disassociation between HR and $\dot{V}O_2$ was the greatest during the lowest intensity activities suggesting that the psychological and emotional responses to video games may alter HR responses. This therefore questions HR monitoring as an effective method to predict EE.

The influence of gaming experience on energy expenditure during active gaming

In the present study, the physiological responses to the active video games, including EE and $\dot{V}O_2$, were not altered by prior Wii Sports gaming experience which opposes a previous study involving male college students (Sell et al., 2008). In this study it was found that experienced video game players had significantly higher EE than non-experienced gamers. The differences found between the studies may be due to the different nature of the games played. Additionally, Sell et al. (2008) observed that the more experienced players played the game more continuously than the inexperienced players which would likely result in more 'active' time than inexperienced players. In relation to 'active' time, several of the Wii Sports games were self-paced and therefore players, regardless of skill and experience, could stop and start without the overall outcome of the game being affected. However, this 'non-active' time would have an impact on reducing the mean physiological response to the game.

The influence of aerobic fitness on energy expenditure during active gaming

In the present study, aerobic fitness did not affect the amount of energy expended during any of the video games. However, an association was found between $\dot{V}O_{2\,\mathrm{peak}}$ and resting $\dot{V}O_2$. This suggests that fitter children have higher RMRs than children who are less fit. Furthermore, children who were more fit had significantly lower BMI scores and chose to run at a significantly faster self-selected pace during the running activity compared to the less fit children. However, the fitness of the sample population was relatively low compared with international data (Olds, Tomkinson, Léger, & Cazorla, 2006). Indeed, in a meta-analysis involving 15,480 samples from boys aged 11 years, the mean speed reached in the MST was 10.7 $km.hr^{-1}$ (Olds et al., 2006). In this study, only 15% (n=4) of participants reached a speed greater than 10.7 $km.hr^{-1}$. This suggests that the study may have been biased towards attracting less fit volunteers as participants.

Conclusions

Energy expenditure during active video game play is significantly higher than resting, watching television or playing traditional video games. The level of experience or fitness does not affect the physiological responses to playing active video games. The most active Nintendo® Wii video games were similar to walking and based on $METS_{meas}$ and physical demands are classified as low intensity activities. The Nintendo® Wii active video games may provide children with a better alternative to sedentary gaming but are not a sufficient replacement for physical activity. Intervention studies are needed to determine whether active video games can provide long term health benefits.

CHAPTER 4. SEDENTARY ACTIVITIES, ACTIVE VIDEO GAMES AND PHYSICAL ACTIVITIES: DO CHILDREN ENJOY THESE ACTIVITIES?

Abstract

Background: Converting sedentary screen-time into active screen-time might provide an effective way to encourage children to accumulate more health-related physical activity. However, there is little empirical evidence available to determine whether children enjoy active video games equally or more than, traditional sedentary activities or traditional physical activities. **Purpose:** 1) To determine children's enjoyment of several activities including two sedentary activities, four active video games and two physical activities; and 2) to determine whether fitness, weight status, and game-playing experience influenced children's enjoyment of active video games. **Method:** Twenty-six boys aged 11.4 ± 0.8 years were recruited on Nintendo® Wii Sport video game experience and were divided into beginners, intermediate, and experienced Wii Sport gamers. Fitness (multi-stage fitness test) and weight status (BMI) were also collected. Following each activity children completed a Physical Activity Enjoyment Questionnaire. **Results:** Walking was the least enjoyable activity 3.42 ± .63 (where 1 is *not enjoyable* and 5 is *enjoyable*) scale whereas the active video game, Wii Bowling, was the most enjoyable activity 4.30 ± .60 (where 1 is *not enjoyable* and 5 is *enjoyable*). Children ranked the four active video games as the most enjoyable activities irrespective of fitness, experience and weight status. No significant differences were found between groups. Walking, television, running and the inactive game were consistently ranked as the least enjoyable activities. Whereas, Wii Bowling, Wii Fit, Wii Boxing and Wii Tennis were consistently ranked as the top four activities. **Conclusion:** Children's enjoyment of active video games could be capitalised on in order to develop interventions to increase physical activity.

Introduction

Media rich home environments are contributing to the amount of time children are spending in sedentary pursuits. Several studies have reported that children spend between 2.5 and 4 hours per day participating in screen-time activities including television watching, playing video games, playing computer games, and playing games on handheld devices (Andersen et al., 1998; Robinson et al., 1993). This is concerning as recent research indicates that sedentary activity may independently contribute to increasing the risk of chronic health diseases (Hamilton et al., 2004; Hamilton et al., 2007). Propositions within the inactivity physiology paradigm suggest that replacing sedentary behaviour with even small amounts of activity may effectively help to alleviate some of the risks associated with being sedentary (Zderic & Hamilton, 2006).

Children's physical activity and inactivity patterns may be influenced by a number environmental and psychosocial factors (Kohl & Hobbs, 1998). Environmental factors that influence inactivity include: weather, day of the week and neighbourhood safety. Studies using objective measures of activity (e.g., pedometers) show that children are least active during winter months (Loucaides et al., 2003) and weekends (Duncan et al., 2006). Also, children who are most active are more active after school and during weekends (Cox et al., 2006). Psychosocial factors which encourage sedentary behaviour and discourage physical activity include: children's lack of interest or desire to participate in activity (Kohl & Hobbs, 1998) and parents using television to entertain their children (Jordan et al., 2006). This information suggests that enjoyable and sustainable interventions need to be designed within the parameters of home environments which currently encourage physical inactivity.

There have been few interventions specifically designed to reduce sedentary behaviour; despite the need for them. Sedentary behaviour interventions have utilised behavioural interventions where children "earn" their television time based on the physical activity contingencies they complete (Faith et al., 2001; Roemmich et al., 2004). For example, "earning" two minutes of television time for each minute that is spent pedalling a bike (Faith et al., 2001), pedalling a bike in order to keep the television powered (Jason & Brackshaw, 1999), and determining weekly television allowances based on time spent in physical activity the previous week (Roemmich et al., 2004). Although these interventions have yielded promising results, the long-term sustainability of pedalling a bike in order to keep a television powered is doubtful. As well, making sedentary behaviours contingent on physical activity may result in children viewing physical activity negatively. Therefore, for interventions to be sustainable long-term they need to be acceptable and enjoyable.

Activity promoting video games may prove to be an acceptable and sustainable physical activity intervention. For many, traditional gaming environments have tremendous appeal (Ryan, Rigby, & Przybylski, 2006), therefore it may be possible to capitalise on this in order to promote physical activity. Several research groups have suggested that activity promoting video games may provide an opportunity for children to convert traditional sedentary time into activity (Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006; Maddison et al., 2007). Indeed, active gaming can increase energy expenditure up to 400% from rest (Maddison et al., 2007). One of the factors which may determine whether children engage in the new revolutionised games is the appeal of such activities. Although, the concept of active video games may seem equally or even perhaps more enjoyable than traditional sedentary video games, there is little evidence available to support children’s enjoyment of such activities. Additionally, there is a need to understand whether factors such as experience, weight status and fitness affect children’s levels of enjoyment of such activities.

The aim of this study was twofold. The first objective was to compare children’s enjoyment of active video games with other physical activity and sedentary behaviours. The second objective was to determine whether experienced, fitter and normal weight children enjoyed active video games more than inexperienced, less fit and overweight children.

Methodology

Experimental design

A cross-sectional repeated measures design was employed for this study. The independent variables included eight activities that children participated in. These activities were walking, running, watching television, playing a sedentary video game, and playing four active video games. Enjoyment was the dependent variable.

Participants

Twenty-six boys aged 11.4 ± 0.8 years were recruited for the study through personal contacts, local schools, and community advertisements. Participants' characteristics are presented in Table 4.1. Boys aged 10-12 years were included in this study. Exclusion criteria included children who were not healthy (for example, those suffering from coughs and colds), injured, had asthma, or were not able to exercise at moderate to high intensities. Written informed consent and assent was provided from parents/guardians and participants, respectively. Ethical approval for the study was granted by the Auckland University of Technology Ethics Committee (Appendices 2-5). Participants were divided into three groups: beginner, intermediate and experienced Wii Sports gamers. Experienced gamers (n=9) were classified as children who played Wii Sports games once a week or more often. Intermediate gamers (n=7) were those who had spent at least five hours playing Wii Sports games but did not play on a regular basis (i.e. < once per week). Finally, beginner gamers (n=11) were classified as those who had not played Wii Sports games prior to the study.

Table 4.1. **Participants' characteristics (n=26)**

Measure	Mean ± SD	Range
Age (years)	11.4 ± 0.8	10.0-12.4
Body Mass (kg)	41.9 ± 9.2	27.9-57.3
Height (cm)	146.4 ± 6.9	131.0-156.0
BMI (kg/m^2)	19.4 ± 3.6	14.2-27.6
MSFT Speed Reached (km.h^{-1})	9.9 ± 0.9	8.1-11.6
Predicted $\dot{V}O_{2\,peak}$ (ml.kg^{-1}.min^{-1})	43.5 ± 4.8	36.0-50.6
HR_{peak} (b.min^{-1})	200 ± 9.1	181-218

Outline of procedures

Participants individually attended three testing sessions during which they performed different tasks (Table 4.2). During Session 1, participants completed a questionnaire on their physical activity and screen-time behaviour. Baseline measures, including height and body mass, were taken before participants completed the walking and running activities. These activities were followed by a Maximal MultiStage 20 Meter Shuttle Run Fitness Test (MSFT) to assess cardiovascular fitness. The session was concluded with a 20-minute familiarisation period to ensure that all children were accustomed to the range of video games. During Sessions 2 and 3 participants completed one sedentary activity (watching television or playing a sedentary video game [PS3]) and two active video games. Participants were given a 3-minute break between all activities during which they answered questions relating to their enjoyment of the activity (Appendix 9).

Table 4.2 Outline of testing sessions

Session 1	Session 2	Session 3
Baseline height & weight	Sedentary activity 1	Sedentary activity 2
Walking at a self-selected pace	Active video game 1	Active video game 3
Running at a self-selected pace	Active video game 2	Active video game 4
MSFT		
Games familiarisation		

Testing protocols

Baseline measures

Participants' baseline height (Mentone Stadiometer, Moorabbin, Australia) and body mass (Seca 770, Germany) were recorded during Session 1 using standard anthropometric techniques. A brief questionnaire (Appendix 10) was administered to participants to determine their physical activity and screen time behaviours. Specifically, the questionnaire provided information on: the number of household televisions; participants' access to computers and gaming consoles; travel to and from school; and the amount of time spent on homework, physical activity and screen based leisure.

Aerobic fitness

The MSFT (Léger et al., 1988) was used to assess aerobic fitness. The MSFT is an incremental shuttle run test to exhaustion during which the speed of running starts at a pace of 8.0 $km.hr^{-1}$ and is progressively increased by 0.5 $km.hr^{-1}$ every minute. The MSFT is both a valid and reliable predictor of fitness in children (Léger et al., 1988; Winsley, 2003). The MSFT was carried out in an indoor sports stadium. The 3-minute self-paced walking and 3-minute self-paced running activities (see section below) were completed before the fitness test and therefore used as the warm up. Prior to beginning the MSFT a verbal explanation of the test was given to the participant. Participants were asked to complete as many shuttles as they could while keeping in time with the audible beeps. The researcher completed the first four stages with each child in order to ensure that they paced themselves and turned correctly. A heart rate (HR) monitor (Polar S810, Kempele, Finland) was worn around participants' chest so that peak HR (HR_{peak}) could be determined. Peak oxygen uptake ($\dot{V}O_{2\,\mathrm{peak}}$) was predicted using the equation y=31.025 + 3.238 x - 3.248a + 0.1536.ax. Where $y=\dot{V}O_{2\,\mathrm{peak}}$ ($ml.kg^{-1}.min^{-1}$), x=maximal speed reached ($km.h^{-1}$) and a=age (years). This has been shown to be a valid and reliable equation to predict $\dot{V}O_{2\,\mathrm{peak}}$ from the MSFT in children (r = 0.71) (Kendzierski & DeCarlo, 1991; Motl et al., 2001).

Gaming and physical activities

Eight activities were assessed over three testing sessions on separate days. The activities included: walking, running, watching television, playing a sedentary video game (PS3) and playing four active video games. All of the activities, with the exception of walking and running, were carried out in a temperature controlled room (20-24°C, 60% humidity). To replicate a home environment, the room was fitted with a couch, table and cushions.

Self-paced walking and running. The walking and running activities were performed in an indoor sports stadium. Participants were instructed to walk around a 50m circuit for 3-minutes at a pace they would typically walk to school at. Following a 3-minute rest participants were instructed to run around the same 50m circuit for 3-minutes at a pace they could maintain for the duration of the time. Participants had a 3-minute rest before completing the MSFT.

Screen-based activities. Children participated in six screen-based activities including two sedentary activities and four active video games. During the sedentary screen-based activities (television and sedentary video game) participants were required to sit comfortably on the couch. A 10-minute 'G' rated DVD (SpongeGuard on Duty, Nickelodeon, Australia) was chosen for the participants to watch. The traditional video game (Need for Speed ProStreet, Electronic Arts, Australia) was played on a PlayStation® 3 console (PlayStation®, Sony Computer Entertainment, New Zealand). Four active video games (Boxing, Tennis and Bowling, Wii Sports, Nintendo®, Australia; and Wii Fit, Nintendo®, Australia) were played for 8-10 minutes on a Wii console (Wii, Nintendo®, Australia). The active video games included in the study were chosen to represent a range of activity levels which required upper, lower or combined upper and lower body movements. All participants played all games in the same standardised environment. The order in which the active video games were played was randomised. Detailed descriptions of the games can be found in Appendix 7.

Measurement of enjoyment

Following the completion of each activity the 16-item Physical Activity Enjoyment Scale (Appendix 9) was used to determine the extent to which the activity was enjoyed by the participant (Kendzierski & DeCarlo, 1991; Motl et al., 2001). The researcher read out a series of statements to which the participant was required to indicate how much they identified with the statement by giving a numerical rating on a Likert scale anchored by 1 (disagree a lot) and 5 (agree a lot). This instrument has been shown to have construct and internal validity and reliability (r=0.75, p<0.01) (Davison, Werder, Trost, Baker, & Birch, 2007). Negatively worded items were reverse coded (Ni Mhurchu et al., 2008). Total enjoyment was recorded as the mean of the 16 items.

Statistical analysis

Data was analysed in SPSS version 14. Descriptive statistics (mean ± SD) were calculated for the total enjoyment of each activity. The total enjoyment scores were analysed using repeated measure mixed model analysis of variance. Between group differences were analysed using analysis of variance and within group differences were analysed using paired samples t-tests. Statistical significance was determined at the alpha level p<0.05.

Results

Baseline characteristics

Participant characteristics are displayed in Table 4.1.

Enjoyment scores

The means ± SDs of participants' enjoyment of two sedentary activities, four active video games, and two physical activities are displayed in Table 4.3. The percentages of children that enjoyed each activity were: walking (39%), television (58%), running (60%), PS3 (73%), Wii Boxing (88%), Wii Tennis (77%), Wii Fit (75%) and Wii Bowling (89%). These were calculated as the percentage of children that ranked each game a 4 or a 5 on the PACES inventory. The least enjoyed activity was walking. The active video game, Wii Bowling, was the activity most enjoyed by the participants. All of the Wii Sport active video games (Tennis, Boxing and Bowling) were significantly (p<0.05) more enjoyable than walking, television and running. However, only Wii Bowling was significantly (p<0.05) more enjoyable than playing a traditional sedentary video game (PS3).

Table 4.3. Participants' enjoyment of sedentary activities, active video games and physical activities (mean ± SD of ratings according to the PACES scale where 1= not enjoyable, 5= very enjoyable.).

Activity	Mean ± SD	Walk	TV	Run	PS3	Wii Tennis	Wii Boxing	Wii Fit
Walk	3.42 ± .63							
TV	3.65 ± .61							
Run	3.73 ± .68							
PS3	3.88 ± .79	*						
Wii Tennis	4.14 ± .77	**	*	*				
Wii Boxing	4.14 ± .69	*	*	*				
Wii Fit	4.22 ± .64		*	*				
Wii Bowling	4.30 ± .60	**	**	**	*	*		

Where: * $p \leq 0.05$ and ** $p \leq 0.001$; TV = television

Overweight children's vs. normal weight children's enjoyment scores

Children were classified into two groups, overweight and normal weight, based on Cole et al.'s (2000) BMI cut off points (Appendix 1). There were no statistically significant differences in the mean enjoyment scores of each activity between the overweight and normal weight groups. However there were significant within group differences. The means ± SDs enjoyment scores for the overweight and normal weight groups are displayed for each activity in Table 4.4. The overweight children least enjoyed watching television whilst the normal weight children least enjoyed walking. The normal weight children significantly enjoyed all of the other activities more than walking (p<0.001 except television and Wii Fit p<0.05). Whereas, the only activity the overweight children enjoyed significantly more than walking was the traditional sedentary video game (PS3; $p<0.05$). For both groups, the active video games were ranked as the four most enjoyable activities.

Table 4.4. Overweight vs. normal weight children's enjoyment of different activities. (Mean ± SD of ratings according to the PACES scale where 1= not enjoyable, 5= very enjoyable.)

Activity	Over-weight (n =10)	Normal Weight (n=16)	Walk	TV	Run	PS3	Wii Tennis	Wii Boxing	Wii Fit
Walk	3.71 ± .70	3.23 ± .52							
TV	3.66 ± .70	3.64 ± .59	*						
Run	3.69 ± .75	3.76 ± .65	**						
PS3	3.75 ± 1.03	3.96 ± .53	† **						
Wii Tennis	3.75 ± .99	4.38 ± .53	**	*	*	*			
Wii Boxing	4.00 ± .85	4.23 ± .58	**	*	*				
Wii Fit	4.43 ± .64	4.13 ± .65	*	*	†		*		
Wii Bowling	4.04 ± .78	4.46 ± .39	**	**	**	*			

Where: Overweight † $p \leq 0.05$ and †† $p \leq 0.001$
Normal weight * $p \leq 0.05$ and ** $p \leq 0.001$

The relationship between Wii Sport experience and enjoyment of activities

There were no significant differences found in enjoyment between beginner, intermediate and experienced Wii Sport gamers. The means ± SDs of the enjoyment scores for each group and activity are displayed in Table 4.5. The experienced group enjoyed all of the activities (excluding Wii Fit) significantly more than walking ($p \leq 0.05$). Whereas, there were no significant differences found between enjoyment of walking and enjoyment of the other activities in the beginner group. Intermediate gamers enjoyed Wii Boxing and Wii Bowling significantly more than walking ($p \leq 0.05$). The active video games were consistently ranked among the top four activities irrespective of the experience levels of gamers.

Table 4.5. Beginner, intermediate and experienced gamer's enjoyment of different activities. (Mean ± SD of ratings according to the PACES scale where 1= not enjoyable, 5= very enjoyable.)

Activity	BEG (n=11)	INT (n=7)	EXP (n=9)	Walk	TV	Run	PS3	Wii Tennis	Wii Boxing	Wii Fit
Walk	3.78 ± .59	3.26 ± .43	3.08 ± .59							
TV	3.66 ± .69	3.57 ± .54	3.67 ± .62	‡						
Run	3.91 ± .73	3.20 ± .49	3.88 ± .57	‡						
PS3	3.98 ± .88	3.55 ± .84	3.97 ± .48	‡‡						
Wii Tennis	4.18 ± .82	3.77 ± 1.00	4.33 ± .58	‡‡	†‡	‡				
Wii Boxing	4.31 ± .79	3.82 ± .41	4.13 ± .71	*‡	†‡	*				
Wii Fit	4.64 ± .18	3.90 ± .53	4.01 ± .83		†	†				
Wii Bowling	4.21 ± .76	4.28 ± .58	4.41 ± .40	*‡‡	†‡	*‡	*		*	

Where: Beginner (BEG) † $p \leq 0.05$ and †† $p \leq 0.001$
Intermediate (INT) * $p \leq 0.05$ and ** $p \leq 0.001$
Experienced (EXP) ‡ $p \leq 0.05$ and ‡‡ $p \leq 0.001$

The relationship between fitness and enjoyment of activities

Participants were classified into low (n=13 $\dot{V}O_{2\,peak}$ < 43.0 ml.kg^{-1}.min^{-1}) and high fitness (n=13; $\dot{V}O_{2\,peak}$ > 43.0 ml.kg^{-1}.min^{-1}) groups based upon their MSFT scores. There were no significant differences found in enjoyment between fit and less fit gamers. The means ± SDs of the enjoyment scores for each group and activity are displayed in Table 4.6. Gamers with higher fitness levels enjoyed Wii Tennis and Wii Bowling significantly more than walking, television, running and the sedentary video game (PS3). Gamers with lower fitness levels significantly enjoyed the active video games Wii Boxing, Wii Fit and Wii Bowling more than watching television.

Table 4.6. Fit vs. unfit children's enjoyment of different activities. (Mean ± SD of ratings according to the PACES scale where 1= not enjoyable, 5= very enjoyable.)

Activity	High Fitness (n =13)	Low Fitness (n=13)	Walk	TV	Run	PS3	Wii Tennis	Wii Boxing	Wii Fit
Walk	3.17 ± .51	3.70 ± .64							
TV	3.76 ± .44	3.52 ± .76	†						
Run	3.71 ± .63	3.75 ± .75	†						
PS3	4.00 ± .49	3.74 ± .97	††						
Wii Tennis	4.30 ± .53	3.94 ± 1.00	††	†	†	†			
Wii Boxing	4.15 ± .61	4.13 ± .80	†	† *	†				
Wii Fit	4.10 ± .66	4.34 ± .64		*					
Wii Bowling	4.37 ± .40	4.21 ± .78	††	†† *	†	†			†

Where: High fitness † $p \leq 0.05$ and †† $p \leq 0.001$
Low fitness * $p \leq 0.05$ and ** $p \leq 0.001$

Discussion

Converting sedentary screen-time into active screen-time might provide an effective way to encourage children to accumulate more health-related physical activity. There are now several studies available in which the EE during active video games has been determined (Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006; Maddison et al., 2007). Additionally, study 1 of this thesis has indicated that Nintendo® Wii video games can increase EE by 63-190% from rest. This is the first study to evaluate children's enjoyment of such games. Therefore, this study is able to provide a new insight into the potential effectiveness of future video gaming interventions. The first aim of this study was to determine children's enjoyment of several activities including two sedentary activities, four active video games and two physical activities. Results show that children enjoy playing Nintendo® Wii active video games. Children ranked the four most enjoyable activities as Wii Tennis, Wii Boxing, Wii Fit and Wii Bowling (Table 4.3). The most enjoyable activity, Wii Bowling, was enjoyed significantly more than all other activities, excluding Wii Fit and Wii Boxing, thus suggesting that there is a strong preference towards this game. The activity least enjoyed by the participants was walking, followed by watching television, running and playing a traditional sedentary video game.

The sedentary video game (PS3) was ranked as the fifth most enjoyable activity, after the four active video games. The only activity which was significantly more enjoyable than the sedentary video game was Wii Bowling. This suggests that the children did not have a strong preference towards the active video games over the traditional video game. This is important to consider, as even if children are given the opportunity to play active video games they may still choose sedentary games over the active video games. Intervention studies are needed to determine which type of games children prefer to play when given an option. To date there has only been one intervention study designed to evaluate the effectiveness of active video games on children's physical activity levels (Ni Mhurchu et al., 2008). In this 12-week study, the intervention group received a video games upgrade package which consisted of an EyeToy camera, EyeToy active games and a dance mat. Children were instructed to substitute usual non active video game playing time with active video game playing. Results of this pilot study indicated that children in the intervention group spent less overall time playing video games (-44 minutes per day; p=0.06), more time playing active video games (14 minutes per day; p=0.3) and less time playing inactive video games (-52 minutes per day; p=0.04) when compared to the control group who received no intervention. Although enjoyment was not measured in this study, the results suggest that children may indeed enjoy and choose to play active video games when the active video game option is available. However, before reaching such conclusions, it is important that long term interventions are designed to test these assumptions.

The second aim of this thesis was to determine whether fitness, weight status, and game-playing experience influenced children's enjoyment of active video games. There were no significant differences in enjoyment found between: 1) fit and less fit children; 2) overweight and normal weight children; or 3) beginner, intermediate and experienced gamers. The four active video games were consistently ranked as the most enjoyable activities, whilst walking, television, running and the sedentary video game were consistently ranked as the least enjoyable activities, irrespective of the aforementioned factors. A limitation of this study is that the homogeneity of the participants may have been too great to detect differences between groups.

To date, there has only been one study looking at participants' enjoyment of active video games (Sell et al., 2008). In this study, involving male college students, it was found that experienced (n=12) active video game players enjoyed the games significantly more than the inexperienced (n=7) game players (4.7 ± 0.5 vs. 3.9 ± 1.1, respectively; on the basis of a 1 [*not enjoyable*] to 5 [*enjoyable*] scale). In our study, the reason why children's enjoyment of active video games may not have been influenced by gaming experience is because the skill level of the characters in the video game increases or decreases depending on how well the participant plays (Nintendo, 2006). Therefore, the gamers and their "opposition" are generally well matched in skill. This may have enhanced children's enjoyment as the Wii Sport games were challenging without being too difficult.

The results from this study provide evidence that children enjoy electronic media activities. Technology and electronic media is often portrayed negatively and is blamed as a significant contributor to the obesity epidemic (Hillier, 2008). However, technology should not be seen as the problem, rather, the problem is how to use technology in order to fight obesity (Hillier, 2008). Active video games may provide children with a unique opportunity to increase their amount of daily physical activity. They are enjoyable and conducive to being played within the home environment. As active video games are able to be played indoors they may be a good substitute for sedentary behaviour during times when children are least active e.g. after school, on weekends and during winter (Duncan et al., 2006).

While having children playing traditional games in outdoor environments is ideal, this would simply not be a reality for most Western countries. Media rich home environments are the cause of health problems for some children and their families. However, removing electronic media from home environments is not a practical solution to this problem. There is a need for other avenues to be explored by game developers; such as the possibility of taking the new active video games outdoors. Creating outdoor versions of the games for parks, school playgrounds, or even sidewalks that use digital audio players, cell phone displays, or personal digital assistants (PDAs) to instruct gamers might revolutionise outdoor play, and trips to and from school (Hillier, 2008; Lanningham-Foster et al., 2006). Finding solutions which are driven by technology may at least be a partial solution to the problem of inactivity.

Conclusions and Implications

Active video games are more enjoyable than walking, running, television and traditional video games. Enjoyment of active video games was clearly evident irrespective of weight status, fitness and gaming experience. Children's apparent enjoyment of active video games and electronic media should be capitalised on by those designing interventions to reduce sedentary behaviour. However, future studies are needed to track children's long term enjoyment of active video games.

CHAPTER 5. DISCUSSION AND IMPLICATIONS

Children are spending a significant proportion of time partaking in sedentary screen-time behaviours (Andersen et al., 1998; Christakis et al., 2004; Jordan et al., 2006). This is believed to be one of the significant factors contributing to the increase in the prevalence of childhood obesity (Hancox & Poulton, 2006), cardiovascular disease (Healy et al., 2008) , hypertension (Healy et al., 2008) and type 2 diabetes (Hamilton et al., 2007). Therefore, decreasing the amount of time that children spend participating in sedentary activities should be considered among the priorities in the discipline of paediatric public health. The aims of this thesis were to: 1) determine the metabolic costs of different activities; 2) establish whether experience and fitness influence the metabolic costs of active video games; and 3) determine children's enjoyment of active video games interventions that are appealing are more likely to be successful.

The following section explores the findings in relation to the thesis aims. Ways in which research can be applied within the physical activity and health field will be identified and areas for future research will also be briefly discussed.

Metabolic Costs of Children's Activities

A gap in the literature exists in terms of the data available quantifying the metabolic costs of children's activities. This information is important as metabolic cost data can be used to develop interventions that promote activities which result in greater amounts of EE being produced. The metabolic costs of sedentary activities, active video games and physical activities will be discussed in this section.

Metabolic costs of sedentary activities

Sedentary activities have low energy costs. An early study indicated that children's metabolic rate whilst watching television was significantly lower than when resting (Klesges, Shelton, & Klesges, 1993). In contrast, the findings of this thesis have indicated that there are no significant differences between RMR and EE during television watching. Other studies have demonstrated similar results (Borusiak et al., 2008; Lanningham-Foster et al., 2006). This shows that television watching results in limited metabolic activity and it is possible that the amount of time spent watching television may directly contribute to chronic health diseases that are associated with sedentary behaviours. Vandewater et al. (2004) have hypothesised that video games involve more mental, and physical effort than resting and watching television. Thus they say that it is less relevant to link video game use to obesity. However, this thesis and other studies (Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006; Maddison et al., 2007) have provided convincing evidence to show that sedentary video games do not significantly increase EE above resting levels. Therefore, the link between obesity and video game use should be considered clinically relevant.

Another reason why the link between obesity and video game use may be potentially concerning for clinical practitioners is because children enjoy sedentary video games. Findings from this thesis showed that the sedentary video game (PS3) was enjoyed by 73% of the children whereas walking was only enjoyed by 38% of the children. The sedentary video game was also found to be significantly more enjoyable than running and watching television. The popularity of video games is also evidenced by their huge worldwide sales. In 2006, revenues from the gaming industry exceeded US$24.5 billion and sales are expected to reach US$55 billion by the end of 2008 (Alpert, 2007). It seems apparent that children are reluctant to give up such pursuits. In fact, the ever increasing availability of new electronic media in the market may be contributing to developing a home environment conducive to physical inactivity. Fortunately however, the results of this thesis show that the introduction of active video games into the gaming market may be one way in which time spent in sedentary activities can be reduced.

Metabolic costs of active video games

This thesis showed that EE increased significantly more during the Nintendo® Wii active video games compared to when children were resting, watching television or playing a sedentary video game (Chapter 3). Other types of active video games such as EyeToy, Dance UK and Dance Dance Revolution have also caused EE to increase significantly above resting levels (Graves et al., 2008; Graves et al., 2007; Lanningham-Foster et al., 2006; Maddison et al., 2007). Previous studies demonstrating increases in EE during active video gaming have provided useful comparisons between resting and active games; however, this is the first study to compare the same group of individuals during active video games and during exercise.

A major strength of this thesis is that the physiological and metabolic responses of Nintendo® Wii activities were directly compared with those physiological responses determined from walking and running - two physical activities that children perform on a daily basis. Self-paced running, completed at 8.7 ± 1.2 $km.hr^{-1}$ and 89% of predicted $\dot{V}O_{2\,\mathrm{peak}}$, resulted in significantly higher EEs than all of the other activities and based on $\%\dot{V}O_{2\,\mathrm{peak}}$ can be considered as vigorous exercise. Although none of the active video games can be considered as vigorous exercise, the study results indicated that self-paced walking and the most active video games (Wii Step and Wii Boxing) yielded similar EEs. Heart rate responses to the most active video games were lower than 80% HR_{peak} which suggests that they are not played at a high enough intensity to maintain or develop cardiovascular fitness (Baquet et al., 2003). Another pertinent finding was that in some cases a disassociation was seen between the increases in HR and EE, particularly during the lower intensity activities. Thus, suggesting that HR should not be used as a method to predict EE during screen-time activities. However, the $METS_{meas}$ calculated for screen-time activities from this thesis may provide other researchers with a useful measure to predict EE.

Metabolic equivalents

It was beyond the scope of this thesis to compare the EE of bowling, tennis, boxing, skiing and step aerobics to the Nintendo® Wii video game equivalent of the actual sport. Therefore, the MET_{meas} values of these activities can be compared, where possible, to the MET values found for the actual activities within the compendium of physical activities for adults (Ainsworth et al., 2000) and children (Harrell, 2005; Table 5.1 and Table 5.2). The sedentary and physical activities that were measured in this thesis are relatively similar to those reported by both Ainsworth et al. (2000) and Harrell et al. (2005), although the video game $METS_{meas}$ were slightly lower in the present study (Table 5.1). This may have been due to different levels of mental and emotional involvement in the chosen video games. In Table 5.2 the METS of the actual sports (when performed by adults) have been compared to the $METS_{meas}$ of the video game versions of the sport. The $METS_{meas}$ for Wii Bowling were also relatively similar to those reported by Ainsworth et al. (2000). However, all the other activities in the compendium were found to be approximately three fold greater than the Nintendo® Wii versions of the sport which questions the ability of active video games to replace real sports. This may be because in comparison to the actual sport, active video games are relatively stationary. Therefore, game developers may consider incorporating more of the movements e.g. running that are associated with sports like tennis. However, space around the screen may be a limitation to developing such games. The findings from this thesis can be used to contribute to the compendiums of physical activity as both of the compendiums do not contain data on different types of video games.

Table 5.1. Comparison of metabolic equivalents for sedentary and physical activities with Ainsworth et al.'s (2000) and Harrell et al.'s (2005) compendiums of physical activities.

	$METS_{meas}$ **Present Study CHILDREN**	METS **Ainsworth et al. (2000) ADULT**	$METS_{meas}$ **Harrell et al. (2005) CHILDREN**
Television	1.04	1.00	1.03
Video game	1.12	1.50	1.22
Walking*	2.99	3.00	3.23
Running*	5.60	8.00	6.72

*walking at ~5km.hr^{-1} and running at ~8.5km.hr^{-1}

Table 5.2. Comparison of metabolic equivalents from the Nintendo® Wii game and METS from the actual version of the activity.

	Nintendo® Wii $METS_{meas}$ **Present Study CHILDREN**	**Actual Activity METS (Ainsworth et al., 2000) ADULTS**
Bowling	3.03	3.00
Boxing	3.05	9.00
Skiing	1.65	7.00
Step aerobics	2.43	8.50
Tennis	2.16	7.00

Contributions of active video games to NEAT

It is possible that active video games may be able to contribute to increasing NEAT by increasing time spent participating in physical activity. However, it is unlikely that active video games can be considered as exercise as the intensity of these games is too low to either improve or maintain fitness. The active video games used in this thesis caused a 63-190% increase in EE compared to rest. Although the increase was lower than some studies (Lanningham-Foster et al., 2006; Maddison et al., 2007), active video game-play may still have the potential to provide significant health benefits. One of the propositions of the newly proposed inactivity physiology paradigm is that converting sedentary time to standing and ambulatory activity can offer health benefits by increasing LPL activity (Hamilton et al., 2007; Zderic & Hamilton, 2006). LPL is the primary enzyme responsible for the conversion of lipoprotein triglyceride into free fatty acids and monogylderides (Goldberg & Merkel, 2001) and has strong inverse relationship with cardiovascular disease (Hamilton et al., 2004; Wittrup, Tybjærg-Hansen, & Nordestgaard, 1999). Therefore, the results from this thesis suggest that playing active video games may have more health benefits.

Levine et al. (2005) reported that sedentary individuals spend approximately two hours longer per day sitting than their lean counterparts and speculated that if obese individuals adopted behaviours that enhanced NEAT they may expend an additional 350 kcal per day. Specifically in adults, Levine et al. (2000) reported that even movements as small as fidgeting can significantly increase EE, thus increasing daily NEAT. Therefore, the significant increases in EE seen during active Nintendo® Wii gaming may be a novel way in which useful contributions to NEAT can be made. In a comprehensive analysis of data from the National Health and Nutrition Examination Survey, Wang et al. (2003) calculated the energy gap of US children to be between 110 kcal and 165 kcal per day. Data from this study shows that if a child chose to play the most active video game, Wii Boxing, for 40-60mins per day instead of playing on an alternative sedentary video game they may be able to reduce the gap between energy intake and EE (Figure 5.1). Not only can active video games increase daily EE, but there is the possibility that children will be less likely to snack while playing active video games. One study showed that approximately 26% of total daily energy was consumed in front of the television (Matheson et al., 2004). It seems plausible that children would be less likely to eat during screen-time activities if their hands are busy.

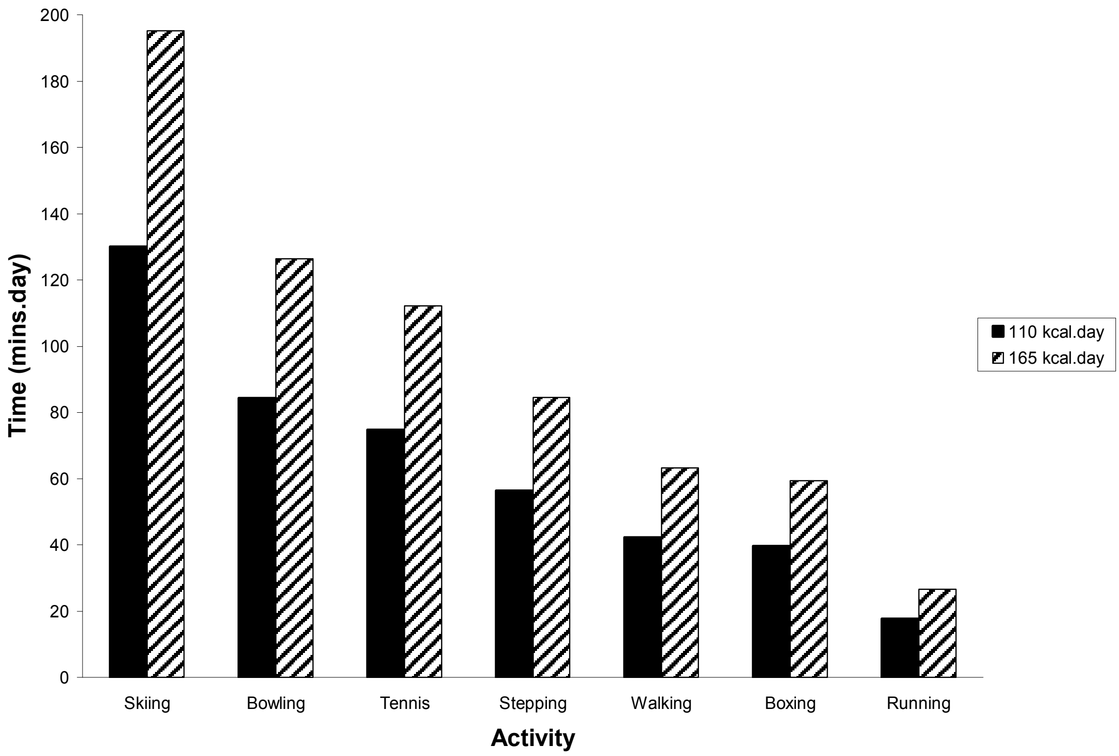

Figure 5.1. Time (minutes per day) children need to spend performing various activities to maintain energy balance. Where 110 kcal is equal to the lower limit and 165 kcal is equal to the upper limits of the range as per Wang et al. (2003).

Active video games and physical activity

The current New Zealand physical activity guidelines recommend that children should engage in 60 minutes of moderate to vigorous physical activity per day (SPARC, 2008). Additionally, the guidelines recommend that children's screen-time should be limited to less than 2-hours per day (SPARC, 2008). It is important to consider active video games within the context of these guidelines. Active video games, such as EyeToy Knockout (5 $METS_{meas}$), Homerun (4.8 $METS_{meas}$) and Dance UK (3.9 $METS_{meas}$; Maddison, 2007), may be able to contribute to the 60-minutes of moderate to vigorous physical activity. However, the data presented in this thesis (Chapter 3) showed that the Nintendo® Wii video games used within this study are only low to moderate intensity activities and it would therefore not be appropriate to use them as a physical activity substitute. However, substituting sedentary behaviour with these games may provide multiple benefits associated with greater daily NEAT. Thus, the greatest benefits may be seen by incorporating active screen-time into children's two-hour daily screen-time limit. Initially, it may be more appropriate to consider active video games as part of the 2-hour per day screen-time limit given that there appears to be substantial differences between the intensity of different active video games as well as a lack of research on the long-term effects of active video game use in children.

Despite there being an emphasis placed on the importance of developing interventions to increase physical activity and to reduce sedentary behaviour, little is known about how active or sedentary New Zealand children are at a population level. To date, the only large scale (n = 3,725) study in which an attempt has been made to establish how active New Zealand children are is the National Children's Nutrition Survey (Ministry of Health, 2003). The survey indicated that 63.7% of New Zealand children walk for at least 15 minutes per day, less than 50% of the children were likely to be physically active after school on four or more weekdays and over 90% of the children watched ≥ 2 hours of television per day (Ministry of Health, 2003). However, the data from the survey may not give a clear representation of New Zealand children's activity levels as it was limited by the data collection method used. The Physical Activity Questionnaire for Children (PAQ-C) was used to collect the physical activity data. The PAQ-C provides information on the frequency of the activities that the children participate in but gives no indication of the intensity, duration or energy expended during the activities. The PAQ-C does not take into account incidental activity and fails to capture children's sporadic and spontaneous activity patterns (Bailey et al., 1995). The questionnaire also requires children to recall all of the activities that they were involved with over a week. Research indicates that a 7-day recall is less accurate when measuring children (Trost, 2001; Welk et al., 2000). Therefore, there is a need to measure New Zealand children's physical activity using a more objective and reliable instrument.

Although there are other instruments that could be used to provide more objective data on New Zealand children's physical activity levels, there are currently no "gold standard" physical activity measures (Ridley, Olds, & Hill, 2006). Table 5.3 provides a brief summary of the currently available physical activity measures and their limitations. Pedometers and accelerometers are relatively inexpensive and easy to use in large scale studies but they fail to measure non-ambulatory movements.

Table 5.3. Physical activity measures – strengths and limitations

Measure	Units	Freq.	Int.	Dur.	EE	Cost	Comments
Doubly labelled water	CO_2 production	X	X	X	√	Expensive	Only provide information on total EE.
Indirect calorimetry	O_2 consumption	√	√	√	√	Expensive	Cannot be used in free living conditions.
Pedometers	Steps	X	X	√	X	Affordable	Not a good measure of non ambulatory activities.
Accelerometers	Movement	√	√	√	X	Affordable	Not a good measure of non ambulatory activities.
Heart rate	BPM	√	√	√	√	Affordable	Relies on linear relationship between $V0_2$.
Direct observation	Activity rating / time	√	√	√	X	Time consuming	Inaccuracies can occur due to tedious process.
Questionnaires / self-report	Activity rating / time	√	√	√	X	Affordable	Limited by recall.

Freq. = frequency, Int. = intensity, Dur. = duration, √ = measures, X = does not measure, EE = energy expenditure, BPM = Beats per minute, O_2 = oxygen, CO_2 = carbon dioxide

Heart rate monitoring has been used as an objective measure to determine how active children are (Welk et al., 2000). The advantages of HR measures is that they are able to give an indication on the frequency, intensity, duration and EE of an activity (Corder, Brage, Wareham, & Ekelund, 2005). To do this HR monitors rely on a linear relationship between HR and $\dot{V}O_2$ (Sirard & Pate, 2001). The findings of this thesis indicated that, particularly at lower intensity activities, HR increased significantly more than EE. The significant increase in HR may have been caused by excitement, anxiety or increases in body temperature. The disassociation found between HR and EE can have significant implications for future researchers. If HR monitoring is being used as an EE measure it may lead to overestimations in daily EE. Therefore, it may be more appropriate to use $METS_{meas}$ values calculated for children when estimating children's EE.

Ridley et al. (2006) have been developing a physical activity instrument which they created to overcome a number of the issues associated with accurately measuring physical activity. The Multimedia Activity Recall for Children and Adolescents (MARCA) is a computer delivered use of time instrument. The advantage of the MARCA is that it is able to measure each of the four components of physical activity: frequency, duration, energy expenditure and intensity. The MARCA enables the day to be segmented into periods that children can easily associate with, thus helping them to recall the activities they have been involved in. Children then fill in each five minute period of the day using a list consisting of over 200 activities. Energy costs and physical activity levels are determined by the software. This method has been shown to be both reliable (r=0.88-0.94) and valid (rho=0.36-0.45). Instruments such as the MARCA may prove to be an effective physical activity measure in the future. However, there remains a need for further metabolic research to be conducted with children, as a number of the metabolic costs of the activities in the MARCA have been based on adults' measurements.

Although the data from this thesis has added to the body of research on quantifying the metabolic costs of children's activities, there are still significant gaps in the literature remaining in this area. Age, body mass, gender, pubertal status and body composition have all been reported to influence the metabolic costs of activities. Also, the number of activities in which the metabolic costs have been directly measured is very limited. Therefore, the energetic costs of children's activities need to be further researched and defined. Further establishing the metabolic costs of children's activities will enable more accurate comparisons to be made between the energy children consume and the energy children expend.

The influence of experience and aerobic fitness on energy expenditure

The findings from this thesis did not provide any evidence to suggest that there was a relationship between experience and EE during active video gaming. Similarly, there was not a relationship between aerobic fitness and EE during active video gaming. Examining the influence of experience on EE during active video gaming was important because if it was found that more experienced children's EE was substantially, lower due to a familiarity, effect then a long-term intervention may not be as successful. However, as noted in study 1, reasons for no changes in EE may have been due to the low intensity, intermittent and self-paced nature of the active video games or it could have been due to a lack of statistical power.

The influence of active video games on enjoyment

Overall enjoyment while playing active video games was high (Table 4.3). The percentages of children that enjoyed each activity were: walking (39%), television (58%), running (60%), PS3 (73%), Wii Boxing (88%), Wii Tennis (77%), Wii Fit (75%) and Wii Bowling (89%). The active video games were all ranked as the four most enjoyable activities while walking was ranked as the least enjoyable activity. A reason why the active video games may be considered more enjoyable than walking and running (Table 4.3) is because they may provide more mental stimulation and challenge for participants. Due to the nature of the active video games they may also be considered to be unstructured physical activity. Therefore, the children may have not perceived themselves to be participating in physical activity when they were playing the active video games. Unstructured activity is important to target as it makes up a significant proportion of total daily physical activity (Vandewater et al., 2004). In a study of American boys aged 6-12 years (n=119) it was found that nearly half of the accumulated minutes in moderate to vigorous physical activity were attributed to unstructured activities (Vandewater et al., 2004). Therefore, replacing sedentary time with moderate intensity active video games may help to increase the amount of time children spend in moderate to vigorous activity each day. In the same study, it was also found that on the days that children did not participate in organised sport, the children engaged in significantly more sedentary activity (Vandewater et al., 2004). This suggests that it is important to have a wide range of physical activity options available to children within the home environment.

If children do not have access to enjoyable physical activities then they may switch to other sedentary behaviours (e.g. reading, playing board games) when targeted sedentary behaviours are decreased (e.g. electronic media) instead of increasing physical activity (Epstein et al., 2000). Enjoyment is an important factor to consider in order for developing sustainable interventions that are successful long-term (Motl et al., 2001). Enjoyment may help to sustain motivation. In a study in which children's motivation to play an interactive dancing game was evaluated it was found that reasons for not playing the game included technical mistakes, the need for space to play the game properly, dull music and boredom (Chin A Paw, Jacobs, Vaessen, Titze, & van Mechelen, 2008). Therefore, if active video games are to be used as a physical activity or sedentary behaviour intervention, it is important that the active games are well-designed, are enjoyable and, capture and maintain the attention of children.

Although there have been a number of interventions aimed at encouraging children to walk, this may not be the most effective way to promote physical activity. The self-selected walking pace chosen by the children in this study was relatively slow (4.5 ± 0.4 $km.hr^{-1}$). This may have been because walking was not a particularly enjoyable activity (3.42 ± 0.63; on a scale where 1 is *not enjoyable* and 5 is *very enjoyable*). However, energy expended during the two most active video games, Wii Boxing and Wii Bowling was similar to the energy expended during walking. Therefore, in some cases it may be beneficial to substitute walking with an active video game ($\approx$3 $METS_{meas}$). However, care needs to be taken to ensure an active video game of similar intensity to walking is selected.

Limitations

In light of the findings, there were some limitations to the thesis that should be considered. Firstly, the sample population for the study consisted of only 26 boys aged 10-12 years. Research indicates that the energy costs of activities are sensitive to differences in age, gender, pubertal status and body composition. Therefore, the results of this thesis cannot be generalised to other populations.

Due to the nature of the study it was difficult to control the amount of exercise done and the type, amount and time food was eaten by the subjects prior to testing. To try and ensure consistency children were asked to eat the same amount and the same type of food before testing and to avoid exercise during the preceding day. The metabolic costs of the activities may have also been affected by having multiple activities within one session. This may have heightened children's physiological responses to some of activities. Ideally, it would have been preferable to measure RMR prior to each activity to account for any residual effects (EPOC). However, this study was an improvement on other studies (Lanningham-Foster et al., 2006; Maddison et al., 2007) as each session was limited to three activities that were significantly more intense than resting.

The children participating in the enjoyment study may have scored their enjoyment of active video games higher due to the novelty of the situation. It is important that studies are designed so that enjoyment can be measured sequentially over a period of time. Children's enjoyment of activities may also be influenced by peers. For example, children may find an activity less or more enjoyable when competing against a friend or sibling. Children performed the activities individually during these studies. Therefore, future research may consider the effect of peer influence on children's enjoyment of active video games.

In this thesis, no between group differences were detected. This may have been because the homogeneity of the group may have been too great i.e. there may not have been enough spread of experience, weight and fitness among the participants.

Additionally, the ethnicity, pubertal status and body fatness of subjects were not examined in this study.

Finally, only activity promoting video games from the Nintendo® Wii range were used in this study. These games appear to yield smaller increases in EE than the dance and EyeToy video games measured in previous studies (Maddison et al., 2007). Therefore, future research may consider comparing the acute and chronic effects of different types of game consoles e.g. Nintendo® Wii games vs. PlayStation® EyeToy games. Likewise, the difference in enjoyment between different types of active video games needs to be considered.

Future Research

Future physical activity and health research

Due to the cross-sectional nature of the study it was not possible to determine whether active video games may elicit long term anthropometric and physiological changes, for example decreased BMI, decreased %BF and increased fitness. Physical activity research shows that engaging in physical activity offers a range of benefits including; increased bone density (Molgaard et al., 2001), decreased risk of developing type 2 diabetes (Schmitz et al., 2002), cardiovascular disease (Woo et al., 2004) and hypertension (Ewart et al., 1998). If interventions such as active video gaming are going to be the way of the future then researchers may consider exploring whether long-term involvement in active video game play offers similar benefits. This thesis indicates that active video game interventions may be a practical method used to increase NEAT and physical activity, depending on the type of game. However the next step forward in this field of research would be to design interventions to determine whether anthropometry, physiology and enjoyment are positively affected by longer-term interaction with active video games. There is a need to determine whether active video games will influence long-term behavioural and health changes.

It is also important for an increased emphasis to be placed on reducing the amount of time that children are spending participating in sedentary activities. There is now evidence available to show that there is an association between a number of metabolic risk variables and time spent in sedentary behaviour, irrespective of whether physical activity guidelines are being met (Healy et al., 2008). In New Zealand there is little information available on children's physical activity and sedentary behaviour levels. This is important to ascertain in order to help research progress in this field. Therefore, there is a pressing to develop more objective and reliable physical activity and sedentary behaviour measures.

The future of active video games

Active video games offer unique advantages as they have the potential to overcome many of the perceived barriers to physical activity. The literature shows that there are a number of factors that children and their parents perceive as barriers to being physically active. The amount of physical activity that children participate in is influenced by the environment and family members (Kahn et al., 2008; Williden et al., 2006). Environmental issues include neighbourhood safety, suburb designs and the weather. Family influences are also a significant factor. In research by Jordan et al. (2006) it was concerning to note that some parents viewed television as a method to entrain their children whilst they did other things. Also, there is an increasing number of children that have televisions in their own rooms (Jordan et al., 2006). This could perhaps be due to lack of parental knowledge about the health risks associated with sedentary behaviour. The advantages of active video games are that they can be played indoors and irrespective of weather conditions, they are safe to play and they can be played individually or with others. Therefore, they can be substituted for a sedentary behaviour relatively easily.

For many working within public health, the ultimate goal would be to see children participating in sport and playing outdoors on a daily basis. However, children's reluctance to give up electronic media activities may be one of the factors preventing this from happening. Hillier et al. (2008) has noted that technology (such as electronic media), although often portrayed negatively in public health, can also aid in creating solutions to the problems. The portability of today's electronic media may be able to be used in such a way that children take their screen-time into the outdoors. For example, future game designs on PlayStation® Portables (PSPs) may be able to make walking to school more exciting. Likewise, games may be designed to incorporate "real activity" into portable media that can be played using playgrounds, parks and beaches.

Already, active video games are being used in a novel way in Weymouth Massachusetts where an interactive fitness arcade recently opened (Van Aarem, 2008). The fitness arcade, advertised as a health club for children, has been designed to give children, aged 8-15 years, the opportunity to socialise as well as "exergame" (Van Aarem, 2008). Weymouth XRKade has been said to boast multiple selections of exergames, including the Nintendo® Wii range (Van Aarem, 2008). However, given that the findings from this thesis and from other studies suggest that the intensity of Nintendo® Wii games is relatively low; children would not be experiencing the same acute and chronic physiological consequences that are associated with exercise. Therefore, careful consideration needs to be given to the selection of available games if such arcades are the children's gyms of the future.

CHAPTER 6. CONCLUSIONS

The first aim of this thesis was to determine the metabolic costs of several different activities. It was found that watching television and playing a sedentary video game had similar metabolic costs to resting. Active video games, on the other hand, cause a significant increase in EE expenditure. However, the metabolic costs of active video game play were significantly less than the metabolic cost of running. In fact, three of the active video games had significantly lower metabolic costs than the metabolic cost associated with walking, and the remaining two active video games resulted in similar metabolic costs to walking. Overall, it was found that active video games are low intensity exercises and therefore should not be considered as a replacement for physical activity. Active video games may however, prove to be a better alternative to sedentary behaviour.

The second aim was to establish whether experience and aerobic fitness influence the metabolic costs of active video games. It was found that there were no relationships between these variables. This may have been due to a lack of statistical power to detect between group differences. However, if differences do not exist between these variables this would suggest that active video games could be used as an intervention to decrease sedentary behaviour regardless of the aerobic fitness or experience of the gamers. The final aim of this thesis was to determine children's enjoyment of active video games. It was found that active video games were the four most enjoyable activities irrespective of participants' weight status, fitness and experience. This is an important finding as interventions that are appealing are more likely to be successful.

Overall, the findings from this thesis show that active video games can significantly increase EE beyond the energy expended during resting, television watching and sedentary video game play. However, active video games have only been found to be less than, or equal to, the intensity of self-paced walking. However, there was clear evidence to show that active video games were more enjoyable than walking. The active video games used in this thesis may not be sufficiently intense enough to contribute to a child's recommended 60 minutes of daily moderate to vigorous physical activity but they may be providing significant health benefits by increasing NEAT. The findings of this thesis indicate that an active video game intervention aimed at decreasing sedentary behaviour is a plausible option for the future.

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APPENDICES

APPENDIX 1: INTERNATIONAL BMI CUT OFF POINTS FOR CHILDREN

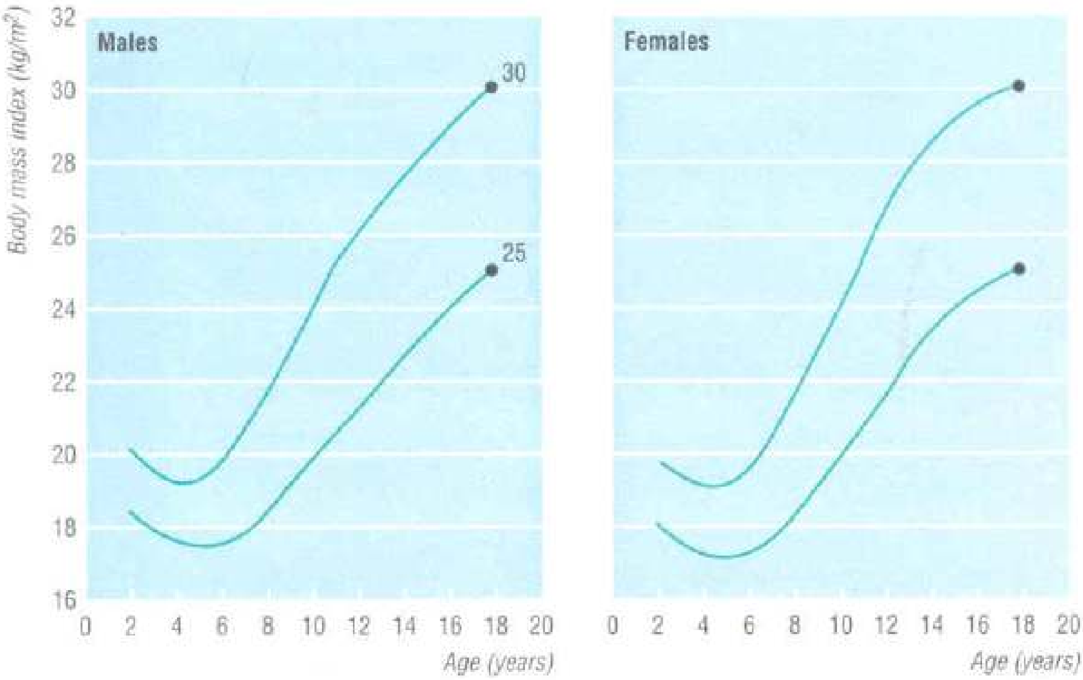

Fig 3 International cut off points for body mass index by sex for overweight and obesity, passing through body mass index 25 and 30 kg/m² at age 18 (data from Brazil, Britain, Hong Kong, Netherlands, Singapore, and United States)

(Cole et al., 2000)

APPENDIX 2: PARENT / GUARDIAN INFORMATION SHEET

Parent / Guardian Information Sheet

Date Information Sheet Produced:

26/11/2007

Project Title

Can playing active video games contribute to a child's daily physical activity?

An Invitation

Your child has been invited to participate in this research study which aims to determine what the physiological responses are to playing a range of active video games. Their participation in the study is voluntary and that they may withdraw at any time without any adverse consequences. Withdrawal from the study will not affect your's or their relationship with AUT. The data collected during this study will help to contribute to a Masters of Health Science thesis.

What is the purpose of this research?

There is a growing amount of concern over the amount of time children spend engaging in daily sedentary behaviours such as watching television, playing computer games and playing video games. In addition to this it has been noted that children are reluctant to eliminate television and video games from their leisure time activities. The purpose of this research study is to determine whether the physiological responses to active video games are sufficient to meaningfully contribute to a children's daily physical activity. The data gathered in this study may be presented and conferences and published in academic journals.

How was my child chosen for this invitation?

Your child has been selected for the study as they are a 10-12 year old boy and are able to participate in moderate-high intensity exercise.

What will happen in this research?

Your child will be required to attend three testing sessions at AUT University, 90 Akoranga Drive, Northcote, North Shore City. During each session they will be fitted with a heart rate monitor and a face mask which measures the volume and air breathed during rest and exercise. They will be required to participate in a range of activities as shown in Table 1. After each activity they will be asked to answer a questionnaire indicating how much they enjoyed each activity.

Table 1: Outline of Testing Sessions

Testing Session 1	Testing Session 2	Testing Session 3
Height and weight measures Resting energy and HR measures (lying down) Walk at a self-selected pace. Run at a self-selected pace. Perform Multistage Fitness test (shuttle running) Practice video games	Resting energy and HR measures (lying down) Play a non-active (seated) video game Play an active video game	Resting energy and HR measures (lying down) Watch a DVD (seated) Play an active video game

What are the discomforts and risks?

There may be some discomfort associated with the multistage shuttle test (shuttle run/beep test). However, this would not be beyond what would be experienced during a typical game of sport.

What are the benefits?

Some of the benefits of participating in this research include finding out how fit your child is and establishing which video games are better for your child to play.

What compensation is available for injury or negligence?

In the unlikely event of a physical injury as a result of your child's participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

How will my child's privacy be protected?

Your child's data will coded in order to ensure that they cannot be identified. The data collected will remain in locked storage and will only be accessible to the principal investigators of the project in accordance with the Privacy Act 1993.

What are the costs of participating in this research?

Your child will be required to attend one x 1.5hr session and two x 1hr sessions.

What opportunity do my child and I have to consider this invitation?

- You may take the time you need to consider this invitation to participate in the study.
- Your child has the opportunity to withdraw from the study at any point.
- Your child's participation in this study should be voluntary.

How do I and my child agree to participate in this research?

If you and your child decide that you would like to be involved in the study please contact Kate White (contact details below).

Will I receive feedback on the results of this research?

Yes, a report will be provided to you with your child's individual results.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, *Dr. Andrew Kilding, andrew.kilding@aut.ac.nz , 921 9999 ext 7056*

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, *madeline.banda@aut.ac.nz* , 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:

Kate White
School of Sport and Recreation
Faculty of Health and Environmental Sciences
AUT University
Private Bag 92006
Auckland 1020

Phone: 921 9999 ext. 7128
Mobile: 027 634 9299
Email: kate.white@aut.ac.nz

Project Supervisor Contact Details:

Dr. Andrew Kilding
School of Sport and Recreation
Faculty of Health and Environmental Sciences
AUT University
Private Bag 92006
Auckland 1020

Phone: 921 9999 ext. 7056
Email: andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee* on *20/12/07*, AUTEC Reference number *07/221.

APPENDIX 3: PARENT / GUARDIAN CONSENT FORM

Parent / Guardian Consent Form

Project title: Can playing active video games contribute to a child's daily physical activity?

Project Supervisor: Dr. Andrew Kilding
Researcher: Kate White

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 26/11/2007.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw my child/children and/or myself or any information that we have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ If my child/children and/or I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.
- ○ My child/children are not suffering from heart disease, high blood pressure, any respiratory condition, any illness or injury that impairs my physical performance, or any infection.
- ○ I agree to my child/children taking part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Child/children's name/s :

…………………………………………………………………………………………

Parent/Guardian's signature:

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Parent/Guardian's name:

......................................……………………………………………………………

Parent/Guardian's Contact Details (if appropriate):

……………………………………………………………………………………………..

……………………………………………………………………………………………..

Date: ....………………

Approved by the Auckland University of Technology Ethics Committee* on *20/12/07*, AUTEC Reference number *07/221. Note: The Participant should retain a copy of this form.

APPENDIX 4: PARTICIPANT INFORMATION SHEET

Participant Information Sheet

Date Information Sheet Produced:

26/11/2007

Project Title

Can playing active video games contribute to a child's daily physical activity?

An Invitation

Hi, my name is Kate White and I am inviting you to help me with my research project. My project involves asking you to play different types of video games so that I can try and find out which ones are healthier for you and other children to play. Together, you and your parents should decide whether or not you would like to be involved. You can stop being involved in the study at any time.

How were you chosen for this invitation?

You have been chosen to be involved in the study as you are;

- 10-12 years old
- Male
- Are able to exercise

What will happen in this research?

You will need to attend three testing sessions. During each session you will need to wear a special mask over you face which will measure your breathing. We will also put a strap around your chest to measure your heart rate.

To be involved in the study you will need to visit us three times including: 1 x 90 minute visit and 2 x 60 minute visits.

In the table below you can see what you will be doing during each visit.

Table 1: What you will be doing during each visit

Visit 1	Visit 2	Visit 3
Lying down Walking Running Shuttle running Practicing video games	Lying down Playing a non-active video game Playing an active video game	Lying down Watching a DVD (seated) Playing an active video game

During the shuttle running (beep test) you may become tired. This will be similar to how you feel when playing a game of sport.

What chance do I have to decide whether or not I would like to be involved in the study?

- You may take the time you need to talk to your parents and decide whether or not you would like to participate in the study.
- You can stop being involved in the study at any point.
- Your participation in this study should be voluntary.

How do I agree to become involved in this research?

If you and your parents decide that you would like to be involved in the study please ask your parents to contact Kate White (contact details below).

Will I receive feedback on the results of this research?

Yes, a report will be provided to your parents with your results.

What happens if there are concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, *Dr. Andrew Kilding, andrew.kilding@aut.ac.nz , 921 9999 ext 7056.*
Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, *madeline.banda@aut.ac.nz* , 921 9999 ext 8044.

Whom do I contact for further information about this research?

Researcher Contact Details:
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Project Supervisor Contact Details:
Dr. Andrew Kilding
School of Sport and Recreation
Faculty of Health and Environmental Sciences
AUT University
Private Bag 92006
Auckland 1020
Phone: 921 9999 ext. 7056
Email: andrew.kilding@aut.ac.nz

Approved by the Auckland University of Technology Ethics Committee* on *20/12/07*, AUTEC Reference number *07/221.

APPENDIX 5: PARTICIPANT ASSENT FORM

Participant Assent Form

Project title: Can playing active video games contribute to a child's daily physical activity?

Project Supervisor: Dr. Andrew Kilding
Researcher: Kate White

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 26/11/2007.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- ○ I am not suffering from heart disease, high blood pressure, any respiratory condition, any illness or injury that impairs my physical performance, or any infection.
- ○ I agree to take part in this research.
- ○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participant's signature:

....……………………………………………………

Participant's name:

....……………………………………………………

Participant Contact Details (if appropriate):

………………………………………………………………………………………..

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Date: ……………………………..

Approved by the Auckland University of Technology Ethics Committee* on *20/12/07*, AUTEC Reference number *07/221. *Note: The Participant should retain a copy of this form.*

APPENDIX 6: PARTICIPANTS FOOD DIARY

Food Diary

Date _____________ Session # __________ Participant# __________

Please fill in everything that you eat and drink 24 hours before the testing session.

Time	**What?** (everything you eat **and** drink)	**How much?** (portion size or estimate)	**How cooked?** (grilled, fried, raw, toasted, etc)

APPENDIX 7: INSTRUCTIONS / DESCRIPTIONS OF NINTENDO WII GAMES

WII BOWLING

The Wii remote is held in the player's "bowling" hand. Bowling instructions are shown in Figure A7.1.

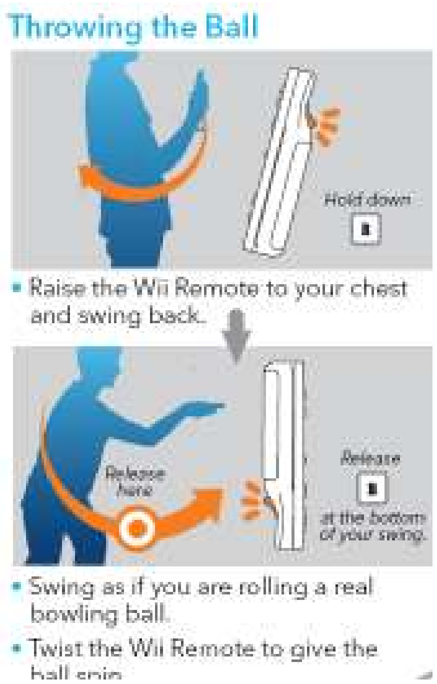

Figure A7.1 Wii Bowling instructions (Nintendo, 2006)

WII TENNIS

During Wii Tennis the Wii remote is held in the player's dominant hand like a tennis racquet. Serving and stroke instructions are shown in Figure A7.2.

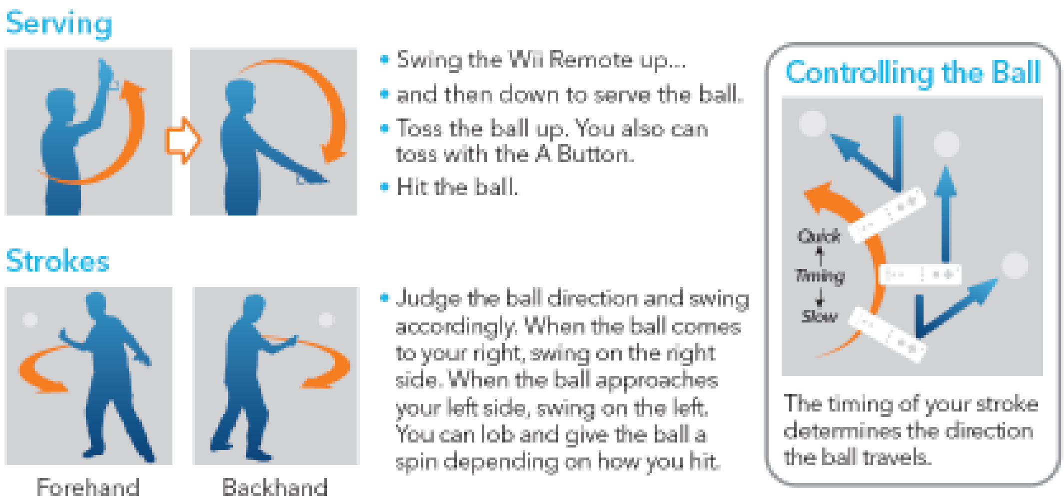

Figure A7.2 Wii Tennis serving and stroke instructions (Nintendo, 2006)

WII BOXING

The player holds the Wii remote in their dominant hand and the nunchuk in their non-dominant hand. Instructions for blocking, punching and moving are shown in Figure A7.3.

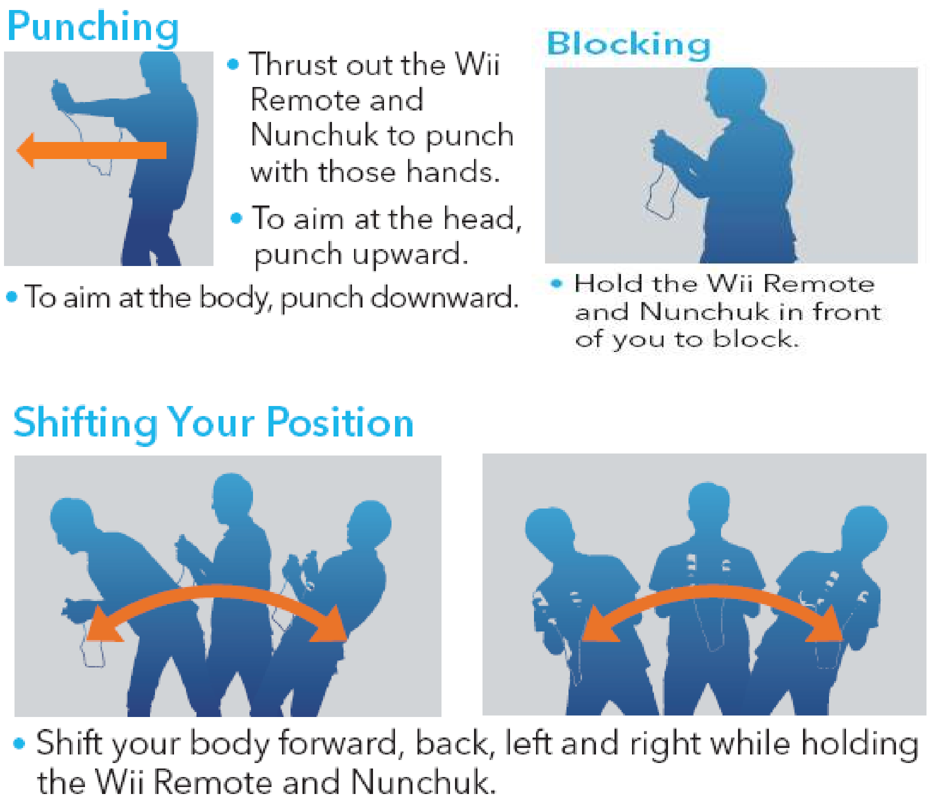

Figure A7.3 Wii Boxing blocking, punching and moving instructions (Nintendo, 2006)

WII SKIING

The player stands on the Wii Balance Board. To turn left the player puts their weight on their left foot. To turn right the player puts their weight on their right foot.

WII STEP AEROBICS

The player steps on and off the Wii Balance Board in time with the Wii Miis' on the screen.

APPENDIX 8: P VALUES OF PHYSIOLOGICAL AND METABOLIC DATA

Table A8.1 Statistical significance of $\dot{V}O_2$ (ml.kg^{-1}.min^{-1}) between activities

	Rest	DVD	PS3	Tennis	Bowl	Box	Walk	Run	Step
Rest									
DVD	0.983								
PS3	0.041	0.119							
Tennis	0.000**	0.000**	0.000**						
Bowl	0.000**	0.000**	0.000**	0.000**					
Box	0.000**	0.000**	0.000**	0.000**	0.328				
Walk	0.000**	0.000**	0.000**	0.000**	0.819	0.908			
Run	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**		
Step	0.000**	0.000**	0.000**	0.475	0.008*	0.002*	0.024*	0.000**	
Ski	0.000**	0.000**	0.004*	0.002*	0.000**	0.000**	0.000**	0.000**	0.001**

Statistical significance ** $p \leq 0.001$; * $p \leq 0.05$

Table A8.1 Statistical significance of EE (J.kg^{-1}.min^{-1}) between activities

	Rest	DVD	PS3	Tennis	Bowl	Box	Walk	Run	Step
Rest									
DVD	0.977								
PS3	0.168	0.287							
Tennis	0.000**	0.000**	0.000**						
Bowl	0.000**	0.000**	0.000**	0.256					
Box	0.000**	0.000**	0.000**	0.000**	0.000**				
Walk	0.000**	0.000**	0.000**	0.000**	0.000**	0.977			
Run	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**		
Step	0.000**	0.000**	0.001**	0.573	0.253	0.084	0.084	0.000**	
Ski	0.013*	0.000**	0.052	0.047*	0.043*	0.000**	0.000**	0.000**	0.004*

Statistical significance ** $p \leq 0.001$; * $p \leq 0.05$

Table A8.2 Statistical significance EE (J.min^{-1}) of between activities

	Rest	DVD	PS3	Tennis	Bowl	Box	Walk	Run	Step
Rest									
DVD	0.684								
PS3	0.149	0.335							
Tennis	0.000**	0.000**	0.000**						
Bowl	0.000**	0.000**	0.000**	0.231					
Box	0.000**	0.000**	0.000**	0.000**	0.000**				
Walk	0.000**	0.000**	0.000**	0.000**	0.000**	0.961			
Run	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**		
Step	0.000**	0.000**	0.000**	0.457	0.048*	0.007**	0.043*	0.000**	
Ski	0.001*	0.000**	0.013*	0.027**	0.018*	0.000**	0.000**	0.000**	0.001**

Statistical significance ** $p \leq 0.001$; * $p \leq 0.05$

Table A8.3. Statistical significance of heart rate (b.min^{-1}) between activities

	Rest	DVD	PS3	Tennis	Bowl	Box	Walk	Run	Step
Rest									
DVD	0.001**								
PS3	0.000**	0.038*							
Tennis	0.000**	0.000**	0.000**						
Bowl	0.000**	0.000**	0.000**	0.861					
Box	0.000**	0.000**	0.000**	0.000**	0.000**				
Walk	0.000**	0.000**	0.000**	0.075	0.581	0.094			
Run	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**		
Step	0.000**	0.000**	0.000**	0.289	0.030*	0.000**	0.581	0.000**	
Ski	0.000**	0.000**	0.000**	0.677	0.973	0.000**	0.949	0.000**	0.035*

Statistical significance ** $p \leq 0.001$; * $p \leq 0.05$

APPENDIX 9: PHYSICAL ACTIVITY ENJOYMENT QUESTIONNAIRE

AUT UNIVERSITY

TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Modified Physical Activity Enjoyment Scale

Participant #: ____________ Activity: _____________________

The following questionnaire will be used to determine how much you enjoyed the activity you have participated in. All answers will be kept confidential.
Please place a tick in the box that best describes how you felt during the activity you have just completed.

	Disagree a lot 1	2	3	4	Agree a lot 5
1. I enjoyed it					
2. I felt bored					
3. I disliked it					
4. I found it entertaining					
5. It was not fun at all					
6. It gave me energy					
7. It made me unhappy					
8. It was good fun					
9. My body felt good					
10. I got something out of it					
11. It was very exciting					
12. It frustrated me					
13. It was not at all interesting					
14. It made me feel as though I had achieved something					
15. It felt good					
16. I felt as though I would rather be doing something else					

APPENDIX 10: PHYSICAL ACTIVITY AND SCREEN TIME QUESTIONNAIRE

Physical Activity and Screen Time Questionnaire

This brief questionnaire will help us understand more about your physical activity and leisure time activities. All answers will be kept completely confidential.

Thank you.

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1. What is your birth date?

______/______/______

2. If you have any other young people (less than 20) living with you, please list their age and relationship to you:

e.g. *Brother, 15 years*

____

____

____

____

____

____

3. How many rooms in your household have a television?

- None ☐
- 1 ☐
- 2 ☐
- 3 ☐
- 4 or more ☐

4. Do you have a television in your room?

- Yes ☐
- No ☐

5. Do you have access to a games console (e.g., PlayStation, Xbox, Nintendo etc) at home?

- Yes ☐
- No ☐

6. Do you have access to a personal computer at home?

- Yes ☐
- No ☐

7. How often do you spend time on the following activities:

	Never	Sometimes	Often	N/A
Television	☐	☐	☐	☐
Games Console	☐	☐	☐	☐
Computer	☐	☐	☐	☐

8. How often do your parents restrict the amount of time you spend on the following activities:

	Never	Sometimes	Often	N/A
Television	☐	☐	☐	☐
Games Console	☐	☐	☐	☐
Computer	☐	☐	☐	☐

9. How often do you spend time on homework?

- Never ☐
- Some nights ☐
- Most nights ☐
- Every night ☐

10. How do you usually travel **<u>to</u>** school? (tick one)

- Car ☐
- Bus ☐
- Bicycle ☐
- Walk ☐
- Other ____________________

11. How do you usually travel **<u>from</u>** school? (tick one)

- Car ☐
- Bus ☐
- Bicycle ☐
- Walk ☐
- Other ____________________

12. How many days each week do you play or practise organised sport outside of class hours?

- None ☐
- 1-2 ☐
- 3-4 ☐
- 5 or more ☐

13. What do you consider your activity levels to be:

- Below average ☐
- Average ☐
- Above average ☐