Department of Clinical Sciences

ENERGY EXPENDITURE OF "KINECT™" EXERGAMING IN SCHOOLCHILDREN

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Steve Smallwood
0819201

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Energy expenditure of Kinect™ exergaming in schoolchildren.

Abstract

Objective: With declining levels of physical activity and increasing body mass indexes recent research has proposed that active video gaming could be a potential tool in the fight against childhood obesity. This study was designed to evaluate the energy and physiological costs of the latest technology of active gaming, Kinect™ for the Xbox360®, in healthy schoolchildren. The hypothesis was that energy expenditure would be significantly greater when children engaged in activity promoting video games using Kinect™ compared to both traditional sedentary video gaming and rest.

Methods: Energy expenditure, heart rate and oxygen consumption were measured in 18 healthy schoolchildren (10 boys and 8 girls) aged 11 to 15 years during rest, whilst playing a traditional non-active video game and also whilst playing two activity promoting Kinect™ video games. Participants played each game for 15 minutes in a fixed order and measurements were made by indirect calorimetry using the Cosmed K4 b^2 metabolic cart. Repeated measurement mixed-model analysis was conducted to compare the physiological costs and energy expenditures across conditions with multiple post hoc comparisons.

Results*:* Mean heart rates, oxygen and energy costs all increased significantly ($p < .05$) during activity promoting video game play compared to rest and sedentary gaming. Mean heart rate increased by 53% above rest (77.4 ± 14.6 bpm) during a dance simulation game (118.3 ± 17.8 bpm) and by 70% during a boxing game (131.3 ± 15.3 bpm). Mean energy expenditures of 3.00 ± 1.03 kcal·min^{-1} and 4.35 ± 1.55 kcal·min^{-1} were demonstrated during “Dance Central” and “Kinect Sports Boxing”, 150% and 263% greater than resting values (1.20 ± 0.25 kcal·min^{-1}) and 103% and 194% higher than during sedentary gaming (1.48 ± 0.33 kcal·min^{-1}). Activity levels of 2.91 and 4.02 child-specific METs were achieved when playing the Kinect™ dance and boxing game.

Conclusion: Active gaming using Kinect™ on the Xbox360® significantly increased energy expenditure compared to rest and almost tripled when compared to traditional sedentary gaming. In our sample, Kinect™ active gaming expended up to the equivalent of 261 kcal·h^{-1}, 172 kcal·h^{-1}greater than sedentary gaming. Such expenditure could potentially help bridge the ‘energy gap’ that is thought to be responsible for the increasing incidence of obesity seen in children and adolescents.

Keywords: active video gaming, childhood obesity, physical activity.

Declaration

This work is original and has not been previously submitted in support of a degree qualification or other course.

Signed…………………………………………………………….

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CHAPTER 1 – INTRODUCTION

Obesity in children has seen a dramatic and continued rise worldwide and this condition is now considered one of the ten top global health problems (World Health Organisation, 1998). The International Obesity Task Force's review of obesity in children and young people has estimated that at least 155 million school age children worldwide are overweight or obese, representing one in ten of all children (Lobstein, Baur & Uauy, 2004).

The presence of overweight and obesity in childhood is related to multiple physical health problems and is also associated with a higher risk of premature death and disability in adulthood (WHO, 2011). Childhood obesity is a risk factor for a number of chronic diseases in adult life including cardiovascular disease and many cancers. The psychosocial impact of obesity may also be devastating for a child and can have a significant negative impact on well-being (Warschburger, 2005).

Obesity is a complex chronic condition and there are many modifiable and non-modifiable risk factors that contribute to its aetiology. Whilst genetics may play a part in the predisposition of overweight or obesity, the physical environment which the child is exposed to is believed to be a major determinant of obesity risk (Carlos Poston & Foreyt, 1999).

The term "obesogenic environment" has evolved to express the "sum of influences, opportunities, or conditions of life have on promoting obesity in individuals" (Swinburn, Egger & Raza, 1999) and may include socio-economic status, family structure, family food choices and physical activity levels. Recent changes in both diet and physical activity levels in particular are believed to be major influences in the recent increase in the prevalence of child obesity.

Over the last few decades there have been shifts towards diets with greater intakes of energy dense foods, higher in both fat and sugars. This trend and its impact on waistlines has been further compounded by declining levels of physical activity and exercise. Guidelines in the UK from the National Institute for Health and Clinical Excellence (2006), on behalf of the Department of Health, state that children and young people should undertake a range of moderate to vigorous intensity activities for at least 60 minutes a day. Most children, however, have been falling well short of this amount (Health Survey for England, 2008).

A multitude of factors are believed to underpin this shortfall in childrens' activity levels. There has been a decline in the amount of time spent in physical education within schools and an increase in competing sedentary activities, particularly television viewing and other electronic media use. Video gaming, especially, plays a much greater part in young people's lives today, with children in the UK now dedicating up to two hours of their time daily to such activities (Pratchett, 2005).

Whilst video gaming has been implicated as a factor in reduced activity levels and childhood obesity risk due to its sedentary nature (Vanderwater, Shim & Caplovitz, 2004), the last decade has seen the development of activity promoting gaming platforms, most notably the Nintendo Wii which was launched in late 2006.

Previous research has demonstrated that active gaming uses significantly more energy than sedentary activities and preliminary evidence seems to support active gaming as an enjoyable medium of physical activity of light to moderate intensity. As traditional interventions designed to increase activity levels or promote weight loss in children have been relatively unsuccessful (Epstein, Valoski, Kalarchian, & McCurley, 1995) researchers have proposed that active gaming may be a useful tool in promoting physical activity and increasing energy expenditure in children (Graf, Pratt, Hester & Short, 2009).

In November 2010 the latest technology in active gaming, Kinect™ for the Microsoft Xbox360®, was launched. Unlike most previous forms of active gaming, Kinect™ differs from its counterparts in that it utilises a webcam style sensor device and software technology that allows the gamer to interact with the Xbox360® without the need for a game controller. Effectively the player ‘acts’ as the controller.

To date, evaluations have not been made to the physiological and energy costs of Kinect™ video gaming and this study was designed to examine the energy expenditure and physiological responses of two different active games, “Dance Central” and “Kinect Sports Boxing”, when played by healthy schoolchildren, compared to both traditional sedentary gaming and rest.

CHAPTER 2 – LITERATURE REVIEW

2.1 The childhood obesity epidemic

The latest statistics from the World Health Organisation (2008) suggest that up to 1.5 billion people worldwide are overweight, with up to 500 million of them clinically obese, a figure that exceeds the number of people who suffer from malnutrition (Food and Agricultural Organisation of the United Nations, 2008). Over the last few decades the prevalence of worldwide obesity for all age groups has risen dramatically however it has been proposed that childhood and adolescence is the most critical period for its development (Wang & Lobstein, 2006).

On top of the immense health burden that childhood obesity has created the financial consequences of this epidemic have also been dramatic. In the United States of America up to 1999 the annual hospital costs for the treatment of obesity related diseases in adolescents and children was reported as $127 million (Wang and Dietz, 2002) however the total annual cost, including medication, emergency room and outpatient costs has been estimated at $14.1 billion (Trasande & Chatterjee, 2009).

In the USA the Centers for Disease Control and Prevention (CDC) define overweight in children as a body mass index (BMI) at or above the 85th percentile and obese as at or above the 95th percentile, for children of the same age and sex based on data from five large representative American surveys (Table 1).

Table 1. CDC classification of overweight and obesity in children (Adapted from Kuczmarski, Ogden, Grummer-Strawn, Flegal, Guo, Wei et al, 2000).

Classification	BMI (percentile)
Underweight	< 5th
Normal Weight	5th - 84th
Overweight	85th - 94th
Obese	≥ 95th

In 2008 obesity levels in children and adolescents aged 2 – 19 years reached a level of 16.9%, more than triple the level recorded in 1980 and a further 15% of children and adolescents aged 6 to 19 have been classified as overweight (National Center for Health Statistics, 2002). Whilst the most recent survey data from National Health and Nutrition Examination Survey (NHANES) 2005-2006 suggests that BMIs are beginning to stabilise in the USA, there is still an indication that some of the most obese children are still getting heavier (Ogden, Carroll & Flegal, 2008).

In the UK all schoolchildren in Reception (4 - 5 years of age) and Year 6 (10 – 11 years of age) are measured for height and weight as part of the annual National Child Measurement Programme (NCMP). According to the latest survey from December 2010 it was reported that 13% of Reception year children were overweight and a further 10% obese, rising to 15% overweight and 18% obese at Year 6 (Figure 1).These calculations used age and sex-specific body mass index (BMI) centiles from the British 1990 growth reference. Whilst the same overweight and obese classifications are used as the CDC, these charts have been based on UK population data and adjusted for skewness (Cole, 1997).

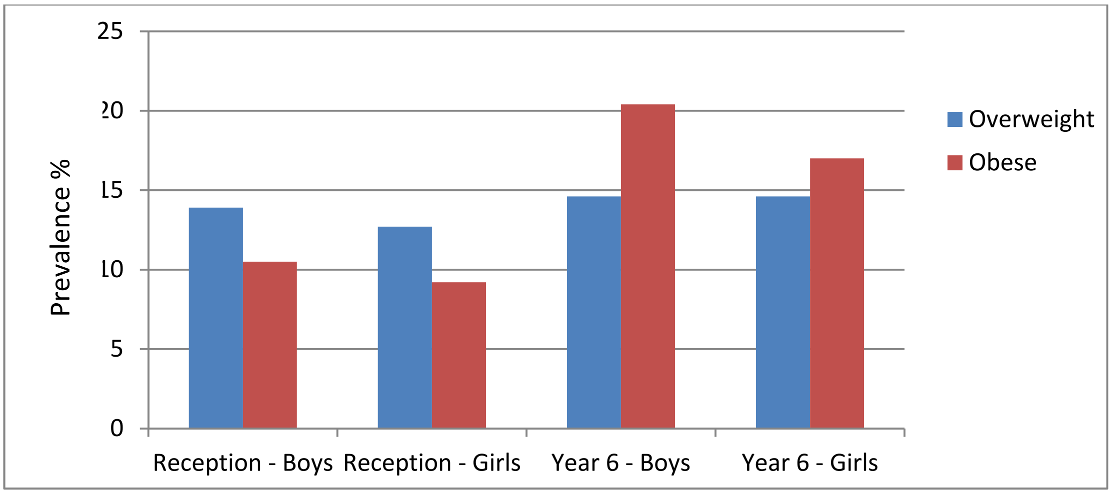

Figure 1. UK prevalence (%) of overweight and obesity in Reception and Year 6 children 2009/2010 (Adapted from National Child Measurement Programme, 2010)

Future projections based on Health Survey for England data 1993-2004 estimated that by 2050 a quarter of young people below 20 years of age would be obese (Foresight Report, 2007) although the latest Health Survey for England data 2000-2007 has suggested, as in the USA, that the increase in the prevalence of childhood obesity is beginning to level off (McPherson, Brown, Marsh & Byatt, 2009).

Increasing childhood obesity prevalence trends have also been seen in other developed nations around the world. Childhood obesity doubled or trebled between the early 1970s and late 1990s in Australia, Brazil, Canada, Chile, Finland, France, Germany, Greece, Japan, Spain as well as the UK and USA (Lobstein, Baur & Uauy, 2004; Wang & Lobstein, 2006). Different nations have in their surveys, however, considered different child age ranges and utilised different definitions for calculating childhood overweight and obesity, such as the International Obesity Task Force (IOTF) reference - based on data from 6 different populations, Great Britain, Brazil, the Netherlands, Hong Kong, Singapore and the USA and linked to the adult cut-off points of 25 and 30kg/m² (Cole, Bellizzi, Flegal & Dietz, 2000).

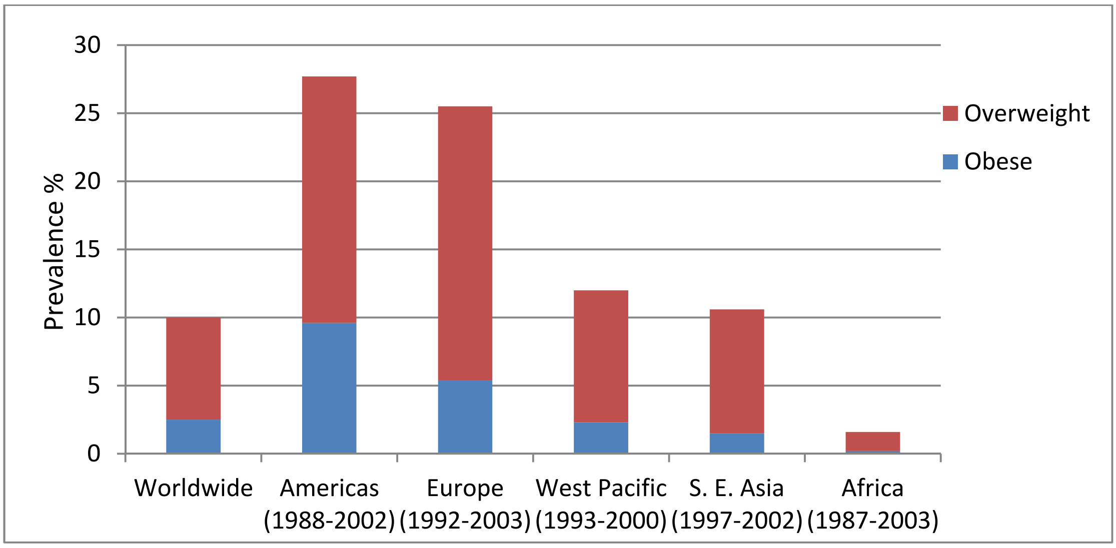

Figure 2. Prevalence (%) of overweight and obesity in school-aged children based on IOTF criteria (latest survey in brackets). Adapted from Lobstein et al. (2004), Wang and Lobstein (2006).

Until recently the recognition of obesity as a serious health problem has generally been confined to industrialised nations. During the last two decades, however, there has been a rapidly increasing prevalence of overweight and obesity in developing nations, particularly amongst schoolchildren. De Onis and Blossner (2000) reported that a number of developing countries, particularly in North Africa, the Caribbean and South America, had a percentage of overweight children exceeding that of the United States.

Whilst the levels of global childhood obesity are cause for immense concern, it has been further suggested by some authors that the problem may be much worse. BMI is not a direct measure of adiposity in the way that waist circumference measurements are a marker for central body fat accumulation and its use, some authors have claimed, has resulted in a systematic underestimation of the prevalence of obesity in children and adolescents (McCarthy, Ellis & Cole, 2003).

2.2 Childhood obesity and physical health

Type II or "adult onset" diabetes and insulin resistance, conditions previously associated with adulthood, are some of the endocrine disorders that are more frequently being observed in obese children. The circulatory system in particular is affected by increased childhood adiposity, resulting in health problems related to hypertension, hyperlipidaemia, and dyslipidaemia (National Institute for Health and Clinical Excellence, 2006). A population based sample of over 9000 children in the USA identified that nearly 60% of obese children aged 5 to 10 years had at least one cardiovascular disease risk factor, such as elevated total cholesterol, triglycerides, insulin or blood pressure and 25% had two or more (Freedman, Dietz, Srinivasan & Berenson, 1999).

Children with severe obesity may experience a range of sleep associated breathing disorders including sleep apnoea (Redline, Tishler, Schluchter, Aylor, Clark & Graham, 1999) and are also more likely to experience psychological or psychiatric problems (Reilly, Methven, McDowell, Hacking, Alexander, Stewart et al., 2003).

The Department of Health (2004) stated that children who are obese are more likely to become obese adults and this likelihood increases the more obese a child is. Some researchers have claimed that up to two thirds of all obese children will be obese in adulthood (He & Karlberg, 1999). WHO (2008) have attributed overweight or obesity as the cause of death worldwide for an estimated 2.8 million people each year including an estimated 15 - 20% of all cancer deaths in the United States (Calle, Rodriguez, Walker-Thurmond & Thun, 2003). Obesity, especially severe obesity, is also linked to infertility and an increased risk of complications during pregnancy (Galtier-Dereure, Boegner & Bringer, 2000).

2.3 Childhood obesity and mental health

Dietz (1994) stated that childhood and adolescence is a critical period, as obesity in early life is not only associated with potential health problems but may also have a considerable influence on young people's psychosocial development. The psychological consequences of childhood and adolescent obesity have been well documented and the stigmatisation and discrimination of obese children from very young ages has been long recognised and is highly prevalent. Dietz (1998) reported evidence of bias and stereotyping by teachers, parents and peers towards overweight children with commonly held attitudes of greater dislike, attribution of negative stereotypes and discriminatory treatment (Latner & Schwartz, 2005) as well as an increase in the likelihood of being the target of teasing or bullying. Early research by Richardson, Hastorf, Goodman and Dornbusch (1961) indicated that overweight children were ranked by other children as the least desirable friends and Kilpatrick and Sanders (1978) claimed that negative attitudes towards obese children could develop in children as young as six years old who often attributed negative characteristics to overweight children such as meanness, stupidity, ugliness, unhappiness and laziness.

In educational settings students who are overweight or obese can face harassment and ridicule as well as a negative bias from teachers. This has been well demonstrated by physical education teachers who have placed higher expectations on normal weight children compared to overweight children (O'Brien, Hunter & Banks, 2007). Bauer, Yang and Austin (2004) also reported that middle school children received negative comments from their teachers regarding athletic abilities and this had led them to avoid participating in physical education lessons. Similar prejudices and stereotyping have also been demonstrated towards overweight and obese children by health professionals (Teachman & Brownell, 2001).

Bias and stigma have particular negative implications for emotional wellbeing in children. Weight based teasing is associated with low self-esteem and low self-esteem has been reported to influence depression, social interactions and relationships, performance in school and work, and the ability to lose weight (Davison & Birch, 2001). Strauss (2000) found that overweight and obese children with decreasing levels of self-esteem were more likely to exhibit greater rates of nervousness and sadness. Overweight adolescents are also more likely to be socially isolated (Tershakovec, 2004**)** and this can be particularly damaging as friendship is considered to be essential for the social and psychological development of adolescents. As body image, appearance and also physical fitness play an important role in social and emotional development, overweight may have lasting social and psychological consequences on child development and adolescent well-being. Recent research by Swahn, Reynolds, Tice, Miranda-Pierangeli, Jones and Jones (2009) potentially reinforces such concerns by documenting an alarming positive association between obesity and attempted suicide among youth.

With such widespread negative bias, devastating psychological implications are impacting an ever increasing number of overweight and obese children and adolescents than ever before.

2.4 Genetic factors

Heredity is one contributing factor and twin and adoption studies have shown that genetic factors play an important role in childhood obesity. Whilst Yang, Kelly and He (2007) have suggested that the genetic predisposition to obesity can vary from 6% to 85%, depending on the population studied, research on an international sample of identical or monozygotic twins that were reared apart estimated that the heritability of BMI to be between 50% to 70% (Allison, Kaprio, Korkeila, Koskenvuo, Neale & Hayakawa, 1996).

Daniels, Arnett and Eckel's (2005) claimed that having an obese parent increased the likelihood of child obesity four to five fold and Whitaker, Wright, Pepe, Seidel and Dietz (1997) stated that whilst an obese pre-school child with normal weight parents has a 25% risk of becoming obese in adulthood, this figure jumps to 60% should the child have an obese parent. Recent research on over 4000 families, using data from annual Health Surveys for England, concluded that children with two obese parents were 12 times more likely to be obese when compared to children with two normal weight parents (Whitaker, Jarvis, Beeken, Boniface & Wardle, 2010). As parents are now twice as likely to be obese compared to 30 years ago, the likelihood of producing overweight or obese offspring has significantly increased (Whitaker et al., 1997) but while such research regarding genetics and childhood obesity is compelling, the rapid increase in its prevalence over the last few decades suggests that genetics, alone, cannot be the main driver behind this epidemic.

2.5 Ethnicity

In common with adulthood obesity, certain ethnic backgrounds may be more prone to childhood overweight and obesity. A complex combination of factors including genetics, culture, socio-economic status and differing environments may be responsible for differences in the prevalence of childhood obesity between ethnicities. The CDC (2003) reported that in the U.S.A. Black, Hispanic and American Indian children were more likely to be overweight or obese than non-Hispanic white children. In the UK the Department of Health (2004) similarly stated that Asian children were four times more likely to be obese than white children. More recent data, however, has suggested that these disparities in levels of childhood obesity between ethnic groups may be diminishing, in part due to the dramatic increases in obesity in white children (Caprio, Daniels, Drewnowski, Kaufman, Palinkas, Rosenbloom et al., 2008).

2.6 The family

Shaltin and Philip (2003) purported that parental obesity is the most important risk factor for obesity in children, not only due to biological factors but also because parents create the living environment for their children, which includes both exposure to food and physical activity. A study of 6400 American children by Crossman, Sullivan and Benin (2006) found that children who grew up in families with poor eating habits and sedentary lifestyles were a third more likely to become overweight or obese as young adults. Wardle, Sanderson, Gibson and Rapoport (2001) also reported that children from overweight families demonstrated a preference for fatty foods and a lower preference for vegetables than children from families of normal weight.

The socio-economic status of the family may be a factor behind poor food choices, eating habits and the subsequent risk of obesity. Research has demonstrated an inverse relationship between energy density and food cost (Drewnowski & Specter, 2004) and

National Health Interview Survey data in the USA has found that the highest obesity rates were associated with the lowest incomes and low educational levels (Schoenborn, Adams & Barnes, 2002). As the family environment is a major influence in the food choices and eating behaviours of children it is not surprising to find that obesity and other chronic disease risk factors tend to cluster in families (Davison & Birch, 2002).

Over the last 40 years family structures have changed significantly with more single-parent households and mothers working outside of the home (Moag-Stahlberg, Miles & Marcello, 2003). Single mother families in the USA increased from 3 million in 1970 to 10 million in 2003 (US Census Bureau, 2004) and with higher total fat intakes and reduced vegetable purchases associated with single-parent households compared to dual-parent parent households (Ziol-Guest, DeLeire & Kalil, 2006), it is maybe not surprising that children within such single-parent family structures are more likely to be overweight or obese (Sado & Bayer, 2001; Huffman, Kanikireddy & Patel, 2010).

The restructuring of the family has also decreased the time available for meal preparation and increased the demand for meals that are easily and quickly prepared. This has resulted in a higher consumption of prepared or fast foods which has in turn increased the fat content in childrens' diets. Bloomgarden (2003) reported that, since the 1970's, fast food has on average increased from 2% to 15% in American childrens' diets and such repeated exposure to high fat foods is believed to encourage children to develop a taste for them (Johnson, McPhee & Birch, 1991).

2.7 Dietary factors

Changes in dietary patterns and intakes are believed to be important contributors to the prevalence of overweight and obesity in children. Population-based surveys (American Dietetic Association, 2006) have revealed that an increasing number of children, particularly adolescents, miss breakfast and other meals and subsequently eat more food later in the day. A European research study conducted in the UK, France, Italy and Sweden comprising of normal, overweight and obese children aged 6 to 16 years found that obese children, in particular, were less likely to eat breakfast (Proponnett, 1997). Children are also falling well short of the dietary guidelines for fruit and vegetables (Heimendinger, Van Duyn, Chapelsky, Foerster & Stables, 1996) and the "State of the Plate" report in 2002 identified that 96% of children aged 2 to 12 years were not consuming the recommended five portions per day (Produce for Better Health Foundation, 2002).

The consumption of sweetened beverages, including soft and flavoured drinks, has been strongly linked to childhood obesity (Ludwig, Peterson & Gortmaker, 2001). Such drinks considerably increase caloric intake without providing the nutrients that are required for a child's growth. Guthrie and Morton (2000) reported that in the United States between 1978 and 1994 soft drink consumption tripled and was being consumed by infants as young as seven months old (Fox, Pac, Devaney & Jankowski, 2004). Soft drink consumption within schools has also risen, with a subsequent decrease in consumption of nutrient rich milk (Bray 2004).

Many children, particularly in the USA and UK, consume a considerable proportion of their daily calories at school. Concerns have been raised regarding the nutritional quality and content of foods provided through school lunches as well as food that is available for purchase on school grounds. In the UK, prior to the introduction of food based standards for school lunches in 2006, the Schools Food Trust stated in the "Turning the tables: Transforming school food" report that nearly half of secondary school meal eaters ate high fat main dishes, such as burgers, and chose sugary drinks (Schools Food Trust, 2005). Millimet's (2008) evaluation of data from more than 13,500 school children in the USA found that those who ate lunch as part of the government's National School lunch program - which supplies lunch to over 29 million school children each day (Cooper & Levin, 2006) were more likely to become overweight compared to those who brought their lunch to school. Many initiatives to improve the quality of school lunches, in both the UK and USA, have subsequently been implemented since this time.

Most schools also house vending machines and tuck-shops that offer sugary drinks and calorie dense snacks, often without lower fat or healthy food alternatives (Story, Hayes & Kalina, 1996). Green (2004) reported that considerable numbers of overweight and obese children eat food from vending machines and snack bars although no relationship between BMI and the consumption of snack foods was found in a study of two hundred 8 to 12 year old girls, over a ten year period (Phillips, Bandini, Naumova, Colclough, Dietz et al., 2004).

Another factor that has been linked to increased total energy intakes is an increase in food portion sizes. Young and Nestle (2002) identified that the sizes of many food products began increasing in the 1970's, peaking sharply in the 1980's and have continued to rise since, in tandem with increasing levels of obesity. This includes food eaten outside the home, especially energy dense confectionery and savoury snacks which are frequently offered in extra-large portions, often at minimal additional cost (Swanton & Frost, 2006). Neilsen and Popkin (2003) found that typical portions of salty snacks, soft drinks, hamburgers and French fries had increased on average 49 to 133 kilocalories, between 1977 and 1996.

The real price of many foods, adjusted for inflation, has declined over the last few decades and it has been claimed that this decrease in the relative price of food strongly correlates with increases in body mass index (Lakdawalla & Philipson, 2002). Christian and Rashad (2009) reported that between 1990 and 2007 the real price of a two litre bottle of Coca-Cola dropped by almost 35% and decreases in real price were also noted for fast foods. Ironically within the same period the relative cost of fruit and vegetables rose by 17% (Auld & Powell, 2009).

Recent research by Swinburn, Sacks and Ravussin (2009) for the European Association for the Study of Obesity concluded that the rise in child obesity in the U.S.A. since the 1970's was virtually totally due to increased energy intake and that children would need to reduce their caloric intake by around 350 kilocalories a day to return to the average weights of the 1970's. This view, however, is not universally held and other research has contradicted Swinburn's claim that increases in energy intake is responsible for the obesity epidemic. The Bogalusa Heart study has followed the health and nutrition of children in this Louisiana city since 1973 and Nicklas (1995) reported from study data that the average energy intake of 10 year old children remained unchanged from 1973 to 1988. NHANES survey data from 1970 to 1994 (Troiano, Briefel, Carroll & Bialostosky, 2000) and UK government statistics (MAFF, 1994) has also suggested that calorie consumption has over the last few decades has remained steady or may have even declined.

2.8 Physical activity.

Physical activity is an important factor in the prevention of weight gain, not only through increasing daily energy expenditure but also, to some degree, by suppressing excessive appetite (Broom, Batterham, King & Stensel, 2009). Parental support for a child's physical activity, as well as the child's perceptions of their parents physical activity habits, do appear to be important variables influencing physical activity in children. Parents who do not engage in physical activity, due to their own lack of interest or ability, are unlikely to enrol their children into recreational sports or activities. Without parental support or encouragement it is highly questionable whether a child will find the opportunity or motivation to engage in physical activity (Anderson, Economos, & Must, 2008).

Parental behavioural factors that influence child exercise habits may also be determined by socio-economic factors. Higher income families are likely to have more resources and time for physical activity and the American Association of Pediatrics (2003) has reported that lower income families may have a lack of access or availability of safe places for physical activity. Gordon-Larsen, McMurray and Popkin (2000) stated that most studies report a positive correlation between parents' education and socio-economic status with childrens' physical activity.

Physical inactivity among children is a serious public health issue as those who spend significant amounts of time in sedentary states are particularly vulnerable to overweight and obesity. The Centers for Disease Control and Prevention (2008) recommended that children and adolescents in the U.S.A. partake in 60 minutes of physical activity a day consisting of moderate to vigorous aerobic activity and both muscle and bone strengthening activities. Moderate to vigorous intensity have been classified as at least 3.0 metabolic equivalents (METs) such as walking at 3.0 miles per hour (Pate, Pratt, Blair, Haskell, Macera, Bouchard et al., 1995).

These recommendations are consistent with UK physical activity guidelines (National Institute for Health and Clinical Excellence [NICE], 2006) although NICE go on to state that at least twice a week there should be "weight-bearing activities that produce high physical stresses to improve bone health, muscle strength and flexibility".

Data from the Health Survey for England (HSE) revealed that in 2008, only 32% of boys and 24% of girls, aged 2 to 15 years, reported taking part in 60 minutes or more of physical activity each day (Figure 3).

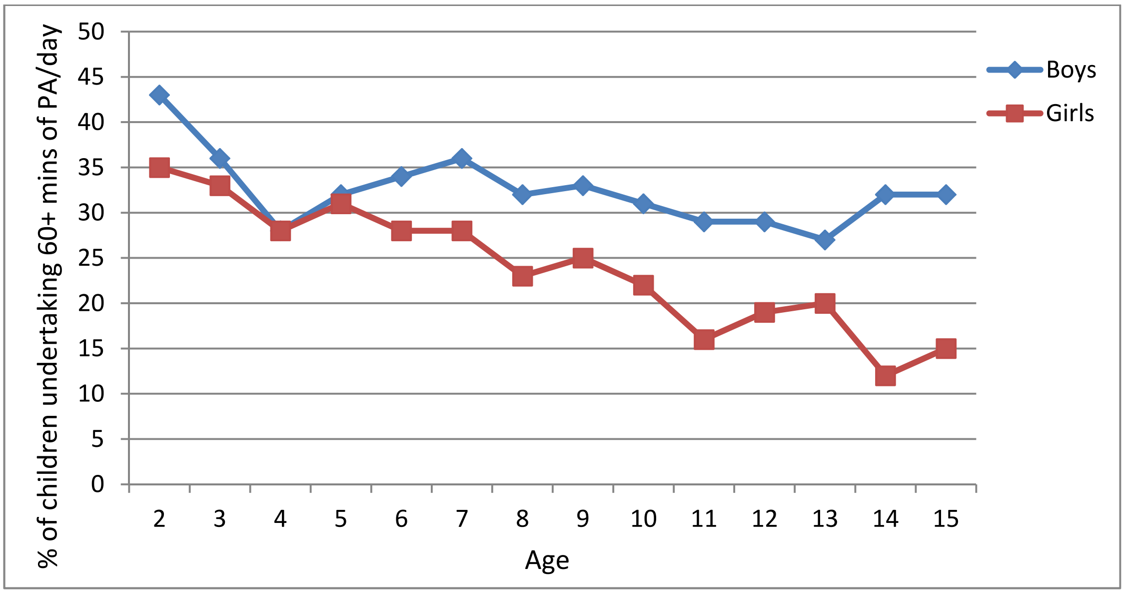

Figure 3. Proportion (%) of children meeting government recommendations for physical activity by gender and age (Health Survey for England, 2008).

These disappointing activity levels in children and adolescents may be even worse than the data suggests as some authors have claimed that surveyed participants tend to over report activity levels when compared with activity measured by physical activity monitors (Pate, Reedson, Sallis, Tayor, Sirard, Trost et al., 2002).

In the U.S.A., the National Institute of Child Health and Human Development (NICHD) Study of Early Child Care and Youth Development tracked activity levels in more than 800 children, aged 9 to 15 years, using accelerometers. From their data it was found that whilst 90% of nine year olds were meeting the one hour recommended guideline of moderate to vigorous physical activity each day, this had dropped to 31% by age 15 and only 17% of these achieved this level at weekends. The authors claimed that between the ages of 9 to 15 years, physical activity declined by about 40 minutes per day (Nader, Bradley, Houts, McRitchie & O'Brien, 2008).

High levels of inactivity among children have also been observed in other developed countries. Self-reported levels of physical activity from the Health Behaviour of School-Aged Children survey of 2001 - 2002 (Currie, Roberts, Morgan, Smith, Settertobulte, Samdal et al., 2004) revealed that France, Italy, Norway and Portugal all had less than 20% of its children achieving the recommended daily one hour of moderate activity.

Many schools have decreased the amount of time that children spend in physical education and according to Kann, Brener, and Wechsler (2007) 22% of schools in the USA do not require children to take any physical education classes. National youth surveys have shown that the number of high school students participating in daily physical activity had declined from 41.6% in 1991 to 28.4% in 2003 (Grunbaum, Kann, Kinchen, Ross, Hawkins, Lowry et al., 2004) and the CDC (2007) reported that only 3.8% of elementary schools, 7.9% of middle schools and 2.1% of high schools provided daily physical activity.

A similar picture has been observed in the UK where Harris (1994) reported that time allocated to physical education in schools had declined by 21% from 1974-1994. Subsequently, in 2000, the School Sport Partnership programme was established, targeted by the Department for Education and Department for Culture, Media and Sport to increase participation in school physical education and sport. Their objective was to increase the percentage of children who spend at least two hours each week on high quality physical education and school sport from 25% to 75% by 2006. This target was subsequently further increased to 85% by 2008.

The first audit in 2003/04 identified 62% of pupils as having achieved the two hour recommendation and this further increased to 71% in 2005. The latest available survey for the 2009/10 academic year showed a further increase to 79% and whilst 94% of primary school children fulfilled the two hour target of physical education these figures dropped sharply to 64% for years 10 - 11 and 23% for years 12 - 13 when PE lessons become an optional part of the curriculum. Whilst this Department for Education report stated that participation levels had increased from previous surveys, a paper by Fairclough and Stratton (2005) less optimistically claimed that students are potentially only active for a third of the time during their physical education lessons.

Figure 4. Proportion (%) of English pupils participating in 120 minutes or more of curriculum PE per week in 2009/10 (Quick, Simon and Thornton, 2010).

School playtime and breaks also offer an opportunity for children to be physically active. In a comprehensive review of school break-time characteristics in over 1500 UK primary and secondary schools Blatchford and Sumpner (1998) reported that around half of the schools had made changes to its previous break-time procedures, with 56% of primary schools and 44% of secondary schools reducing break-times, predominately by decreasing the length of the lunchtime break and removing the afternoon break. National surveys in the USA have reported similar trends in reduced school break-times (Pellegrini, 2005).

As well as physical activity during school hours activity getting to and from school has also diminished. The Department for Transport (1995) reported that in Great Britain in 1975/76, 61% of all 5 - 15 year olds' journeys to and from school were on foot and 11% by car, however thirty years later walking to school had declined to 46% while car use had almost trebled to 30% (Department for Transport, 2007). Analysis from the CDC showed that the percentage of the United States students aged 5 - 18 years who walked or cycled to school decreased from 42% in 1969 to 16.2% in 2001 (Ham, Martin & Kohl, 2008).

There have also been real and perceived changes in the physical environment which has impacted on activity levels in children outside of school. Play England (2007) reported that whilst 71% of adults could play and explore each day in their local neighbourhoods when they were children just 21% of children can do so today with decreasing open spaces, traffic and fear of crime restricting childrens' freedom. A telephone survey of over 4000 adolescents in urban areas of California found that access to a safe park was positively associated with regular physical activity and negatively associated with regular inactivity (Babey, Hastert & Brown, 2008).

In the UK the National Playing Fields Association calculated that between 1992 - 2005 34,000 school and community playing fields had been lost and "The Fair Play for Children" report (Cosgrove, 2011), documented a "catastrophic" reduction in the main form of informal play-space for children - the street. This report estimated that 300,000 to 750,000 acres of street space has been lost to parked cars since the 1970's.

Lack of neighbourhood safety is another factor that has been identified as a potential barrier to childrens' physical activity. A UK study of 400 families revealed that the primary reason for the restriction of the unsupervised play of their children was due to concerns about road safety and harm from strangers regardless of whether adequate local play facilities were present (Valentine & McKendrick, 1997).

The steady reduction in playing fields, playgrounds and open spaces over the last 20 years has, maybe unsurprisingly, occurred at the same time that levels of activity have declined within young people (Street, 2002) The Department of Health (2004) highlighted that reduced play opportunities were one of the contributory factors for the increase in childhood obesity and Dietz (2001) claimed that opportunities for spontaneous play may be the only requirement needed for children to increase their physical activity levels. With such changes in the environment affecting the availability of safe play and activity spaces and the resulting downward trend in activity levels, Durnin (1992) has estimated that childrens' energy expenditures may have fallen by up to 700 kilocalories a day over the last 50 years.

2.9 T.V. and media

Increased sedentary behaviour, such as television watching and other media use, has been highly correlated with declining levels of physical activity in young people (Nelson, Gortmaker, Subramanian, Cheung, & Wechsler, 2007). This trend is not just confined to the developed world and is also now being observed in developing countries, such as China and Brazil, where there have been recent dramatic increases in television ownership (Popkin & Gordon-Larsen, 2004).

It has been suggested that high levels of screen time encourages sedentary lifestyles as it distracts children from other more physically active pursuits. This "couch potato" hypothesis, however, is disputed by some researchers (Fromme, 2003; Crawford 2005) who have not found correlations between hours of screen time and activity. Conversely, Fromme's research suggested that there was some evidence that daily video game play was positively associated with levels of participation in sports. Although statistically non-significant, Fromme found that 62% of daily video game players engage in sporting activities compared to 59% of those who played less regularly.

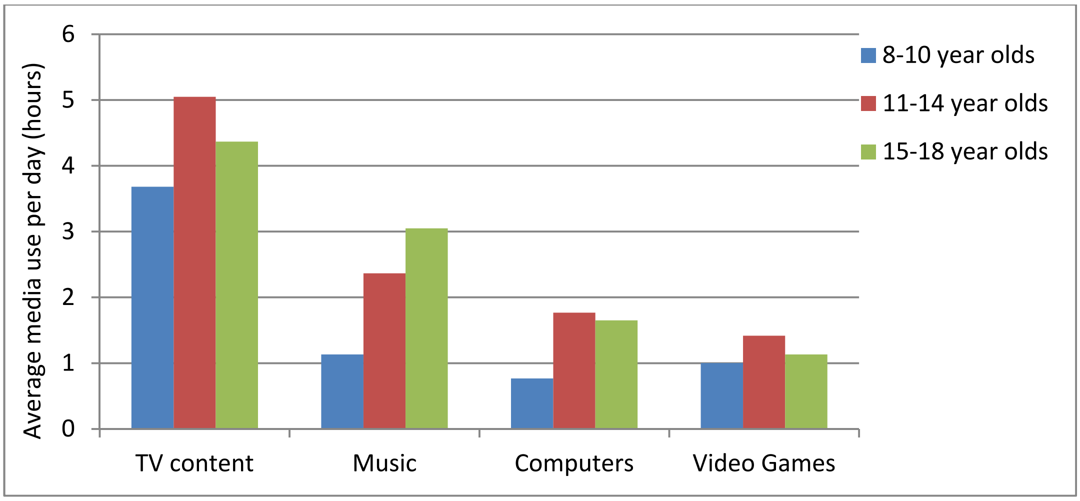

Figure 5. Average hourly media use per day by American children and adolescents.

It is well known that young people devote considerable amounts of time each day to screen-based activities. The Generation M2 study of weekly media usage in over 2000 American 8-18 year olds, found that television viewing, video-game play and computer use averaged over 7 hours and 38 minutes per day in 2009 up from 6 hours and 21 minutes five years earlier (Rideout, Foehr & Roberts, 2010). Although television viewing is still the preferred leisure time activity for the majority of children, with 4.5 hours of viewing a day (Figure 5), recent evidence from Christakis, Ebel, Rivara, and Zimmerman (2004) has suggested that video gaming is rapidly becoming a more popular screen related activity.

GameStop Corporation (2010), an American video game and software retailer, estimated in its 2009 fiscal report that there were around 220 million gaming consoles and handheld devices in the U.S.A, implying that over two-thirds of the 307 million population owned a gaming system. Biddiss and Irwin (2010) reported that 83% of American children had access to at least one video game console with further additional gaming opportunities existing on both desktop and portable computer devices. Data from a British Broadcasting Corporation Audience Research study of over 3000 UK residents, found that 61% of 6 to 10 year olds and 55% of 11 to 15 year olds played video games daily, with gaming sessions lasting on average 1.9 hours (Pratchett, 2005).

Many studies have made an association between the hours that children watch television and a higher prevalence of overweight and obesity (Gortmaker, Must, Sobol, Peterson, Colditz & Dietz, 1996), not only due to decreased energy expenditure but also the potential influence of fast-food and energy dense food advertising. Research has revealed that more than 50% of television advertisements directed at children promote foods and beverages such as snack foods, sugar sweetened beverages and sweetened breakfast cereals that are high in calories and fat and low in fibre and nutrients (Kaiser Family Foundation, 2004).

Food and beverage industries in the United States are believed to spend more than $10 billion per year, marketing specifically to children (Institute of Medicine Committee on Food Marketing and the Diets of Children and Youth, 2006) with $3 million spent in television adverts by fast food companies alone (McNeal, 1999). This strategy appears to be successful as when surveyed about eating habits more than 50% of children reported eating whilst watching TV or when playing computer or video games (Moag- Stahlberg et al., 2003).

According to NHANES III data in the USA, children who spent 4 hours or more watching television daily had higher BMIs than those children who watched less than two hours (Andersen, Crespo, Bartlett, Cheskin, & Pratt, 1998). Analysis of almost 7000 adolescents from an earlier NHANES survey correlated each extra hour of television viewing per day with a 2% increase in the prevalence of obesity (Dietz & Gortmaker, 1985) and a 2006 study of American adolescents found that each additional hour of television viewing was associated with an increased energy intake of 167 kcal (Wiecha, Peterson, Ludwig, Kim, Sobol & Gortmaker, 2006).

The presence of a television set in a child's bedroom has also been identified as a factor influencing television viewing habits in children and has been strongly implicated with an increased risk of overweight or obesity (Dennison, Erb & Jenkins, 2002). Interestingly whilst the Vanderwater et al (2004) study found no relationship with time spent watching television and childrens' weight status a relationship [R^2= 0:06, F(8, 2355) = 4:70, p > .001] was observed between obesity and time engaged in video game play.

Several other studies have investigated the physiological requirements of arcade style sedentary video console games. Segal and Dietz's (1991) study revealed that standing inactive video game play increased heart rate and maximum oxygen consumption to a level of mild intensity activity in young adults. Similarly, Wang and Perry (2006) demonstrated that sedentary action video game play by children resulted in significant increases ($p < .001$) in several metabolic and physiological parameters, including heart rate, oxygen consumption and energy expenditure, however the magnitude of change was lower than national health recommendations. In a recent review Baranowski, Buday, Thompson, and Baranowski (2008) reported that most studies demonstrated positive health-related changes from playing sedentary video games.

2.10 Activity promoting video games

Recently a new generation of wireless based video games that require interactive physical activity, also known as "active gaming" and "exergaming", have been developed and have quickly increased in popularity. Compared to traditional sedentary gaming active video games generate considerably more player interaction and movement and therefore some authors have proposed that exergaming could help children increase their physical activity by integrating play with exercise (Lieberman, Chamberlin, Medina, Franklin, Sanner & Vafiadis, 2011).

Dance Dance Revolution (DDR [Konami Co, Tokyo, Japan]) was one of the first games to promote the idea of physical activity through active gaming. DDR is a music video game where players use a dance mat and step to musical and visual cues with their feet, receiving points for their accuracy in the process. DDR and other 'exergaming' formats have been the subject of various studies to determine whether energy expenditure during these types of activities are sufficient to contribute to a child's recommended daily physical activity requirements.

One of the first such studies was undertaken by Lanningham-Foster, Jensen, Foster, Redmond, Walker, Heinz, et al. (2006) who measured the energy expenditure in 12 boys and 13 girls aged 8 to 12 years, during television viewing, sedentary video gaming, two active video games and treadmill walking at 1.5 miles/hour. The first active video game, Nicktoons Movin' (THQ, Calabasas Hills, CA) used an "EyeToy" camera (Kinetic, Sony Corporation, Tokyo, Japan) to place the child into the game to permit the virtual catching of objects. The second active game was DDR Ultramix 2 on the Xbox (Microsoft, Redmond, WA) platform. Energy expenditure during the sedentary game (7.85 ± 1.51 kJ·kg^{-1}·h^{-1}) increased ($p < .00001$) by 22% compared to rest (6.47 ± 1.51 kJ·kg^{-1}·h^{-1}), whilst the "EyeToy" game (13.61 ± 4.20 51 kJ·kg^{-1}·h^{-1}) and DDR (17.26 ± 4.28 51 kJ·kg^{-1}·h^{-1}) generated energy expenditure increases ($p < .00001$) of 108% and 172% respectively. The authors concluded that energy expenditure more than doubled when sedentary screen time was converted to active screen time and that active gaming could be considered for obesity prevention and treatment.

DDR was also evaluated by Unnithan, Houser and Fernhall (2006) who examined differences in the energy cost of movement in overweight and non-overweight children. They used the 85th percentile from sex specific BMI growth charts to divide their sample of 16 boys and 6 girls aged 11 to 17 years, into two groups – overweight and non-overweight. Both groups then completed 12 minutes of DDR on the Playstation2. The overweight group burned significantly ($p = .00005$) more calories (4.6 ± 1.3 kcal·min^{-1}) while playing DDR compared to the non-overweight group (2.9 ± 0.7 kcal·min^{-1}) however this was not statistically significant when normalised for body weight. They reported no difference in heart rate or energy costs between the two groups during DDR but they did state that heart rate intensity levels which were generated for both groups were considered sufficient for developing and maintaining cardiorespiratory fitness.

Maddison, Mhurchu, Jull, Jiang, Prapavessis and Rodgers (2007) used the "EyeToy" system on the Playstation 2 console in their study of physical activity levels and energy expenditure during seated rest, a sedentary video game and several active video games. Games were played for 5 to 8 minutes and consisted of "Knockout", a boxing game, "Homerun", a baseball game, "Groove", an upper body dancing game, "AntiGrav", a game in which the player controls an on-screen hoverboard around an obstacle course, as well as "Dance UK", a dance simulation game, similar to DDR. Unlike earlier studies game orders were randomised. From the sample of 11 boys and 10 girls, aged 10 to 14 years, significant increases ($p < .001$) in energy expenditure from rest (1.3 ± 0.2 kcal·min^{-1}) were seen during active gaming, ranging from 123% for Groove (2.9 ± 0.3 kcal·min^{-1}) to 400% for Knockout (6.5 ± 1.7 kcal·min^{-1}). Physical activity intensities during active game play were considered to be comparable to light or moderate exercise. The authors claimed that engaging in active video games like those in their study, for 30 minutes or more a day, could have a noticeable effect on body weight, potentially a loss of 1kg of body fat in nine weeks.

Straker and Abbott (2007) also used a five minute game play period in their study examining the cardiovascular and energy costs of TV watching, various forms of sedentary gaming and active video game play. Twelve boys and 8 girls, aged 9 to 12 years, participated in the study and each watched a cartoon and then played an inactive Tetris style game, followed by a car racing game - first using a gamepad, then a keyboard and finally a steering wheel with pedals. "Cascade", the active game, used "EyeToy" and required the player to move to touch virtual targets on the screen.

Cardio-respiratory measurements were made under each condition for five minutes or until steady state was achieved. Heart rates and energy expenditures during all forms of sedentary gaming were not found to be significantly greater than responses during TV watching. Heart rates and energy costs did increase significantly ($p < .001$), however, during active gaming. The authors deemed active gaming exertion levels to be moderate in intensity and they suggested that by playing such active games daily for 15 minutes, a 32.5kg child could lose 2.5kg of adipose tissue a year.

XaviX bowling and J-Mat (Shiseido, Tokyo, Japan), an interactive workout system with choreographed fitness routines, were evaluated by Mellecker and McManus (2008) in their study. Eleven boys and 7 girls, aged 6 to 12 played a seated bowling video game and two different active games for five minutes each, as per earlier studies (Lanningham-Foster et al., 2006; Maddison et al., 2007). Both active game formats generated significantly higher energy expenditures ($p < .001$) compared to rest (0.96 ± 0.19 kcal·min^{-1}) and seated bowling (1.31 ± 0.33 kcal·min^{-1}), with XaxiX bowling estimated at 1.89 ± 0.45 kcal·min^{-1} and XaviX J-Mat gaming at 5.23 ± 1.63 kcal·min^{-1}. It was concluded that substituting 35 minutes of seated gaming with Xavix J-Mat could fill an energy gap of approximately 150 kcal a day (kcal·d^{-1}).

At the end of 2006 the Nintendo Wii (Nintendo, Redmond, WA) video game console was released and to date over 87 million units have been sold worldwide (Nintendo Co. Ltd., 2011). The Wii allows individuals to play simulated sports games and other activities through handheld motion sensors and has been the subject of much research into its potential for increasing childrens’ activity levels and energy expenditures.

Graves, Ridgers and Stratton (2008) used the Nintendo Wii in their investigation of energy expenditure and upper limb and total body movement during sedentary and active video gaming. Seven boys and six girls aged 11 to 17 years played a sedentary car racing game on the Xbox360® (Microsoft, Redmond, WA), as well as Wii Sports Bowling, Tennis and Boxing for 15 minutes each. Energy expenditures were significantly higher ($p < .001$) during active gaming compared to sedentary gaming (115.8 ± 18.3 51 $J \cdot kg^{-1} \cdot min^{-1}$) and were reported as Wii Bowling (182.1 ± 41.3 $J \cdot kg^{-1} \cdot min^{-1}$), Wii Tennis ($200.5 \pm 54.0$ $J \cdot kg^{-1} \cdot min^{-1}$) and Wii Boxing ($267.2 \pm 115.8$ $J \cdot kg^{-1} \cdot min^{-1}$) with rest at $84 \pm 14.$ $J \cdot kg^{-1} \cdot min^{-1}$. Upper limb and total body activity were considerably greater ($p < .05$) during active gaming compared to sedentary gaming and the higher energy costs for Wii Boxing relative to Bowling and Tennis were believed to be due to greater non-dominant limb activity. The authors stated that the substitution of Wii Sports active gaming for sedentary gaming could increase energy expenditure by 61 $kcal \cdot h^{-1}$and if maintained for two hours daily and sustained long term could contribute to weight management.

Brown, Holoubeck, Nylander, Watanabe, Janulewicz, Costello et al. (2008) conducted a study of the energy costs of the Nintendo Wii as well as DDR, sedentary gaming and rest. Thirteen boys and four girls aged 11.06 ± 0.4 years were measured under each condition, in a randomised order for 15 minutes. Whilst the sedentary car racing game produced an oxygen uptake of 3.30 ± 0.55 $ml \cdot min^{-1} \cdot kg^{-1}$ Wii tennis (6.82 ± 1.07 $ml \cdot min^{-1} \cdot kg^{-1}$), DDR ($7.76 \pm 1.19$ $ml \cdot min^{-1} \cdot kg^{-1}$) and Wii Boxing ($8.95 \pm 1.06$ $ml \cdot min^{-1} \cdot kg^{-1}$) were considerably higher. They concluded that the energy expenditure of traditional video gaming did not differ from sitting at rest, however physically active gaming required more than twice as much energy as traditional sedentary gaming. P values were not reported for this study.

Wii Sports games and DDR were the active video games that were evaluated by Graf, Pratt, Hester and Short (2009) who also made comparisons to treadmill walking. Their sample of 14 boys and 9 girls, aged from 10 to 13 years, were measured whilst watching television, walking at 2.6, 4.2, and 5.7 km/hour each for 6 minutes, playing DDR at 2 different skill levels as well as playing Wii Bowling and Boxing, for 15 minutes each. Higher level DDR elicited the highest energy costs from all of the active games as well as treadmill walking and was more than two times greater than rest. Results were reported separately for the male and female groups in their sample and significant differences were observed in the energy costs between genders ($p < .01$) during both levels of DDR and Bowling with boys expending 19% to 33% more. The authors postulated that DDR and Wii Boxing generated a two to threefold increase in energy expenditure above rest which was deemed to be comparable to moderate intensity walking in terms of heart rate, ventilatory response and energy expenditure.

Haddock, Siegel and Wilkin (2010) compared the energy expenditure in a range of Wii Sports games in their recent study. A sample of 15 boys and 22 girls aged 12.4 ± 1.0 years were recruited to play a combination of Wii active games for a total of 20 minutes, switching between game modes as they pleased. Significant increases in heart rate ($p \leq .000$), above a seated baseline resting heart rate, were seen during Baseball, Tennis and Boxing, but not during Bowling or Golf. Similarly, increases in energy expenditures were reported during all Wii games compared to baseline except Golf ($p \leq .000$) with Boxing generating the highest increase in energy expenditure at 4.3 ± $kcal \cdot min^{-1}$. As the 20 minute protocol allowed children to switch between game modes mean play durations for some games were particularly short. Only Baseball and Bowling were played for more than 5 minutes and Boxing and Golf were played for as little as 2.3 ± 4.1 minutes and 0.6 ± 2.2 minutes respectively.

Furthermore, Golf was only played by three of the participants and the lack of any rest time between games may have also been a confounding factor affecting the results. In conclusion, the study reported that energy expenditure values for Wii Sports games were similar to previous research and activity levels were considered to be moderate in intensity, at best.

Penko and Barkley's (2010) study examined not only the physiological response of active gaming in children but also the motivational levels to play compared to a sedentary alternative. A sample of 11 lean and 13 overweight or obese 8 to 12 year olds were measured during four different 10 minute conditions, rest, treadmill walking at 1.5 miles/hour, playing Wii Punch-out! – A seated boxing game, as well as the activity promoting Wii Sports boxing. The oxygen cost of Wii Boxing was reported to be slightly greater than treadmill walking at 1.5 miles/hour and more than double the cost of sedentary gaming and rest. The authors stated that the metabolic equivalent achieved by children during Wii Boxing was 3.3 ± 1.0 METs, based on the calculation of $3.5\ ml \cdot min^{-1} \cdot kg^{-1} = 1$ MET (McArdle, Katch & Katch, 2000) and they qualified such active gaming as moderate physical activity, which could count towards the daily recommended amount of 60 minutes of physical activity. They also reported that both lean and overweight/obese groups demonstrated a greater liking for Wii play compared to sedentary video gaming.

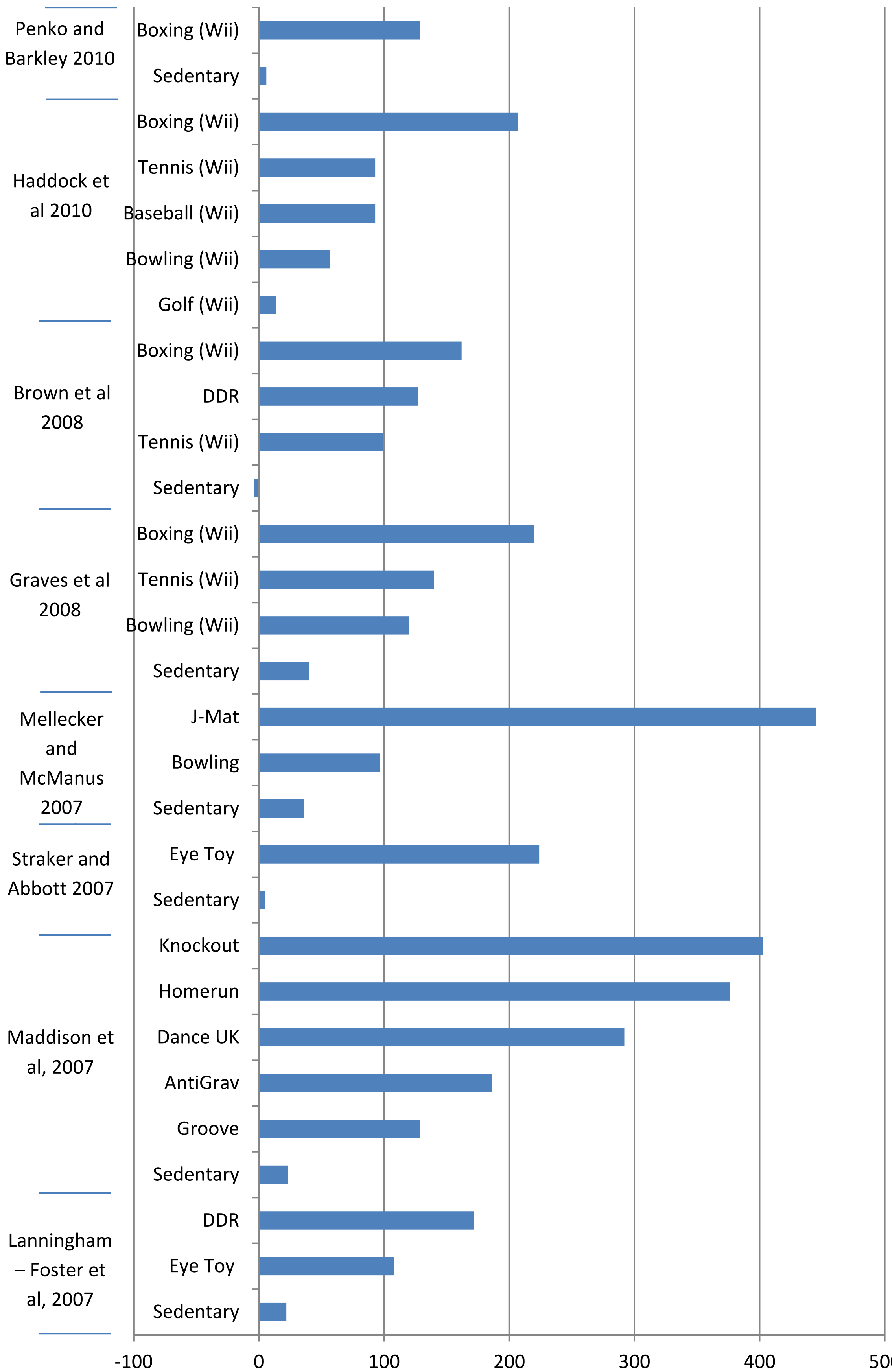

Figure 6. Comparison of increases (%) in energy cost above rest, during sedentary and active game play.

In a review of activity promoting video games in children, Biddiss and Irwin (2010) reported a highly variable range of energy expenditure increases from rest between 100% - 400%. The mean increase in energy expenditure in 21 different active games, from nine separate studies featured in this review, was 222% ± 100%. Including more recent studies made after Biddiss and Irwin's (2010) review, figure 6 illustrates the considerable variances that have been found in energy expenditure increases, above rest, in activity promoting video game studies. Reporting such data and making direct comparisons, however, is fraught with difficulties due to a variety of confounding factors and methodological limitations.

When considering increased energy expenditure from rest the REE protocol must be first examined. Across studies REE protocols have varied considerably and several papers make no reference to the procedures adopted for this measurement. Noted fasting periods have varied from two hours (Graves et al., 2007; Graves et al.; 2008) to 12 hours (Mellecker & McManus, 2008) and REE measurement periods have ranged from six minutes (Graves et al., 2007; Graves et al., 2008) to 20 minutes (Lanningham-Foster et al., 2006). Most REE measurements have been made with subjects in a supine position, however a seated position was adopted in one study (Haddock et al., 2010) and a semi-recumbent position in another (Lanningham-Foster et al., 2006).

Whilst all reviewed studies use school age children for their samples, the mean ages and subsequent weights of these samples also varies considerably between studies. The youngest and lightest sample, age 9.7 ± 1.6 years, body mass 40.8 ± 10.1 kg was recruited by Lanningham-Foster et al. (2006) and this compares to, age 15.1 ± 1.4 years, body mass 62.8 ± 9.5 kg in Graves et al. (2008) research. In cases when reported results are not normalised for body mass, such weight variances may affect the results considerably.

Studies have also reported and compared their data using different units. Whilst Lanningham-Foster et al. (2006) favoured energy expenditure data represented as $kJ \cdot kg^{-1} \cdot h^{-1}$, Brown et al. (2010) used VO² ($ml \cdot min^{-1} \cdot kg^{-1}$) and Haddock et al. (2010) $kcal \cdot min^{-1}$. Other studies have used a combination of one or more of these units, in some cases, but not all, normalised for body mass. Such study data provided does not permit the standardisation of units across all active gaming studies and therefore making comparisons between study data will not always be totally accurate.

The level of game play has not always been reported in active gaming studies and it is not clear to what degree game level may influence exercise intensity and energy expenditure. In the Graf et al. (2009) study results were reported for DDR1, which was referred to as "beginner" skill level, as well as DDR2 which was a higher "basic" skill level. Oxygen uptakes between these two game play levels increased 15% from 13.7 to 15.8 $ml \cdot min^{-1} \cdot kg^{-1}$ in boys and by 30% from 10.2 to 13.2 $ml \cdot min^{-1} \cdot kg^{-1}$ in girls. This would suggest that the game level does impact on the oxygen and energy cost of the activity and although it is often not documented the level of game play could be a factor in differing results between studies.

Moderate to vigorous activity, as recommended for children on most days of the week, equates to an activity level of 3 to 6 METs according to the classification of the energy costs of physical activity (Pate et al., 1995). In Biddiss and Irwin's (2010) active video game review activity levels were deemed to be of a light intensity during eight active video games and a moderate intensity in a further nine games, ranging from 2.0 to 5.0 child specific METs, the mean being 3.3 ± 1.0 METs. Not one activity promoting video game achieved 6 METs, considered vigorous intensity, although this may not be surprising, as such games have been designed for entertainment purposes and generally do not demand highly vigorous exercise to win the game.

Child specific METs were calculated by “dividing the oxygen consumption of the respective activities by the resting values” (Maddison et al., 2007) although not all authors have used this commonly adopted approach. Penko and Barkley’s (2010) reported in their study that Wii Boxing achieved a metabolic equivalent level of 3.3 METs, enough to be considered moderate physical activity. This activity level was calculated using the equation of 1 MET is equal to 3.5 $ml \cdot min^{-1} \cdot kg^{-1}$ (McArdle et al, 2000) but if the Maddison et al. (2007) formula had been applied the child specific metabolic equivalent task value would have been downgraded to 2.3 METs, considered to be light intensity activity. It is possible therefore that Penko and Barkley (2010) have over-reported these physical activity levels. Conversely Biddiss and Irwin (2010), in their active video game systematic review, considered DVD watching as the resting condition in Straker and Abbott’s (2007) study. DVD watching generated an oxygen uptake of 8.06 $ml \cdot min^{-1} \cdot kg^{-1}$ and as such Biddiss and Irwin (2010) reported “EyeToy” active gaming (26.54 $ml \cdot min^{-1} \cdot kg^{-1}$) at 3.3 METs after applying the Maddison et al. (2007) child-specific metabolic equivalent calculation. Many would doubt that 8.06 $ml \cdot min^{-1} \cdot kg^{-1}$ reflects resting oxygen uptake and may question whether Biddiss and Irwin’s (2010) have under-reported the activity level for this exergame.

Table 2 displays the energy costs of active video gaming in those studies which have reported expenditures in terms of kilocalories (kcal) or Joules/Kilojoules (J/kJ), using the formula 1 kcal = 4.186 kilojoules (Birch, MacLaren & George, 2005) as required. Also presented, where appropriate, are the respective energy increases above rest and sedentary gaming. This data illustrates the considerable variance that has been found not only in absolute and weight adjusted active gaming energy expenditures, from 1.6 to 6.5 $kcal \cdot min^{-1}$ and 2.61 to 9.00 $kcal \cdot kg^{-1} \cdot h^{-1}$ but also in the energy increases above rest (0.2 to 5.2 kcal·min^{-1} / 1.41 to 7.20 kcal·kg^{-1}·h^{-1}) and sedentary gaming (0.6 to 4.9 kcal·min^{-1} / 0.96 to 6.60 kcal·kg^{-1}·h^{-1}).

Table 2. Energy expenditures and increases above rest and sedentary gaming from active video game studies.

Source	Active Video Game	kcal•min−1			kcal•kg−1•h−1		
		Active Gaming	↑ Rest	↑ Sedentary Game	Active Gaming	↑ Rest	↑ Sedentary Game
Maddison et al, 2007	EyeToy Knockout	6.5	5.2	4.9			
Maddison et al, 2007	EyeToy Homerun	5.9	4.6	4.3			
Mellecker & McManus, 2008	XaviX J-Mat	5.2	4.3	3.9	9.00	7.20	6.60
Maddison et al, 2007	EyeToy Dance UK	4.9	3.6	3.3			
Unnithan et al, 2006	DDR (overweight)	4.6					
Haddock et al, 2010	Wii Boxing	4.3	2.9				
Straker & Abbott, 2007	EyeToy Cascade				7.62	5.28	5.16
Maddison et al, 2007	EyeToy Anti-Grav	3.6	2.3	2.0			
Unnithan et al, 2006	DDR (non overweight)	2.9					
Maddison et al, 2007	EyeToy Groove	2.9	1.6	1.3			
Haddock et al, 2010	Wii Tennis	2.7	1.3				
Haddock et al, 2010	Wii Baseball	2.7	1.3				
Lanningham-Foster et al, 2006	DDR				4.12	2.57	2.25
Haddock et al, 2010	Wii Bowling	2.2	0.8				
Graves et al, 2008	Wii Boxing				3.83	2.63	2.18
Mellecker & McManus, 2008	XaviX Bowling	1.9	0.9	0.6	3.60	1.80	1.20
Haddock et al, 2010	Wii Golf	1.6	0.2				
Lanningham-Foster et al, 2006	EyeToy Nicktoons Movin'				3.25	1.70	1.38
Graves et al, 2008	Wii Tennis				2.87	1.67	1.22
Graves et al, 2008	Wii Bowling				2.61	1.41	0.96

Whilst activity levels and energy expenditures during active gaming may be lower than during traditional sports (Graves et al., 2007), it has been purported by some authors that active video gaming could potentially fill the “energy gap” which is responsible for the surge in childhood obesity. Mellecker and McManus (2008) claimed that 35 minutes a day of Xavix J-Mat active gaming, in place of sedentary gaming, could increase energy expenditure by 150 kcal·d^{-1} and potentially prevent weight gain.

Calculations of the magnitude of the energy gap responsible for the increasing prevalence of obesity vary considerably. The 110 to 165 kcal·d^{-1} required deficit put forward by Wang et al. (2006) and referred to in Mellecker and McManus’ (2008) study was based on weight gain in 2 to 7 years olds from 1988-1994 NHANES survey data and may not be appropriate or accurate for adolescents. When analysing data for older children, who had acquired five to six times more excess weight than the population average, Wang et al. (2006) estimated that a considerably greater energy deficit of 678 - 1017 kcal·d^{-1} would be needed to prevent weight gain. Using data from American national surveys, Hill, Wyatt, Reed and Peters (2003) claimed that an adjustment of 100 kcal·d^{-1} could prevent weight gain in most of the population however Butte and Ellis (2003) queried these calculations and suggested that they had been considerably underestimated. Based on the assumptions of Hill et al. (2003) Butte and Ellis recalculated this deficit as 342 - 502 kcal·d^{-1} although the results of their own research in changes of body composition in over 300 Hispanic children, pointed towards a deficit of 204 - 263 kcal·d^{-1} to prevent further weight gain in 90% of overweight children. If the true energy gap value in children is in this 204 - 502 kcal·d^{-1} range as Butte and Ellis (2003) have suggested, significantly longer periods of active gaming daily would be required to prevent childhood obesity than Mellecker and McManus (2008) have proposed.

Although studies have produced encouraging results regarding both physical activity levels and the energy costs involved in playing active video games, in the main these studies have been individual trials lasting only minutes. Whether adherence to such activities can be sustained on a regular basis for a meaningful amount of time that will elicit meaningful levels of physical activity, energy expenditure and potentially weight loss, as suggested in aforementioned studies is a question for debate. The few trials that have considered the longer term effects of exergaming on physical activity levels and energy expenditures in children have reported mixed results.

One of the earliest uncontrolled trials by Madsen, Yen, Wlasluk and Newman (2007) examined the feasibility of DDR to promote weight loss in overweight children and was conducted over a six month period. A sample of 12 obese boys and 18 obese girls, aged 9 to 18 years, were recruited from a paediatric obesity clinic and instructed to play DDR for 30 minutes each day, five days a week. Telephone interviews were made to encourage their participation, however, after three months only two children reported sustained DDR play of twice or more weekly. No significant changes in participants BMI scores were seen purportedly due to the lack of adherence and engagement in active gaming. Participants reported that they found DDR boring and that greater variety, competition or group play would have increased their motivation to play.

Motivational aspects to support adherence to active gaming appeared to be reinforced by a pilot random controlled trial conducted by Chin A Paw, Jacobs, Vaessen, Titze and van Mechelen (2008). Their trial evaluated the effect of an additional weekly multi-player session on the motivation to play a dance simulation video game over a 12 week period. A sample of 27 children aged 9 to 12 years were randomly assigned to either a home group or a multiplayer group. Whilst the former were instructed to play the active video game at home the second group also had access to a weekly multi-player class on top of their home play. All participants were instructed to play the video game as often as they liked and whilst 64% of the home group dropped out during the trial only 15% of the multi-player group did not complete the 12 weeks.

In a random controlled trial conducted by Ni Mhurchu, Maddison, Jiang, Jull, Prapavessiss and Rodgers (2008), 12 boys and 8 girls, aged 10 to 14 years were randomised into either a group that received an active game upgrade package for their existing PlayStation 2 console, or a control group, who did not receive this upgrade until after the completion of this 12 week study. The active video game upgrade consisted of several EyeToy active games, a dance mat and an EyeToy camera which the intervention group were instructed to use in place of their usual sedentary video games. The children's physical activity levels were found to be significantly higher in the intervention group at both 6 week ($p = .04$) and 12 week ($p = .06$) follow ups, even though they had less overall playing time compared to the control group. Small improvements in both body weight changes and waist circumferences were also demonstrated between groups and this lead the authors to conclude that active games may be effective in increasing childrens' activity levels, at least in the short term.

A longer 28 week trial was conducted by Maloney, Bethea, Kelsey, Marks, Paez, Rosenberg et al. (2008) examining the effectiveness of DDR in increasing physical activity levels and reducing sedentary screen time (SST) in children. A sample of 30 boys and 30 girls, aged 7 to 8 years, were randomly assigned at a ratio of 2:1 to either the DDR group or a wait-list control group, who only had access to DDR 10 weeks after the DDR group. The DDR group were given a written physician prescription to play 120 minutes a week and daily minutes of play were logged for the first 10 weeks of the study. Game play time dropped from 147 minutes at week 1 to 60 minutes by week 10 and mean game use per week, over the 10 weeks, was 89 ± 82 minutes. Whilst increases in physical activity were observed by the DDR group, differences in activity levels between the DDR and control group were not seen. Significant reductions were observed in SST amongst the DDR group as well as significant differences between groups although this did not influence changes in BMI between the two groups.

Whilst there has been some evidence of positive outcomes on activity levels in longer term trials, evidence is still lacking that active video gaming can have a demonstrable effect in preventing or reversing weight gain in children or that adherence to such gaming can be maintained in the longer term. However, as there is no indication that children are likely to give up screen-time pursuits in favour of physical activity - in fact it has been claimed that screen time for children is likely to further increase (Daley, 2009) it seems sensible to encourage active gaming over sedentary gaming with the benefit of increased energy expenditure and physical activity levels.

2.11 Rationale

Several previous studies have examined the effects on physical activity levels and energy expenditures of many different forms of active video gaming, including Dance Dance Revolution, "EyeToy" games for the Sony Playstation, Xavix J-Mat and many different Nintendo Wii active sport simulations. In general, light to moderate increases in physical activity have been observed as well as considerable increases in energy expenditure that could potentially assist in weight maintenance or weight loss in children (Maddison et al., 2007; Straker & Abbott, 2007; Graves et al., 2008; Mellecker & McManus, 2008).

Recently, a new technology in active video gaming, Kinect™ for the Microsoft Xbox360®, has entered the market. Launched in November 2010 sales had reached 10 million units by March 2011 earning an entry in the Guinness Book of Records (Guinness World Records, 2011) for the fasting selling consumer electronics device. Unlike most previous forms of active gaming, Kinect™ differs from its counterparts in that it utilises a webcam style sensor device and software technology that allows the gamer to interact with the Xbox360® without the need for a game controller. Essentially the player acts as the controller and this may generate higher levels of physical activity as anecdotal evidence has suggested that control units on other devices may be manipulated to avoid the need for activity (Healthcare Global, 2011).

To date, physiological responses and energy costs during activity promoting video gaming using the Kinect™ have not been evaluated. This study aimed to examine primarily energy expenditures during Kinect™ exergaming, as well as heart rate response and oxygen uptake, in a mixed weight, mixed gender sample of healthy schoolchildren.

2.12 Objectives and hypotheses

It was hypothesised that playing active video games on the Kinect™ would generate considerably greater energy expenditures and physiological responses compared to inactive or sedentary gaming. The two games evaluated, a dance simulation, “Dance Central” and a boxing game, “Kinect Sports Boxing” were chosen specifically as these formats have been most commonly researched in previous studies, allowing for comparisons between Kinect™ and other gaming platforms.

CHAPTER 3 – METHODS

3.1 Participants

Previous studies whose primary objective was the evaluation of energy expenditures in children during active video gaming have used samples sizes ranging from 11 (Graves et al., 2007) to 37 (Haddock et al., 2010) participants. From Biddiss and Irwin's (2010) review of active video games, the average sample size of the 10 studies exploring energy expenditure in children was 19.4.

This study was conducted at Kirkby Sports College in Liverpool (Appendix E) over a four day period. Kirkby Sports College Centre for Learning was opened in September 2009 and provides secondary education for up to 1200 pupils aged from 11 – 16 years in the Kirkby district. The study was undertaken during normal school hours and as the availability of facilities were limited and access to children was restricted due to other compulsory lessons a maximum of 22 scheduled testing periods were allocated for this study (Appendix F). Recruitment drives were held in school assemblies and study brochures (Appendix H) and participant information sheets (Appendix C) were distributed throughout the school. Children who were interested in participating were required to complete a pre-test questionnaire (Appendix G) as well as an informed consent form (Appendix D) signed by themselves and a parent. All completed forms were returned directly to the school.

From the 45 pre-test questionnaire forms returned, all were checked for contra-indications to exercise or a history of epilepsy and these candidates were excluded from participating in the study. The 42 remaining candidates forms were separated into two groups, male and female subjects, who were each given a three digit identification number. These numbers were recorded and dropped into a hat from which 11 were randomly selected for each gender group. This mix of 11 boys and 11 girls were then allocated a one hour and 15 minute testing period and were from this point referred to by their unique three digit number to ensure patient confidentiality. Ethical approval for this study was obtained by the University of Chester's Faculty of Applied and Health Sciences Research Ethics Committee (Appendix A).

3.2 Study Design

The study was designed to evaluate the energy and physiological cost of active gaming using the Kinect™ system compared to both sedentary gaming and rest. The study followed a cross-sectional comparison design with repeated measures for the different video game conditions which all participants completed in the same order. Between group measures were made to identify differences between genders. The key independent variables measured were energy expenditure, heart rate and oxygen uptake.

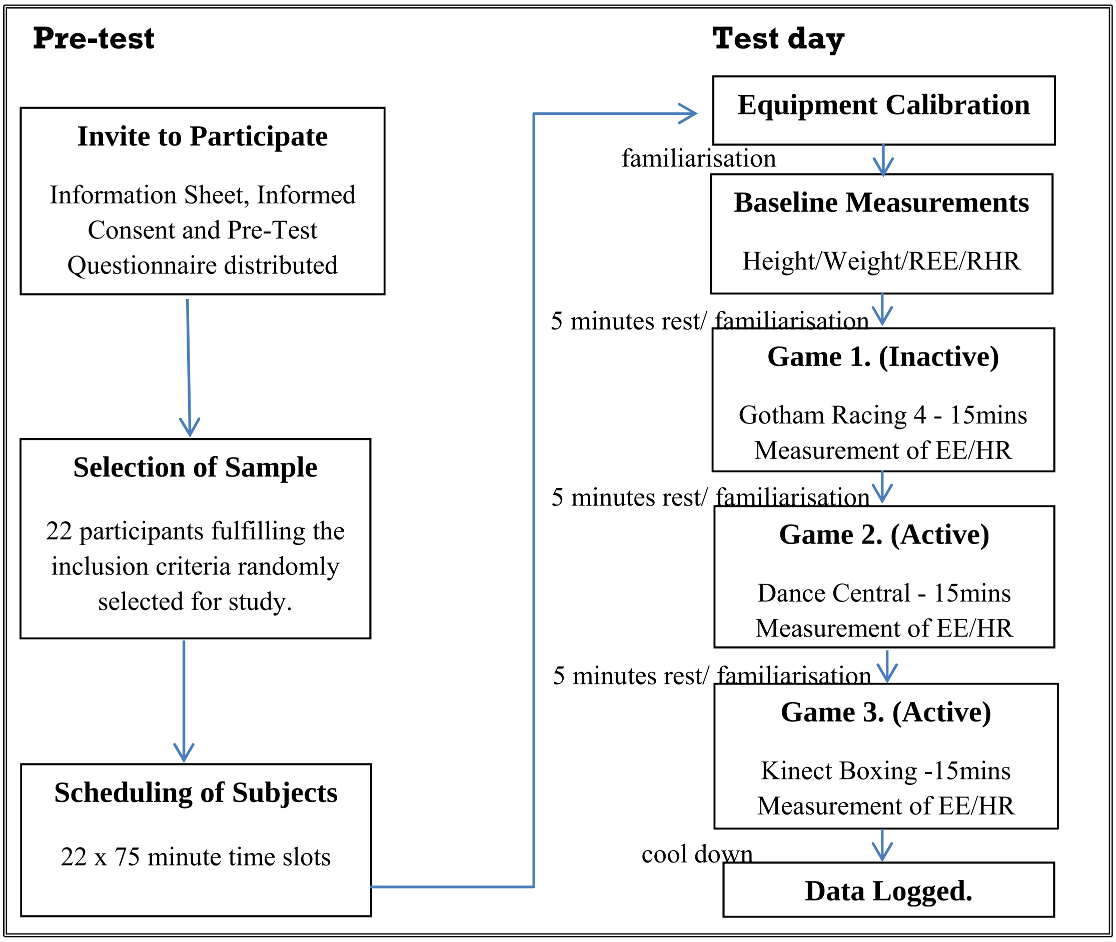

Figure 7. Study flowchart

3.3 Measurement procedures

Measurements and testing were made in a private temperature controlled exercise room maintained at 18 degrees centigrade and 35% humidity. At the beginning of each individual test session participants were given a verbal breakdown of the testing protocol and introduced to the equipment that would be used during the session. As resting energy expenditure (REE) and baseline heart rates were being measured as part of this study all participants had been pre-informed to fast for two hours prior to testing and also to abstain from caffeinated drinks and vigorous exercise. During measurement and assessments, participants wore their standard school PE kit.

3.3.1 Stature

Participant height was measured using a free-standing portable stadiometer (Seca Leicester Height Measure, Birmingham, UK) in accordance with standard anthropometric techniques (Lohman, Roche & Martorell, 1988). After removing footwear and hair buns, in the case of some females, the participant was instructed to stand underneath the stadiometer, facing away from the upright bar. With feet flat on the floor, heels together and both head and buttocks in contact with the upright bar, the participant was asked to inhale deeply and maintain this position whilst the measuring arm was lowered on to the top of the subject's head. The participant was then asked to step away and height was recorded to the nearest 0.5cm.

3.3.2 Mass

With footwear and any heavy clothing removed, weight was measured using a calibrated digital scale (model 877, Seca, Hamburg, Germany) to the nearest 0.1kg.

Height and weight results were used to determine the participants body mass index (BMI) using the formula body weight (kg) / height (m^2). Centers for Disease Control and Prevention (CDC) age and sex specific growth charts (Appendix I/J) were used to calculate BMI percentiles (Kuczmarski et al., 2000).

3.3.3 Resting heart rate

Prior to the measurement of REE a demonstration was given to the correct placement and attachment of a Polar chest strap (Kempele, Finland), which was used to measure heart rate during rest as well as during all game play conditions. After moistening the sensors the participant was then sent to a private room to fit the chest strap. A Polar heart rate monitor was then used to check that heart rate measurements were being transmitted correctly.

3.3.4 Gas sampling and analysis

Measurements of oxygen uptake were made during all conditions by indirect calorimetry, using a Cosmed K4 b^2 metabolic cart (Rome, Italy) and a correctly sized Hans Rudolph facemask. In accordance with the manufacturer's instructions and in line with Cosmed K4 b^2 validation (McLaughlin, King, Howley, Bassett & Ainsworth, 2001; Pinnington, Wong, Tay, Green & Dawson, 2001) an 18mm flow-meter was used for measuring resting energy expenditure (REE) and a 28mm flow-meter during physical activity. Before each testing session the gas analyser was calibrated using known gas concentrations of O^2 16%, CO^2 5% and Nitrogen Balance as per the manufacturer's recommendations (Cosmed Srl, 2008). Respiratory volume was calibrated using a 3L calibration cylinder.

Oxygen uptake measurements were collected at 30 second intervals during rest and with each breath, at approximately three second intervals, during both sedentary and active gaming. During both active games there were natural short pauses in activity, for example at the end of each dance and between boxing rounds. These lulls in exercise were considered as part of the activity and physiological data from these periods was included in the overall data output. To ensure that steady state had been reached in each game condition averaged data from the last 10 minutes of each 15 minute game was used in the analysis.

A password protected, participant database was created on a laptop computer and all patient data and anthropometric measures were entered into this database. Through the use of a wireless transmitter and the K4 software physiological data was instantly transmitted directly to this laptop during all testing conditions.

3.3.5 Resting energy expenditure

A 20 minute protocol was used for measuring REE as in previous studies (Lanningham-Foster et al., 2006; Mellecker & McManus, 2008). Once the participant was connected to the gas analyser with an appropriately sized Hans Rudolph facemask they were then instructed to lie on an exercise mat in a supine position for 5 minutes to ensure that they were totally relaxed. After this initial period of 5 minutes oxygen uptake measurements commenced and were recorded for a period of 15 minutes with the participant remaining in the same position. Subjects were constantly observed to ensure that they stayed awake.

3.4 Testing protocol

Following the measurement of REE participants played the three video games in the same order for 15 minutes, consistent with previous research (Graf et al., 2009; Graves et al., 2007; Lanningham-Foster et al., 2006). All games were projected onto a 70 inch screen and the active games were played in an eight by five foot square area, six feet away from the screen. Prior to testing the Cosmed K4 b^2 portable unit was attached to the participant by a harness and the Kinect™ sensor was recalibrated for each new participant before the commencement of the active video games. Participants had been informed, prior to gaming that the highest scorer of each game would receive a prize to ensure that they were motivated to fully engage in each game mode.

3.4.1 Inactive gaming – Project Gotham Racing 4

The first game was “Project Gotham Racing 4”, a sedentary car racing simulation game that the participant played using a hand held game controller whilst seated in front of the screen. Brief instruction was given for the use of the game controls and then “Eliminator” game mode (Event 4) was selected in the “Final Countdown” menu. Participants played an eight car street circuit race game in which the last driver was eliminated after every 30 seconds of the race. The easiest level “Steel” was initially selected and participants continuously moved through the increasingly more difficult levels of “Bronze”, “Silver”, “Gold” and “Platinum” if they survived elimination. If they were eliminated from the race the game was repeated at the same level until 15 minutes had elapsed.

3.4.2 Active gaming – Dance Central

After 5 minutes of rest, during which time the participant was allowed to sit and also drink water, they were then familiarised with the second game, the activity promoting "Dance Central", a game in which players are required to mirror the moves of the on-screen dancer to the rhythm of the song earning points in the process. In "Dance" mode two different songs "Body Movin" and "Don't Sweat the Technique" were selected from the "Challenge Hardcore" menu. The difficulty level was set to "Easy" on the "Perform It!" menu. The participant was allowed one practice with each song to familiarise themselves to the dance routines and then had two further attempts at each dance accumulating 15 minutes of activity.

3.4.3 Active gaming – Kinect Sports Boxing

Following a further seated rest period of five minutes the participant then played a final game "Boxing", part of the "Kinect Sports" software. Prior to play subjects were demonstrated correct punching and shielding techniques and were encouraged to mix up a combination of both high and low punches. The participant then played against a computer opponent in a three round fight, starting with the easiest level – "Beginner", moving through the progressively more difficult levels of "Amateur", "Professional" and "Champion" if they won, either by knockout or a points decision. If they lost, the bout was replayed at the same level until the 15 minutes were completed.

3.5 Statistical analysis

Descriptive statistics including mean and standard deviations were calculated for all key variables. As the sample size was less than 100, the normal distribution of data was tested using the Shapiro-Wilks W test and homogeneity of variance was assessed using Levene's statistic (Coakes & Stead, 2007). Comparisons of descriptive data according to gender were made using Independent *t* tests for body weight and BMI and Mann-Whitney U tests for age and weight (Appendix M), for which normal distributions were not observed (Appendix L). One-way repeated measures analysis of variance was conducted to compare the cardio-respiratory and energy expenditure effects of different gaming conditions with post hoc pairwise analysis using multiple paired t-tests (Appendix N). Statistical significance was set at $p \leq .05$ and all statistical analysis was made with SPSS for Windows (Version 17) with the raw data presented in Appendix K.

CHAPTER 4 – RESULTS

4.1 Participant data

From the original sample size of 22 three participants failed to attend and one further subject was ill on the day of testing. The remaining group of 18 children (10 boys and 8 girls; 13.4 ± 1.2 years of age) were all of Caucasian descent and were of varying height (156.6 ± 10.6 cm) and weight (52.9 ± 15.7 kg) with a BMI of 21.2 ± 4.5 kg/m² and BMI percentile of 59.67 ± 34.31.

Twelve of the children were considered to be of normal weight (5^{th} percentile ≤ BMI ≤ 84^{th} percentile), one was overweight (85^{th} percentile ≤ BMI ≤ 94^{th} percentile), four were obese (BMI ≥ 95^{th} percentile) and the remaining child was underweight (BMI < 5^{th} percentile). No significant differences were seen in the age (Z = -.044, p = .965), stature (Z = -.845, p = .398), body mass (p = .872), BMI (p = .577) of the children between genders (Appendix M). Participant characteristics are shown in table 3.

Table 3. Physical characteristics of study participants

	All (n=18) mean ± SD	Boys (n=10) mean ± SD	Girls (n=8) mean ± SD
Age	13.4 ± 1.2	13.5 ± 1.5	13.3 ± 0.7
Stature (cm)	156.6 ± 10.6	159.0 ± 12.26	153.7 ± 7.71
Body Mass (kg)	52.9 ± 15.7	53.5 ± 17.95	52.2 ± 13.64
BMI (kg/m2)	21.3 ± 4.5	20.7 ± 4.4	22.0 ± 4.9
BMI (percentile)	59.67 ± 34.31	56.40 ± 35.48	63.75 ± 34.74

4.2 Summary of results

Physiological data during rest, inactive gaming and both forms of active gaming play is presented in table 4.

Table 4. Mean heart rate, oxygen uptake and energy expenditure for all participants during each test condition.

	REST	SEDENTARY Project Gotham Racing	ACTIVE Dance Central	ACTIVE Kinect Boxing
HR (bpm)				
All	77.4 (14.6)	88.6 (15.0)	118.3 (17.8)	131.3 (15.3)
Boys	77.8 (17.9)	89.0 (19.4)	114.7 (25.7)	134.2 (9.6)
Girls	76.8 (11.6)	88.3 (11.6)	119.6 (16.0)	128.4 (20.4)
Vo2 (ml•min−1•kg−1)				
All	4.41 (0.83)	6.12 (1.26)	12.82 (3.30)	17.71 (5.10)
Boys	4.76 (0.71)	6.38 (1.15)	13.61 (2.93)	20.71 (2.70)
Girls	3.87 (0.73)	5.83 (1.38)	12.03 (3.65)	13.85 (4.95)*
EE (kcal•min−1)				
All	1.199 (0.250)	1.480 (0.334)	2.997 (1.027)	4.353 (1.550)
Boys	1.282 (0.270)	1.549 (0.400)	3.118 (1.312)	5.069 (1.353)
Girls	1.075 (0.167)	1.402 (0.245)	2.877 (0.712)	3.434 (1.347) *

*Significantly lower in girls ($p < .005$)

4.3 Heart rate

Significant increases were observed in heart rates during all gaming conditions (figure 7) compared to rest (77.4 ± 14.6 bpm). Mean heart rates increased to 88.6 ± 15.0 bpm ($p = .001$) during sedentary gaming and this further increased to 118.3 ± 17.8 bpm ($p = .000$) and 131.3 ± 15.3bpm ($p = .000$) during Dance Central and Kinect Sports Boxing (Appendix N). For the two forms of active gaming this represented respective heart rate increases of 53% and 70%, above resting heart rate.

Utilising the 200 bpm maximum heart rate (HR_{max}) formula, considered appropriate for adolescents of this age (Rowland, 1996), mean heart rate responses indicated that 59% of HR_{max} was reached for Dance Central with 45% of all participants working within a 55 – 65% HR_{max} range and 27% of the subjects both above and below this range. 66% of HR_{max} was the mean heart rate achieved during Kinect Sports Boxing and 30% of subjects were within a 55 – 65% HR_{max} range with 10% below and 60% above. The highest individual heart rates recorded were 71% HR_{max} for Dance Central and 73% HR_{max} for Kinect Sports Boxing.

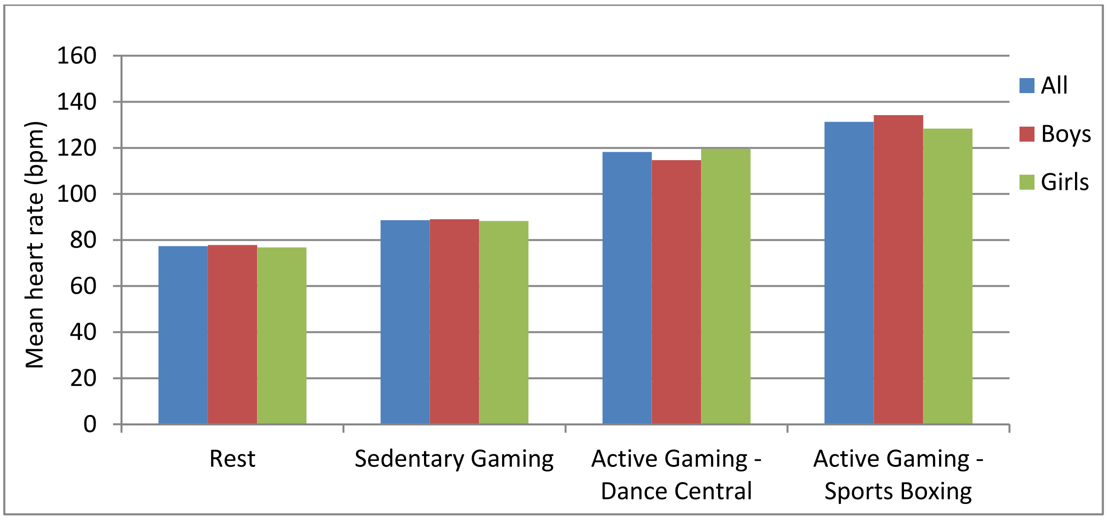

Figure. 8. Mean Heart Rates (bpm) during rest, inactive and active gaming.

Dance Central and Kinect Sports Boxing elicited statistical significant increases in mean heart rate (p = .000) when compared to sedentary gaming, representing increases of 33% and 48% respectively. Significant differences (p = .027) in mean heart rate were also observed between the two forms of active gaming with Kinect Sports Boxing 13 bpm or 11% greater than Dance Central. Statistically significant differences were not observed in heart rates between genders for any of the four measured conditions (p = .914, p = .936, p = .703, p = .581).

4.4 Oxygen consumption

From 72 measurement conditions in this study oxygen cost measurements were missing in eight cases due to equipment malfunction. Mean oxygen consumption significantly increased (p = .000) from 4.41 $ml \cdot min^{-1} \cdot kg^{-1}$ at rest by 38% to 6.12 ml/kg/min during sedentary gaming. During Dance Central mean oxygen consumption rose to 12.82 $ml \cdot min^{-1} \cdot kg^{-1}$ 190% greater than rest (p = .000) and 109% greater than sedentary gaming (p = .000). The highest mean oxygen uptake rates were observed during Kinect Sports Boxing at 17.71 $ml \cdot min^{-1} \cdot kg^{-1}$, 301% higher than rest (p = .000) and 189% higher than sedentary gaming (p = .000). Significant differences (p = .010) in oxygen uptake were also noted, between the two activity promoting video games. Whilst there was no significant difference in oxygen uptakes between genders during sedentary gaming (p = .382) or Dance Central (p = .357), significant differences were observed both at rest (p = .035) and also during Kinect Sports Boxing (p = .003) with the boys producing 20.71 $ml \cdot min^{-1} \cdot kg^{-1}$ and the girls 13.85 $ml \cdot min^{-1} \cdot kg^{-1}$.

Child specific metabolic equivalents were calculated by dividing the oxygen consumption of the activity by oxygen consumption at rest (Maddison et al, 2007) and using this formula the sedentary computer game produced a metabolic equivalent of 1.38 METs, whilst Dance Central was considered to be a light intensity activity at 2.91 METs and Kinect Sports Boxing a moderate intensity activity at 4.02 METs.

4.5 Energy expenditure

All game modes demonstrated statistically significant increases in energy expenditure over resting levels. Mean energy expenditure, as shown in Table 5, increased ($p = .001$) to 1.48 ± 0.33 kcal·min^{-1} during sedentary video game play from a mean resting value of 1.20 ± 0.25 kcal·min^{-1}. During activity promoting video games mean energy expenditures further increased ($p = .000$) to 3.00 ± 1.03 kcal·min^{-1} and 4.35 ± 1.55kcal/min during Dance Central and Kinect Sports Boxing, 150% and 263% greater than resting values.

Table. 5. Mean energy expenditures during all study conditions

Activity	kcal•min−1	kcal•h−1	kcal•kg−1•h−1
REST	1.20	71.94	1.36
SED Game	1.48	88.80	1.68
Dance Central	3.00	179.82	3.40
Kinect Sports Boxing	4.35	261.18	4.94

Significant differences ($p = .000$) in energy expenditures were also observed between sedentary gaming and both active games with respective increases of 103% and 194% for Dance Central and Kinect Sports Boxing.

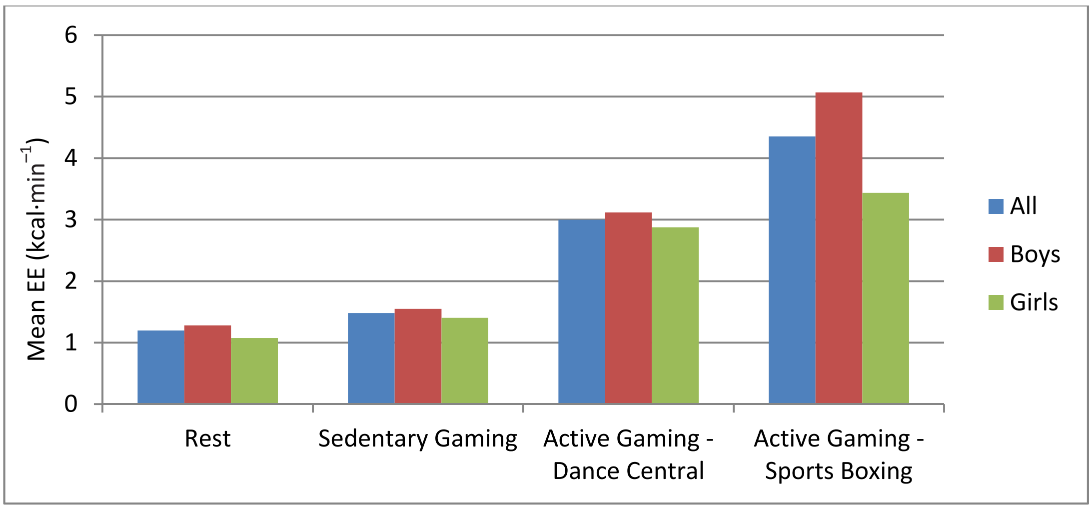

Figure 9. Mean energy expenditure (kcal·min^{-1}) during rest and game modes

Energy expenditure differences between genders were not observed during rest ($p = .119$), sedentary gaming ($p = .383$) or Dance Central ($p = .655$) however during the Kinect Sports Boxing activity the expenditure of 5.07 $kcal \cdot min^{-1}$ for the boys compared to 3.43 $kcal \cdot min^{-1}$ for the girls (Figure 8) was statistical significant ($p = .031$). This difference was still significant ($p = .004$) when caloric expenditure was normalised for body weight (Appendix O)

CHAPTER 5 – DISCUSSION

5.1 Overview

This aim of this study was to evaluate the energy costs of activity promoting video game play using Kinect™ for the Xbox360®. The results confirm the hypothesis that participating in active gaming using Kinect™ would generate considerably greater energy expenditures compared to sedentary gaming. Measurements of the physiological responses to active gaming also revealed statistically significant increases in heart rate and oxygen consumption when compared both to rest and to traditional sedentary gaming. These results may not necessarily be surprising as, as Pate (2008) attests, there is no reason why the fundamental principles of exercise physiology would not apply during active video game play as they do in traditional activities. However, the magnitude of the physiological and energy costs generated by the different game formats, are appropriate for discussion.

5.2 Heart rate

Marginal but also significant effects on heart rate were seen during sedentary seated gaming and mean heart rate increases of 14% (11 bpm) were similar to increases reported in other studies (Wang & Perry, 2006), as may be expected.

A mean heart rate of 118bpm demonstrated during Dance Central corresponds with heart rate responses for DDR in other active game studies (Brown et al., 2008; Graf et al., 2009). At 59% of HR_{max}, Dance Central was comparable to DDR play in Unnithan et al. (2006) study which generated a heart rate response of 64% of HR_{max}. The authors went on to state that such a heart rate response satisfies the criteria of 55 – 65% HR_{max}, prescribed by the American College of Sports Medicine (ACSM [2000]) for increasing cardiovascular fitness. During Dance Central.

The 55 – 65% HR_{max} recommendation prescribed by the ACSM is based, however, on adults and a subsequent review of endurance training in young people indicated that training intensities of over 80% HR_{max} would be needed to improve cardiovascular fitness (Baquet, van Praagh & Berthoin, 2003). If this is the case, Dance Central and other dance game simulations may not be suitable for improving aerobic fitness in children.

Kinect Sports Boxing generated a higher mean heart rate of 131bpm, the equivalent of 66% HR_{max}. When comparing heart rates demonstrated during Kinect Sports Boxing against studies that have evaluated Nintendo Wii Boxing, the results were relatively uniform. From five studies that examined physiological responses during Wii Boxing, reported heart rates have ranged from 121 – 140 bpm (Brown et al., 2008; Graf et al., 2009; Graves et al., 2008; Haddock et al., 2010; Penko & Barkley, 2010). Whilst Kinect Sports Boxing and other boxing video games fulfil ACSM recommendations for improving cardiovascular fitness they do not satisfy the 80% HR_{max} requirement put forward by Baquet et al. (2003).

5.3 Oxygen uptake

Significant increases in oxygen uptake were observed across all gaming conditions from rest as well as between both active gaming conditions and sedentary gaming. Using Maddison's (2007) definition to calculate child specific metabolic equivalents, a mean oxygen uptake of 12.82 ml·min^{-1}·kg^{-1} during Dance Central was calculated as 2.91 METs. As such this activity was considered to be of light intensity and comparable with non-gaming physical activities such as ballroom dancing, bowling and walking at 2 mph (Table 6). Predictions of child-specific METs for video dance simulations have varied considerably in other studies, from less than 2 METs (Brown et al., 2008) to 3.9 METs (Maddison et al., 2007) both based on the dame game, DDR. The activity levels exhibited by children during Dance Central are in the centre of this range and are consistent with the oxygen uptake responses that were reported for DDR by Unnithan et al. (2006), Graf et al. (2009) and Penko and Barkley (2010).

Table 6. Selected sporting activities with comparable physical activity levels to Dance Central and Kinect Sports Boxing (Adapted from the Compendium of Physical Activities, Ainsworth, Haskell, Herrmann, Meckes, Bassett, Tudor-Locke et al., 2011).

3 METs (Light Activity)	4 METs (Moderate Activity)
Ballroom Dancing	Cycling (<10mph)
Body Boarding	Gymnastics
Bowling	Horseback Riding
Rowing (2.0 - 3.9mph)	Table Tennis
Sailing	Volleyball
Stationary Cycling (50 watts)	Walking (3mph)
Walking (2mph)	Water Aerobics

The much more explosive Kinect Sports Boxing generated a mean oxygen uptake of 17.71 ml·min^{-1}·kg^{-1} which was estimated at 4.02 METs, deemed to be moderate intensity activity and comparable with playing table-tennis, volleyball or walking at

3 mph (Table 6). It is likely that a greater contribution of upper body and limb movement during Kinect Sports Boxing resulted in higher oxygen costs for this active video game compared to Dance Central as was similarly demonstrated by Graves et al (2008) during Nintendo Wii Boxing compared to Wii Bowling and Tennis.

The oxygen demands of Kinect Sports Boxing were considerably greater than demonstrated for Wii Boxing in multiple earlier studies (Graf et al., 2007; Brown et al., 2008; Graves et al., 2008, Penko & Barkley, 2010). Higher child-specific metabolic equivalents during a boxing simulation game have only been reported by Maddison et al. (2007) at 5 METs during "EyeToy Knockout" although this game was only played for 5 – 8 minutes which could explain shorter but more intense bouts of activity. Potentially the absence of a game controller could be a factor in the higher levels of physical activity exhibited during Kinect Sports Boxing compared to Nintendo Wii Boxing although this is not conclusive.

It was evident from observations that the boys were more motivated to exert greater effort during Kinect Sports Boxing than the girls and significant differences in activity levels values were noted between genders (4.35 METs vs. 3.58 METs). Whilst other studies have not identified significant activity or energy differences between genders during Boxing games (Graf et al., 2009; Graves et al., 2007), such differences have been reported for Wii Tennis (Graves et al., 2007) as well as DDR and Wii Bowling (Graf et al., 2009). Observations from our study would infer that as with traditional non-gaming physical activities children have different levels of motivation to engage in different forms of active gaming and therefore the level of physical activity demonstrated was very much dependent on the individual participant.

5.4 Energy expenditure

As hypothesised, mean energy expenditure during active gaming was significantly higher than rest and sedentary gaming. Increases of 150% in energy expenditure above rest during Dance Central were consistent with previous studies using DDR (Lanningham-Foster et al., 2006; Graf et al., 2009; Unnithan et al., 2006; Brown et al., 2009) but significantly lower than other research using Dance UK and Xavix J-Mat (Maddison et al., 2007; Mellecker & McManus, 2008). Gaming periods, however, in both Maddison et al. and Mellecker and McManus studies were significantly shorter, at only 5 - 8 minutes, which may explain shorter but more intense activity levels and energy expenditures.

Energy expenditure increases of 263% compared to rest for Kinect Sports Boxing were significantly greater than other studies research using the Nintendo Wii (Graf et al., 2009; Graves et al., 2008) but lower than reported by other researchers (Maddison et al., 2007), although again shorter activity periods were used.

The energy expenditure of 3.00 $kcal \cdot min^{-1}$ / 3.40 $kcal \cdot kg^{-1} \cdot h^{-1}$ for Dance Central was comparable to the energy costs (Table 2.) reported for Wii Baseball and Tennis (Haddock et al., 2010), EyeToy Groove (Maddison et al., 2007) and DDR using non overweight subjects (Unnithan et al., 2006). Kinect Sports Boxing at 4.35 $kcal \cdot min^{-1}$ / 4.94 $kcal \cdot kg^{-1} \cdot h^{-1}$ was similar in energy cost to Wii Boxing (Haddock et al., 2010) and DDR using overweight subjects (Unnithan et al., 2006).

With increase of 1.52 kcal·min^{-1} and 2.87 kcal·min^{-1} respectively over sedentary gaming, the substitution of Dance Central or the more physically demanding Kinect Sports Boxing in place of traditional gaming would yield an additional 91 kcal·min^{-1} and 172 kcal·h^{-1}. If claims are accurate that UK children spend on average 1.9 hours playing video games daily (Pratchett, 2005), the conversion of daily sedentary gaming to Dance Central or Kinect Sports Boxing could expend an additional 173 – 326 kcal·d^{-1}. A more conservative one hour of Kinect™ active game play daily would generate an additional 91 kcal during Dance Central and 172 kcal during Kinect Sports Boxing.

5.5 Limitations

Whilst this study demonstrated significant increases in energy expenditures for Kinect™ active gaming, the sample size was small and therefore only large effects were detectable between groups. The activities were also not randomised which would have increased the length of the protocol and the study was not conducted in the home environment, although there is no reason to believe that the results would have been any different if this had been the case.

5.6 Future directions

Whilst it is unlikely that active gaming can presently singlehandedly provide the recommended amount of physical activity for children or expend the number of calories required to prevent or reverse the obesity epidemic, it appears that active gaming can contribute to both physical activity levels and energy expenditure, at least in the short-term.

There may be a greater opportunity for active video gaming to play a future role in weight loss interventions as not only do a vast proportion of children already have their attention captured by video gaming, but also because traditional approaches and interventions to promote weight management in children have generally not proved to be effective (Schumann, Nichols & Livingston, 2002). Obese children, who are often found to have low self-confidence regarding exercise (Daley, Copeland, Wright, Roalfe & Wales, 2006) or who may experience social stigmatism and barriers which prevent them from engaging in physical activity, may be inclined to participate in active video games in the comfort of their own home and this may create an increased interest and encourage participation in real activities (Ni Mhurchu et al., 2008).
Also video games are considered fun, exciting and challenging (Griffiths, Hunt, 1998) and enjoyment is considered to be an important factor in both the motivation to, and adherence for, exercise (Dishman, Motl, Saunders, Felton, Ward, Dowda et al., 2005).

The question of whether video gaming can encourage sustainable long term physical activity and energy expenditure, though, as yet remains unanswered. Currently, active gaming studies have not extended beyond 28 weeks and adherence of such active game play beyond this time-frame is unknown. Undoubtedly, opportunities do exist for console and software manufacturers to develop active game formats that promote adherence and more regular active game participation as well optimise physical activity levels and energy expenditure.

Strategies that maximise motivation for engagement in active gaming also requires significant examination and should consider factors such as enjoyment, competition, social interaction and group or network play as well as game sophistication and diversification to prevent boredom. Further extensive research is needed to determine to what degree active gaming can be used in the future as an effective intervention in the fight against childhood inactivity and obesity.

5.7 Conclusion

Kinect exergaming on the Xbox360 has demonstrated, in this study, its potential to increase children's activity levels to a light or moderate intensity (2.91 – 4.02 METs), whilst generating mean heart rates of 59% - 66% HR_{max} and energy expenditures of up to 261 $kcal \cdot h^{-1}$, 172 $kcal \cdot h^{-1}$ greater than sedentary gaming. In the main these physiological responses and energy expenditures are comparable or more favourable to other active gaming formats.

The active video games Dance Central and Kinect Sports Boxing were enjoyed by the participants and created a safe activity intensity for children. If these activities could be sustained they could contribute to the daily recommendation of 60 minutes of moderate to vigorous physical activity (3 – 6 METs) and may also be considered as an appropriate tool in interventions for childhood weight loss.

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APPENDICES