

# **Active Video Games and Energy Balance in Male Adolescents**

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## **Abstract**

Active video games (AVG) have been shown to acutely increase energy expenditure when compared to seated video games; however, the compensatory effects on energy intake and subsequent energy expenditure are largely unknown. The main objective of this thesis was to examine the acute effects of AVG on energy intake and expenditure in male adolescents. Our results suggest that male adolescents compensate for one hour of AVG play by decreasing their physical activity levels for the remainder of the day. There was no compensation in acute energy intake with AVG play. The results from this thesis suggest that the benefits of one hour of Kinect™ AVG play are offset within 24 hours in male adolescents. Therefore, caution must be exercised when prescribing AVG for interventions aimed at preventing/treating childhood obesity.

## **Contributions**

The work contained in this thesis is my own, and I own all responsibility for its content. The data contained in this thesis are original and from my thesis project examining the effects of active video games on energy balance in male adolescents, of which I was a co-investigator. I was responsible for participant recruitment, data collection, data analysis, and writing of the thesis manuscript. For the article contained in Part 2, I am the primary author and all contributions to this article are contained within Part 2. At the time of submission of this thesis the article was published ahead of print in the *American Journal of Clinical Nutrition*.

## Acknowledgements

I would like to acknowledge the advice, guidance, and opportunities that have been provided to me from my supervisor, Dr. Jean-Philippe Chaput. He has been available whenever required throughout this journey and his timely advice and comments on all issues have been greatly appreciated. JP has allowed me to increase my knowledge in the research field and has given me the opportunity to meet leaders in this research realm while attending the 2014 Global Summit on the Physical Activity of Children. JP's advice and guidance were a significant contribution to this thesis and they can be seen in the writing of the thesis manuscript.

My co-supervisor Dr. Éric Doucet and my thesis committee members Dr. Glen Kenny and Dr. Gary Goldfield must be acknowledged for their comments, suggestions, and questioning that was provided throughout the thesis process. Their comments and suggestions were influential in the manuscript writing and can be found within the document. Without the help from all 4 members mentioned above, this manuscript would fail to exist.

I would like to thank Jessica McNeil and Dr. Ollie Jay for lending some of the materials required to complete the study. Dr. Graham Finlayson and Dr. John Blundell analyzed the data from the Leeds Food Preference Questionnaire. I would also like to acknowledge the hard work of Lindsay Dale, Sureesha Samuel and Sydney McNeely who at varying points in time, sacrificed their weekends to assist me with data collection. Their efforts, enthusiasm, and curiosity helped keep spirits lifted and allowed me to develop my communication of the concepts involved.

Finally, the participants and their parents involved in this study must be acknowledged. Without their commitment and adherence to the study guidelines none of this would have been possible.

## **Prelude to Thesis**

This study contains all original data that I collected for the purpose of this study. The study received ethical approval from the Children’s Hospital of Eastern Ontario Research Institute, University of Ottawa Research Ethics Board; and was registered at ClinicalTrials.gov. The study was funded by a research grant held by Dr. Jean-Philippe Chaput from the Canadian Institutes for Health Research (CIHR).

This is a manuscript based thesis that contains one original research paper. In part 1, I have provided a general introduction on the topic, a comprehensive literature review with focus on energy intake, expenditure, and video games in youth. The methodology of the study is also outlined in part 1. Part 2 contains the research article that at the time of thesis submission was submitted for review to the *American Journal of Clinical Nutrition* (now published). Part 3 contains a global discussion of the findings from this study, including the strengths, limitations, and future research opportunities. Part 4 contains a list of references contained in the thesis, a copy of the ethical approvals, and all results that were not contained or presented in part 2.

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## **PART 1**

### **Introduction**

Childhood obesity rates have had a marked increase in recent decades in Canada (Sheilds & Tremblay, 2010). Concurrent with the increase in childhood obesity, an increase in obesity related health problems such as insulin resistance, type 2 diabetes, and hypertension has been reported in children and adolescents (Roberts, Shields, de Groh, Aziz, & Gilbert, 2012; Lobstein, Baur, & Uauy, 2004; American Diabetes Association, 2000; Sorof, Lai, Turner, Poffenbarger, & Portman, 2004). Although these health risks will generally not present themselves symptomatically until later in adulthood (Sheilds & Tremblay, 2010), the result is a decreased quality of life and an increased burden and cost for the health care system in the present and a compounded effect in the future (Katzmarzyk & Janssen, 2004; Lightwood, et al., 2009; Finkelstein, Graham, & Malhotra, 2014). This compounded effect is a result of the typical trend of obese children maintaining their obesity status into adulthood where the health risks associated with obesity manifest (Serdula, et al., 1993; Tjepkema, 2006).

The sustained positive energy balance that leads to childhood obesity can be attributed to a multitude of factors. When combined, these factors create an obesogenic environment, which promotes a positive energy balance and ultimately weight gain (Chaput, Doucet, & Tremblay, 2012). A small positive energy balance over time can result in obesity (Wang, Gortmaker, Sobol, & Kuntz, 2006); therefore, small changes in behaviours can alter the energy balance equation to promote weight stability. Sedentary activities, specifically screen time, have been shown to promote a decrease in physical activity and an increase in food intake (Janz & Mahoney, 1997; Chaput, et al., 2011; Saunders, Chaput, & Tremblay, 2014). One type of sedentary activity that

has gained interest amongst children and adolescents in recent years is video games (Rideout, Roberts, & Foehr, 2005; Rideout, Foehr, & Roberts, 2010).

Sedentary video games, also known as traditional video games, are immensely popular (Dickinson, 2000; Jenkin, 2000). It has been demonstrated that one hour of video game play in a laboratory setting results in a positive energy balance (Chaput, et al., 2011), and in a real world setting each hour of video game play per day has been associated with a twofold increased risk of obesity in children and adolescents (Stettler, Signer, & Suter, 2004).

As technology advances and competition increases, manufacturers have attempted to distinguish themselves and address the rising childhood obesity rates by introducing active video games (AVG). In AVG, the user is required to mimic motor responses requiring the use of limbs and body movements to achieve the desired effect on screen (Barnes, Colley, & Tremblay, 2012). Examining this from an energy expenditure perspective, AVG significantly increase an individual's energy expenditure to an average of 3 METs, compared to 1.5 METs for sedentary video games (Barnett, Cerin, & Baranowski, 2011; Peng, Lin, & Crouse, 2011; Guy, Ratzki-Leewing, & Gwadry-Sridhar, 2011; Smallwood, Morris, Fallows, & Buckley, 2012). However, acute increases in energy expenditure do not seem to translate into higher overall physical activity levels, suggesting that compensatory adaptations might occur (LeBlanc, et al., 2013).

When compared to sedentary video game play, initial investigations in adults have suggested food intake to be lower during AVG play because the user's hands are occupied with the game and eating has a detrimental effect on performance (Lyons, Tate, Ward, & Wang, 2012). The effect of AVG play on acute energy intake, *i.e.* food intake immediately following game play, and short term energy intake, *i.e.* food intake for the remainder of the day, has not

been investigated previously (LeBlanc, et al., 2013). It is also unknown whether individuals compensate for the increase in energy expenditure from AVG play by decreasing their physical activity levels for the remainder of the day (LeBlanc, et al., 2013; Chaput, et al., 2013). It is important to investigate these effects on the energy balance equation to inform policies and recommendations regarding the potential of AVG in the prevention of childhood obesity.

## **Literature Review**

The prevalence of obesity among children and youth observed in Canada and other countries has dramatically increased in recent decades (Sheilds & Tremblay, 2010; Ogden, Carroll, Kit, & Flegal, 2012), with the current estimated rate at 31% for overweight and obesity combined (Roberts, Shields, de Groh, Aziz, & Gilbert, 2012). Despite wide variations in secular prevalence trends, the levels of pediatric overweight and obesity average above 20% in the Americas and Europe (Kosti & Panagiotakos, 2006; Tremblay, et al., 2014), and few countries worldwide remain unaffected by these increases (Tremblay, et al., 2014; Ng, et al., 2014). Along with the increases in obesity rates, the health risks associated with overweight and obesity such as insulin resistance, type 2 diabetes and cardiovascular disease have seen a similar increase in prevalence in children and adolescents, suggesting a strong relationship (Roberts, Shields, de Groh, Aziz, & Gilbert, 2012; Lobstein, Baur, & Uauy, 2004; American Diabetes Association, 2000; Sorof, Lai, Turner, Poffenbarger, & Portman, 2004). The decreased quality of life and increased economic burden associated with these health risks will continue to rise and compound over time (Katzmarzyk & Janssen, 2004; Lightwood, et al., 2009; Finkelstein, Graham, & Malhotra, 2014) as obese children tend to become obese adults (Serdula, et al., 1993; Tjepkema, 2006). It is therefore prudent to attempt to reverse the increasing trend of childhood obesity for both future health and economic reasons.

Obesity is the result of an accumulated imbalance between energy intake and expenditure, known as the energy gap, and also referred to as a positive energy balance (Wang, Gortmaker, Sobol, & Kuntz, 2006). Simply put, a child who consumes more energy than required for basic metabolic demands, growth, and that expended through physical activity – energy intake > energy expenditure – will experience a positive energy balance. Any excess energy is stored and accumulated by the body as fat and protein. Over time, this accumulation of fat from a chronic positive energy balance may lead to obesity. Among all children aged 2-7 years in the United States, it appears that, after controlling for energy requirements required for growth, an average positive energy balance of 110-165 kcal/day has driven excess weight gain over the past decades (Wang, Gortmaker, Sobol, & Kuntz, 2006). After growth requirements are considered, the estimated average positive energy balance leading to overweight among adolescents is substantially larger, ranging from 678 to 1017 kcal/day (Wang, Gortmaker, Sobol, & Kuntz, 2006). This energy gap increases exponentially as the child ages due to the increased energy costs for growth and excess weight gained. The increased metabolic demands from excess weight and growth requires that an increasingly positive energy balance occurs for the child to continue on the path to overweight and obesity, therefore what begins as a small daily energy gap in childhood of ~14 kcal/day during the first year increases to a larger daily energy gap during adolescence of ~247 kcal/day at age 10 (Wang, Gortmaker, Sobol, & Kuntz, 2006). Maintaining energy balance at a normal weight is challenging in today's obesogenic environment, which facilitates consumption of energy and impedes purposeful expenditure of energy (Chaput, Doucet, & Tremblay, 2012). Closing this energy gap is crucial to improve the health of the population and this can be achieved most feasibly by small behaviour changes.

In order to decrease the energy gap through behaviour changes, one must alter energy intake and/or energy expenditure. There are typically two methods of altering energy expenditure to close the energy gap. Common methods are to increase physical activity levels and/or decrease sedentary activities. Physical activities are any bodily movement produced by skeletal muscles that elicit energy expenditure (Longmuir, Colley, Wherley, & Tremblay, 2014). The Canadian guideline for physical activity for adolescents recommends a daily minimum of 60 minutes of moderate, 3 to 6 metabolic equivalents, or higher intensity (Longmuir, Colley, Wherley, & Tremblay, 2014). Sedentary activities are classified as any waking activity where energy expenditure remains at or below 1.5 metabolic equivalents while in a sitting or reclining posture (Sedentary Behaviour Research Network, 2012). The Canadian guideline for sedentary behaviours recommends a maximum of 2 hours of recreational screen time daily for youth (Tremblay, et al., 2011); most recent data suggest that only 31% of youth are meeting this guideline (Colley, et al., 2011). Combined with the lack of youth meeting the recommended 60 minutes of moderate to vigorous physical activity (Gray, et al., 2014; Colley, et al., 2011), it becomes clear that the obesogenic environmental factors need to be altered in order to help facilitate behavioural changes.

Video games are a sedentary activity that has an enormous mass appeal and are omnipresent in the daily schedule of most children and teenagers, especially in boys. As of 2012 the video game market was worth an estimated \$67 billion, and expected to grow to \$82 billion in 2017 (Gaudiosi, 2012). On any given day 60% of children and adolescents play video games (Rideout, Foehr, & Roberts, 2010). A 2004 estimate of media consumption revealed that video game play and non-school-related computer use occupies approximately 2 hours of a typical child's day (Rideout, Roberts, & Foehr, 2005), and 95% of adolescent males report spending

more than 10 hours per week playing video games (Rideout, Foehr, & Roberts, 2010). The health impact of the high prevalence of a sedentary activity, such as video game play, on adolescents' body composition is not trivial and must be accounted for.

The increased prevalence of video game play has been paralleled by an increase in body weight and has prompted researchers to examine the influence of this medium on various aspects of health (Wack & Tantleff-Dunn, 2009). Older epidemiologic studies found lower prevalence rates and usage of video games and generally found no association with obesity (Swinburn & Shelly, 2008; Hernandez, et al., 1999); however, as video game prevalence has risen throughout the years, recent observational studies have been more consistent in showing a direct connection between video games and overweight as well as obesity (Schneider, Dunton, & Cooper, 2007; Carvalhal, Padez, Moreira, & Rosado, 2007; Mota, Ribeiro, Santos, & Gomes, 2006; Tremblay & Willms, 2003). In particular, it has been found that the risk of obesity is almost doubled for every hour spent playing video games daily (Stettler, Signer, & Suter, 2004). Sedentary activities, such as video games, have also been associated with a decreased cardio-metabolic health (Saunders, Chaput, & Tremblay, 2014).

In Canada, only 5% of school aged children and youth achieve the minimum 60 minutes of moderate to vigorous daily physical activity (Gray, et al., 2014). When examining global trends from self-reported data, approximately 80% of 13 to 15 year olds worldwide do not achieve the minimum 60 minutes of moderate to vigorous daily physical activity recommended (Hallal, et al., 2012), while this same age group accumulates over 8 hours of daily screen time (Leatherdale & Ahmed, 2011). This inverse relationship between sedentary time and physical activity results in an energy expenditure imbalance, which can lead to weight gain. In addition to the decrease in physical activity time seen while playing video games, it has been shown that

video games displace the time that teenagers spend on meals (Van den Bulck & Eggermont, 2006). A decreased amount of time spent on meals has been associated with an increased energy intake and increased body mass index (BMI) (Zick, Stevens, & Bryant, 2011) due to the time delay of the satiety signals, and distracted nature of eating while engaging in screen time (Bellisle, Dalix, & Slama, 2004). Simply put, by the time one realizes he is full, overconsumption has already occurred. The increase in energy intake and low levels of energy expenditure seen while playing sedentary video games seem to contribute to the positive energy balance underlying obesity.

Previous studies that have examined the link between video games and obesity are limited by their observational design and mainly focused on linking the sedentary nature of this activity with the increased risk of being overweight or obese. Until very recently, no experimental study had examined the potential of video games to induce increased spontaneous energy intake. This is crucial to draw conclusions about the net impact of these devices from an energy balance standpoint. Using a randomized crossover design, Chaput *et al.* (2011) showed, in a laboratory setting, that 1-hour of seated video game play in adolescents was accompanied by increased caloric intake compared to a resting condition. Interestingly, this overconsumption of food associated with seated video game play was observed without increased feelings of hunger, as previously reported with television viewing (Bellisle, Dalix, & Slama, 2004). This observation was supported by the profiles of glucose, insulin, cortisol and ghrelin that were not suggestive of an up-regulation of appetite. This “eating in the absence of hunger” associated with seated video games emphasizes that the non-homeostatic, hedonic component of feeding behaviour plays an important role (Saunders, Chaput, & Tremblay, 2014).

The issue of “mental stress” associated with video game play might help to explain the increase in food intake associated with this sedentary activity. Results from Chaput *et al.* (2011) showed that heart rate, systolic and diastolic blood pressure and mental workload were significantly higher during the video game play compared to the rest condition. These results are also consistent with other studies that found significant increases in various stress markers with seated video game play in children and adults (Wang & Perry, 2006; Segal & Dietz, 1991). Collectively, these results illustrate that computer-related activities represent a particular type of sedentary activity that is metabolically and mentally stressful (Chaput & Tremblay, 2007; Chaput, Drapeau, Poirer, Teasdale, & Tremblay, 2008). In addition to the increase in stress levels, computer-related activities have been reported to promote overconsumption of food without increased sensations of hunger and appetite (Chaput & Tremblay, 2007; Chaput, Drapeau, Poirer, Teasdale, & Tremblay, 2008). These observations suggest that an increased mental workload could amplify the energy gap that occurs simply from inactivity.

It is widely agreed that children and adolescents should increase their daily physical activities. Although conventional exercise provides additional energy expenditure, it must compete with the entertainment value of video games, which are rapidly becoming the preferred leisure-time activity for many children and adolescents. The key to promoting sustainable activity in children and teenagers is enjoyment; they initiate and sustain video game playing because it is fun, exciting, and challenging (Griffiths & Hunt, 1998; Dishman, et al., 2005). This aspect is reinforced by results showing that dopaminergic responses, a physiological marker of enjoyment, were increased in male adults playing video games (Koepp, et al., 1998). Therefore, in order to increase children and adolescents’ daily physical activity levels, we must make daily physical activity more enjoyable to compete with the currently preferred sedentary activities and

examine the possibilities of using technology to replace these traditionally sedentary activities with active ones.

Accordingly, the new generation of active video games (AVG) might offer an appealing activity alternative for increasing energy expenditure and improving body composition among children and teenagers who would otherwise be spending time in sedentary screen-based activities. Manufacturers have produced video games that require players to mimic motor responses such as dance, play the guitar or drums, or actions used in athletic competition in order to manipulate the game. Such advances in technology have allowed AVG like Wii Fit™, Dance Dance Revolution™ and Xbox® Kinect™ to explode in popularity among children and youth (Barnes, Colley, & Tremblay, 2012). The potential of manipulating the gaming environment as an intervention tool for increasing energy expenditure is supported by recent findings showing that playing AVG acutely increases energy expenditure compared to seated video games (Barnett, Cerin, & Baranowski, 2011; Peng, Lin, & Crouse, 2011; Guy, Ratzki-Leewing, & Gwadry-Sridhar, 2011; Foley & Maddison, 2012; Biddiss & Irwin, 2010; Bonetti, Drury, Danoff, & Miller, 2010; White, Schofield, & Kilding, 2011). This increase in energy expenditure from AVG is comprised mainly of low to moderate intensity physical activity (Graves, Ridgers, & Stratton, 2008; Lanningham-Foster, et al., 2006; Mellecker & McManus, 2008; Unnithan, Houser, & Fernhall, 2006; Smallwood, Morris, Fallows, & Buckley, 2012), and is nearly two fold higher (3 kcal/min) when compared to sedentary video games (1.7 kcal/min) (Graf, Pratt, Hester, & Short, 2009; Smallwood, Morris, Fallows, & Buckley, 2012). Hence, AVG could be a useful addition to the range of opportunities for physical activity available to children and adolescents.

A significant increase in energy expenditure as a result of AVG play might be of little importance to prevent weight gain if one compensates by increasing energy intake and/or decreasing physical activity throughout the rest of the day. This issue is of particular importance in the field of obesity prevention and management because acute exercise-induced increases in energy expenditure are generally accompanied by compensatory adjustments in energy intake (King, et al., 2012; Thivel, Aucouturier, Doucet, Saunders, & Chaput, 2013; Thivel & Chaput, 2014). Specifically, recent results indicate that children consume snacks, when freely available, whether they are playing seated video games or in an ambulatory environment with the addition of a motor component to video gaming (Mellecker, Lanningham-Foster, Levine, & McManus, 2010). In adults, both seated and AVG have been reported to produce an acute energy surplus (Lyons, Tate, Ward, & Wang, 2012). Furthermore, there is evidence to suggest that individuals compensate for exercise interventions by decreasing spontaneous physical activity for the remainder of the day such that the net energy expenditure or total time spent active remains unaffected (Frémeaux, et al., 2011; King, et al., 2007; Ridgers, Timperio, Cerin, & Salmon, 2014). Collectively, these observations support results from recent randomized controlled trials showing that AVG did not significantly enhance physical activity nor reduce adiposity in children when studied under free-living conditions (Maddison, et al., 2011; Baranowski, et al., 2012).

It is thus important and timely to examine the impact of AVG on both sides of the energy balance equation if we do not want to convey the “wrong message” to the population that AVG are a solution to body weight control (Chaput, et al., 2013; LeBlanc, et al., 2013). Based on recent observations and previous evidence that seated video games increase food intake (Chaput, et al., 2011), it seems realistic to postulate that the increase in energy expenditure promoted by

AVG will be offset by compensatory adjustments in food intake and/or physical activity. Given that (i) video game consumption is a powerful influence in the lives of many children and adolescents, (ii) the influence of AVG on energy intake is largely unknown, and (iii) current marketing strategies stress the benefits of AVG for reducing obesity rates without empirical evidence to this effect, an examination of the influence of AVG on both sides of the energy balance equation is needed.

### **Objective**

The main objective of this study is to examine the acute effects of playing AVG on energy intake and expenditure.

### **Hypothesis**

The main hypothesis is that the increase in energy expenditure promoted by AVG will be compensated for by an increase in food intake, thereby offsetting the potential benefits of AVG from an energy balance standpoint. Furthermore, it is hypothesized that there will be a compensatory reduction in spontaneous physical activity subsequent to the AVG condition.

### **Methods**

#### **Participants**

Thirty ( $n=30$ ) male adolescents, 13-17 years old, were recruited; however, only 26 completed all three conditions. Male adolescents were chosen based on their high prevalence of video game play (Lenhart, et al., 2008; Rideout, Foehr, & Roberts, 2010). Participants were recruited through postings in the community, the Healthy Active Living and Obesity Research Group website, and through word of mouth. All participants were recruited within the winter

and spring seasons, and completed their experimental sessions within one season so as to reduce the impact seasonality can have on their physical activity levels (Tucker & Gilliland, 2007).

Participants were excluded from participation for any of the following:

- current smoker
- unstable body weight ( $\pm 4$  kg over the past 6 months preceding testing)
- excessive alcohol intake ( $>10$  drinks/week)
- metabolic disease (*e.g.* thyroid disease, heart disease, diabetes)
- celiac disease
- vegetarian
- medication use that could interfere with outcome variables
- highly restrained eating behaviour (score  $\geq 12$  for cognitive dietary restraint on the Three Factor Eating Questionnaire)
- irregular sleeping pattern (*e.g.* shift work or working overnight shifts)
- unfamiliar with the use of video games
- inability to comply with the protocol.

Participants engaged in 4 visits. The first was a preliminary visit, the purpose of which was to explain the study in detail, obtain written informed consent, and parental assent. Screening questionnaires and physical measurements (anthropometric measures and resting metabolic rate) were also completed to characterize the participants. Vigorous physical activity was not permitted for 24 hours prior to the preliminary visit; participants had to respect a normal sleep schedule 3 days prior to testing (self-reported), had to be in good health, and fasted for 12 hours. The final three visits consisted of the 3 experimental conditions.

## Protocol

The CONSORT guidelines were followed in the conduct of this randomized, 3 conditions, crossover study (within-subjects experimental design). Participants were randomly assigned to produce a balanced order to the three experimental conditions: sedentary video games, AVG, and a control session involving resting in a seated position. The video game FIFA 14 (a soccer video game) was played on the Xbox 360® (Microsoft, Redmond, WA, USA) during the sedentary video game condition, as it is easy to learn, popular, and can be played in 1 hour. XBOX® Kinect Adventures™ was played on the Xbox 360® (Microsoft, Redmond, WA, USA) for the AVG condition, as it is easy to learn and has been used in other AVG studies using similar energy expenditure measurement techniques (Smallwood, Morris, Fallows, & Buckley, 2012). Instructions on how to play the video games were given prior to the start of the condition, and participants were encouraged to do their best.

Participants arrived at the University of Ottawa Behavioural and Metabolic Research Unit (Ottawa, Canada) fasted for 12 hours at 7:30 for each experimental condition, 1-4 weeks apart, and only one participant was tested at a time. Vigorous physical activity was not allowed 24 hours prior to testing, and a normal sleep schedule was observed for the 3 days prior to testing (self-reported). An Actical accelerometer was attached on top of the right iliac crest directly underneath the armpit immediately upon arrival. Visual analogue scales were used to record subjective measures of appetite at 7:45, and the participant was provided a standardized breakfast at 8:00. Participants then refrained from eating until the *ad libitum* lunch, and were asked to relax in a comfortable chair until the condition began. At 10:15 visual analogue scales were administered along with a Brunel Mood Scale and Positive Affect and Negative Affect Scale (PANAS). The one-hour experimental intervention, consisting of one of the three conditions,

began at 10:20. Energy expenditure was measured during the condition with the use of a portable indirect calorimeter, Cosmed K4b2. Immediately following the condition visual analogue scales, the Brunel Mood Scale, the Positive Affect Negative Affect Scale (PANAS), and the Leeds Food Preference Questionnaire (LFPQ) were completed to measure mood and food sensitivity. An *ad libitum* lunch was then given to the participants to measure spontaneous energy intake, and they were instructed to choose whatever they wish from a food menu. Greater than normal portions were provided and participants were instructed to eat as much or as little as they wanted, and to ask for additional food if desired. Participants were given 30 minutes to consume their lunch. After lunch participants were required to complete visual analogue scales and the LFPQ. Energy intake for the remainder of the day was assessed using the food menu, as participants chose items from the menu that they may want to consume for the remainder of the day. Finally, the participants were required to fill out a 3-day dietary record and physical activity log, and wear an accelerometer for 3 days after each experimental condition.

## **Measurements**

### ***Anthropometric measurements***

Body weight was measured with no shoes in scrubs, post voiding to the nearest 0.1 kg on a calibrated electronic scale (Tanita Corporation of America Inc., Arlington Heights, IL, USA). Height was measured, again with no shoes, after a deep inspiration to the nearest 0.1 cm with the participant standing with feet together and head in the Frankfort plane, against a wall mounted stadiometer. Body mass index (BMI) was determined and interpreted with the WHO BMI for age growth charts (de Onis, et al., 2007). Waist circumference was measured to the nearest 0.1 cm using a non extendable linen tape and measured midway between the lower border of the last rib and the upper border of the iliac crest at the end of a normal expiration. These

anthropometric measurements were used to better characterize our participants and to determine body weight status.

### ***Breakfast***

A standardized breakfast was given to the participants at 8:00 am, consisting of 2 pieces of whole wheat bread (78 g, D’Italiano®, 836.8 kJ), peanut butter (18 g, Kraft Smooth Peanut Butter®, 451.9 kJ), raspberry jam (16 mL, Kraft Pure Raspberry®, 217.6 kJ), cheddar cheese (21 g, Kraft Cracker Barrel Marble®, 334.7 kJ), and orange juice (200 mL, Minute Maid 100% Orange Juice®, 418.4 kJ). Participants ate alone in a room with no distractions, and were instructed to consume the entire meal within 15 minutes.

### ***Ad libitum lunch***

Spontaneous food intake, including liquids, was assessed using an *ad libitum* food menu immediately after each experimental condition, which allowed us to assess both total energy intake and macronutrient preference (McNeil, Riou, Razmjou, Cadieux, & Doucet, 2012). The food menu contained a variety of meal type food (both hot and cold), beverages, and snacks differing in macronutrient composition. The foods were offered in large amounts, and the participants were instructed to eat *ad libitum*, alone, in a room without distractions. The participants ate as much or as little as they wanted with no restrictions on the amount consumed. The participants were given 30 minutes for this meal and all foods were measured to the nearest 0.1 g before and after ingestion. *Ad libitum* energy intake was measured by using calculations performed on the amount of the meal consumed. Furthermore, the food menu was used to measure energy intake for the remainder of the day. Participants self-selected what they wanted to eat for the remainder of the day, and all selected foods were packed into coolers for them to

bring home. This type of food menu, which has a high appreciation of food items on the menu, has been shown to produce a reliable measure of energy intake inside and outside the laboratory in both adults and adolescents (McNeil, Riou, Razmjou, Cadieux, & Doucet, 2012; Chaput, et al., in press).

### ***Appetite sensations***

For each session, the participants were instructed to fill in nine visual analogue scales (VAS) for their sensations of hunger, satiety, prospective food consumption, fullness, and desire to eat something sweet, salty, or rich in fat. They also rated their opinion on the general appreciation of the meal and on the overall perceived mental workload of the experimental conditions from “not cognitively challenging at all” to “extremely challenging”. The VAS is a line, 100 mm in length, with statements anchored at each end expressing the most positive and most negative rating of the participants’ appetite sensations. The VAS has been shown to be both reproducible and valid for measurement of appetite sensations in a laboratory setting (Flint, Raben, Blundell, & Astrup, 2000). The VAS were completed during each experimental condition: at fasting (7:45), before the experimental condition (10:15), immediately after the experimental condition (11:20), and immediately after the *ad libitum* lunch (12:30).

### ***Dietary record***

All participants were instructed to complete a 3-day dietary record, with help from parents, following each experimental condition to evaluate the degree of potential compensation in the following days (Tremblay, Sévigny, Leblanc, & Bouchard, 1983). The research coordinator explained to every participant how to complete the record and how to measure quantities of ingested foods. Food intakes were measured by household units or standard portion

sizes. The 3-day food records were reviewed with each participant upon its return to improve the validity of the information provided. Mean energy and macronutrient intakes were determined and analyzed using the Food Processor SQL software (version 9.6.2, ESHA Research).

### ***Resting metabolic rate measurement***

Resting metabolic rate (RMR) was measured during the preliminary visit by indirect calorimetry (Vmax 229 series metabolic cart; SensorMedics Corporation, Yorba Linda, CA, USA). RMR was measured for 30 minutes following a 30 minute rest period and a 12 hour overnight fast. The first and last 5 minutes were excluded from the calculations, thus minutes 6-25 were used in the calculation. Mean RMR was calculated by using the Weir equation (Weir, 1949).

### ***Physical activity behaviour compensation***

Changes in physical activity throughout the experiment possibly associated with the different interventions were examined using an Actical accelerometer (Phillips, Respironics, Oregon, USA). The accelerometer was positioned on the right iliac crest in mid-axillary position immediately upon arrival at the laboratory (7:30) and worn for a 3-day period to insure adequate follow up. The Actical measures and records time stamped acceleration in all directions, omnidirectional, and the digitized values are summed over a user specified interval of 1 minute. The Actical has been validated to measure physical activity in children and adolescents (Puyau, Adolph, Vohra, Zakeri, & Butte, 2004) and has better instrument reliability than other accelerometer models (Esliger & Tremblay, 2006). Accelerometry data underwent standardized quality control and data reduction procedures, as previously reported (Colley, Gorber, & Tremblay, 2010). Physical activity energy expenditure (PAEE) was determined from the Actical

using validated equations (Puyau, Adolph, Vohra, Zakeri, & Butte, 2004). Participants completed an activity log alongside the use of the accelerometer in order to pick up other activities such as cycling and swimming.

### ***Energy expenditure of experimental conditions***

Energy expenditure for each 1 hour experimental condition (control, seated video gaming, and AVG) was measured with the use of a portable metabolic analyzer (Cosmed K4b2, Cosmed, Rome, Italy) as described in detail elsewhere (Bailey & McInnis, 2011). The energy expenditure measurements were performed for the whole hour period. Based on our experience, this assessment is well tolerated by the adolescents and does not interfere with the game played. The device comprises of a mask and a small data unit and the data are transmitted by telemetry, reducing instrumentation. The Cosmed K4b2 portable metabolic system has been shown to be accurate in measuring the metabolic costs of daily life activities (Schrack, Simonsick, & Ferrucci, 2010; Duffield, Dawson, Pinnington, & Wong, 2004; Parr, Strath, Bassett, & Howley, 2001). The metabolic rate measurements as performed in our facilities provide a reliability coefficient of 0.9 and a coefficient of variation of less than 5%.

### ***Questionnaires***

In an attempt to better characterize the adolescents, some questionnaires were administered during the preliminary visit to our facilities. The 51 item Three Factor Eating Questionnaire (Stunkard & Messick, 1985) was used to verify that the participants were not restrained eaters (those with a score  $\geq 12$  for cognitive dietary restraint were excluded). The purpose of this questionnaire is to assess 3 factors related to cognition and eating behaviours: cognitive dietary restraint (intent to control food intake), disinhibition (overconsumption of food

in response to cognitive or emotional cues), and susceptibility to hunger (food intake in response to feelings and perceptions of hunger). This questionnaire has been validated and its 3 scales have been reported to show good test-retest reliability (Laessle, Tuschl, Kotthaus, & Pirke, 1989). The Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) is a self-rated questionnaire that assesses sleep quality and disturbances over the preceding month. Sleep hygiene was assessed in this study because sleep duration has been shown to influence appetite sensations (Chaput, Klingenberg, & Sjödin, 2010; Chaput J. , 2014). A total score  $>5$  is associated with poor sleep. The physical activity pattern of participants was assessed using the Physical Activity Questionnaire for Adolescents, a self-report measure of physical activity that has been validated in white Canadian samples (Moore, et al., 2007). A score of 1 indicates low, while a score of 5 indicates high physical activity participation (Janz, Lutuchy, Wenthe, & Levy, 2008). The pubertal status of participants was evaluated with a self-assessment questionnaire that aims to measure pubertal status by using line drawings of the Tanner puberty stages (Taylor, et al., 2001). The Cohen's Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983) was completed to evaluate the level of stress in participant's daily life. This questionnaire contains 10 questions and a score  $<10$  indicates good stress management.

During the experimental conditions additional questionnaires were completed to measure subjective mood states and food sensitivity. The modified 24-item Brunel Mood Scale (Terry, Lane, Lane, & Keohane, 1999), formerly the Profile of Mood States-A, assesses mood states by asking 24 questions of feelings and emotions at the moment. The questionnaire uses a 5 point scale to measure each feeling and emotion and has been validated in the adolescent population (Terry, Lane, Lane, & Keohane, 1999). The 10 item PANAS assesses both positive affect and negative affect, in the moment, using 10 items for each affect (Watson, Clark, & Tellegen,

1988). The PANAS is widely used, and has been validated for use in both children and adolescents (Laurent, et al., 1999; Giacomoni & Hutz, 2006; Segabinazi, et al., 2012). The implicit wanting and explicit liking and wanting tasks are measured using the LFPQ computerized program that evaluates individual's preference for a specific food type (Finlayson, King, & Blundell, 2007; Finlayson, King, & Blundell, 2008). The program presents 16 different food types that are separated into 4 categories: high fat savoury, low fat savoury, high fat sweet, and low fat sweet (Finlayson, King, & Blundell, 2007; Finlayson, King, & Blundell, 2008). Explicit wanting and liking is determined by presenting foods on their own with the use of a VAS asking how much you want this food now and how pleasant would it be to experience a mouthful of this food now (Finlayson, King, & Blundell, 2007; Finlayson, King, & Blundell, 2008). Foods are also paired with each of the other foods, and the participant is forced to choose which food they most want to eat right now, indicating their preference for a certain food type (Finlayson, King, & Blundell, 2007; Finlayson, King, & Blundell, 2008). The time taken to choose indicates their implicit wanting (Finlayson, King, & Blundell, 2007; Finlayson, King, & Blundell, 2008). The above-mentioned variables will be used as covariates in the analyses if they are found to significantly interact with the outcome variables.

## **Statistical Considerations**

### ***Primary and secondary outcome measures***

The primary outcomes were acute (24 hours) and short-term (3 days) energy intake and expenditure. Food intake was measured using an *ad libitum* test meal immediately following the intervention, a food menu for the remainder of the day, and a dietary record for the subsequent 3 day period. Energy expenditure was measured using indirect calorimetry during the intervention and an Actical accelerometer for the subsequent 3 day period to measure physical activity energy

expenditure. Total energy expenditure (TEE) was calculated using the following formula:  $TEE = (\text{physical activity energy expenditure from the Actical} + \text{RMR}) \times 1.11$  (World Health Organization, 1985) where the thermic effect of food is fixed at 10% of TEE. The secondary outcomes included appetite sensations (VAS) and food reward from the LFPQ.

### *Sample size calculation*

Previous results on the effects of seated video games on energy balance have shown that 18 participants was a sufficient number to detect a significant energy balance difference of 246 kJ (SD: 210 kJ) between the seated video game and the control conditions (repeated measures ANOVA). Since the sample size calculation is based on having adequate power to detect changes in the primary outcomes, a sample size of 26 participants was estimated to provide at least 90% power at 5% level of significance (two sided) to detect 200 kJ difference between the experimental conditions, assuming a standard deviation (SD) of 400 kJ. A large and very conservative SD was used based on previous studies experience, because a large inter-individual variability is normally observed for energy intake and to increase the likelihood of detecting a significant difference between experimental conditions. The use of a paired design in the present study also allows us to substantially reduce the number of participants needed to detect significant differences. The sample size also provides 80% power, two tailed  $\alpha=0.05$ , to detect an effect size of 0.30 for the secondary outcomes.

### *Statistical analysis*

Prior to statistical analysis all data were tested for normality using the Shapiro-Wilk W test and variance homogeneity and transformed if necessary. A two-way repeated measures ANOVA was used to assess the effect of the 3 interventions on outcome measures, and a Tukey

post hoc test was used to compare the mean differences. Effect sizes were examined using the Cohen's *d* method, reflecting the magnitude of the difference between groups in SD units. Cohen's *d* is computed by subtracting the average score for the control group from the average score for the intervention group and then dividing the difference by the pooled SD. Effect sizes are considered negligible if  $<0.2$ , small if between 0.2 and 0.5, moderate if between 0.5 and 0.8, and important if  $>0.8$ . Differences are considered significant at  $P<0.05$ . All statistical analyses were performed using SPSS Statistics 22.0 (SPSS Inc., Chicago, IL, USA).

## **PART 2 - Article**

*This article has been accepted for publication in the American Journal of Clinical Nutrition and is presented in the published format.*

The article only reports the results for acute and short-term energy intake, expenditure, and appetite sensations, *i.e.* the main objective of the study. All of the psychological variables that were measured are not mentioned within the article but reported in the thesis. The main reason for this was that the results from the LFPQ and the PANAS were not available when the article was sent for submission. Of note, the Subjects and Methods section within this article has been previously outlined in Part 1 for the most part.

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## Active video games and energy balance in male adolescents: a randomized crossover trial<sup>1-3</sup>

Aidan Gribbon, Jessica McNeil, Ollie Jay, Mark S Tremblay, and Jean-Philippe Chaput

### ABSTRACT

**Background:** Active video games (AVGs) have been shown to acutely increase energy expenditure when compared with seated video games; however, the influence of AVGs on compensatory adjustments in energy intake and expenditure is largely unknown.

**Objective:** The aim was to examine the acute effects of AVGs on energy intake and expenditure.

**Design:** With the use of a randomized crossover design, 26 male adolescents (mean  $\pm$  SD age: 14.5  $\pm$  1.4 y) completed three 1-h experimental conditions: resting control, seated video game play (Xbox 360; Microsoft), and AVG play (Kinect Adventures on Xbox 360) followed by an ad libitum lunch. A validated food menu was used to assess food intake immediately after the conditions and for the remainder of the day, and a dietary record was used for the subsequent 3-d period. Energy expenditure was measured by using portable indirect calorimetry throughout each experimental condition, and an accelerometer was used to assess the subsequent 3-d period. Appetite sensations were assessed by using visual analog scales at different time points during the testing day. The primary outcomes were acute (immediately after the conditions and 24-h) and short-term (3-d) energy intake and expenditure.

**Results:** Energy expenditure was significantly higher ( $\sim$ 145%;  $P < 0.001$ ) during the AVG condition than during the resting control and seated video game conditions; however, no significant differences in energy expenditure were observed 24 h ( $\sim$ 6%;  $P > 0.49$ ) and 3 d after the experimental conditions ( $\sim$ 3%;  $P > 0.82$ ). No significant differences were observed in absolute energy intake immediately after the conditions ( $\sim$ 2%;  $P > 0.94$ ) or in absolute energy intake 24 h ( $\sim$ 5%;  $P > 0.63$ ) and 3 d ( $\sim$ 9%;  $P > 0.53$ ) after the experimental conditions. Finally, appetite sensations were similar between conditions at all time points ( $P > 0.05$ ).

**Conclusions:** The increase in energy expenditure promoted by a single session of Kinect AVG play is not associated with increased food intake but is compensated for after the intervention, resulting in no measurable change in energy balance after 24 h. These results suggest that the potential of Kinect to reduce the energy gap underlying weight gain is offset within 24 h in male adolescents. This trial was registered at [clinicaltrials.gov](http://clinicaltrials.gov) as NCT01655901. *Am J Clin Nutr* doi: 10.3945/ajcn.114.105528.

**Keywords** exergaming, appetite, energy intake, energy expenditure, food, obesity, teenagers

### INTRODUCTION

Video games have enormous mass appeal and are omnipresent in the daily schedule of most children and adolescents, especially

in boys (1, 2). Until recently, no experimental study had examined the potential of video games to lead to a concomitant increase in food intake, which is crucial if we want to draw conclusions about the net impact of these devices from an energy balance standpoint. With the use of a randomized crossover design, Chaput et al. (3) showed, in a laboratory setting, that 1 h of seated video game play in male adolescents was accompanied by increased spontaneous energy intake when compared with a resting control condition. Similar to television viewing (4), this overconsumption of food was observed without increased sensations of hunger.

The new generation of active video games (AVGs)<sup>4</sup> might offer an appealing activity alternative for increasing energy expenditure and improving body composition among children and youth who would otherwise be spending time in sedentary screen-based activities. Recent advances in technology have allowed AVGs to increase in popularity among children and youth (5). The potential of manipulating the gaming environment as an intervention tool for increasing energy expenditure is supported by recent findings that show that playing AVGs acutely increases energy expenditure in comparison with seated video games (6–8). However, a significant increase in energy expenditure as a result of AVG play might be of little importance to prevent weight gain if one compensates by increasing energy intake, decreasing physical activity, or both subsequent to the activity. This issue is of particular importance in the field of obesity prevention and management because acute exercise-induced increases in energy expenditure are generally accompanied by compensatory adjustments in energy intake that can range from hours to several days after the intervention (9–11).

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<sup>4</sup>Abbreviations used: AVG, active video game; PAEE, physical activity energy expenditure; RMR, resting metabolic rate; TEE, total energy expenditure; VAS, visual analog scale.

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Recent results indicate that children consume snacks when freely available, whether they are playing seated video games or in an ambulatory environment with the addition of a motor component to video gaming (12). In adults, both seated video games and AVGs were reported to produce an acute energy surplus when food was offered while playing (13). Furthermore, there is evidence to suggest that individuals compensate for exercise interventions by decreasing spontaneous physical activity for the remainder of the day, such that the net energy expenditure remains similar (14–16). Collectively, these observations support results from recent randomized controlled trials that show that AVGs did not significantly enhance physical activity or reduce adiposity in children when studied under free-living conditions (17, 18). It is thus important and timely to examine the impact of AVGs on both sides of the energy balance equation (including postintervention energy compensation) to understand the role of AVGs in body weight control (19, 20).

The objective of this study was thus to examine the effects of AVGs on acute energy intake and expenditure. On the basis of recent observations and previous evidence that seated video games increase food intake (3), we hypothesized that the increase in energy expenditure promoted by AVGs would be compensated for by an increase in food intake, thereby offsetting the potential benefits of AVGs from an energy balance standpoint. Furthermore, we hypothesized that there would be a compensatory adjustment in physical activity subsequent to the AVG condition.

## METHODS

### Subjects

Male adolescents between the ages of 13 and 17 y were recruited for the study via advertisements and word of mouth. We chose to focus on adolescent males in this study because of the high prevalence of video gamers in this age group (1, 2). Volunteers were excluded for any of the following reasons: smoking, unstable body weight ( $\pm 4$  kg) during the 6 mo preceding testing, excessive alcohol intake ( $>10$  drinks/wk), celiac disease, metabolic disease (e.g., thyroid disease, heart disease, diabetes), vegetarian, medication use that could interfere with the outcome variables, highly restrained eating behavior (score  $\geq 12$  for cognitive dietary restraint on the Three-Factor Eating Questionnaire), irregular sleeping patterns (e.g., shift work or working overnight shifts), unfamiliarity with the use of video games, and inability to comply with the protocol. Written informed parental consent and child assent were obtained from all participants, and ethical approval was obtained from the University of Ottawa and the Children's Hospital of Eastern Ontario Research ethics boards. Participants received \$30 per condition for their participation in the study. Before testing began, all participants and parents engaged in a preliminary visit in which information on the procedures and protocol requirements was discussed and completed screening questionnaires and physical measurements (anthropometric measures and resting metabolic rate) to characterize the participants. Vigorous physical activity was not permitted 24 h before testing, and participants had to respect a normal sleep schedule 3 d before testing (self-reported). All participants were required to arrive at the University of Ottawa Behavioral and

Metabolic Research Unit in a fasted state and in good health on testing days. A Consolidated Standards of Reporting Trials–style diagram of participant flow through the study is presented in **Figure 1**.

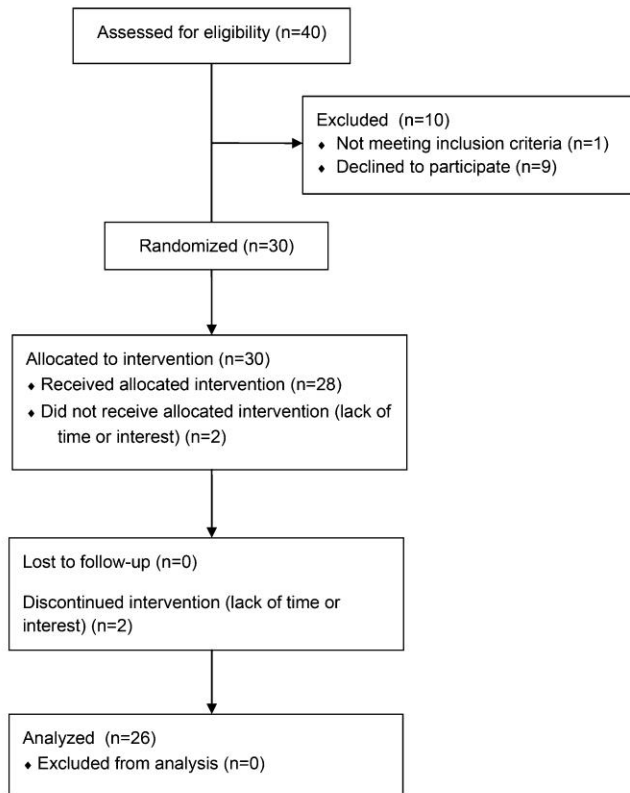
### Study protocol

This study was a randomized, 3-condition crossover study (within-subjects experimental design), in which each participant was engaged in each of the following three 1-h experimental conditions followed by an ad libitum lunch: 1) resting in a seated position (control condition), 2) playing Xbox 360 (Microsoft; seated video game condition), and 3) playing Kinect for Xbox 360 (AVG condition). These 3 conditions were randomly assigned by using a computerized randomization scheme and were counterbalanced. The video game FIFA 14, a soccer video game for the Xbox 360, was played during the seated video game condition, because it is easy to learn, popular, and can be played in 1 h. The video game Xbox Kinect Adventures for the Xbox 360 Kinect was played during the AVG condition, because it is easy to learn and has been used in other AVG studies that used similar energy expenditure measurement techniques (21). The AVGs were selected by the experimenter, and all participants played the same games. The AVGs consisted of a series of mini-games that involved total body movement with increased difficulty as the participants progressed throughout the games. There was only one game played (adventures), with transition time between mini-games of only a couple of seconds. Instructions on how to play the video games were given to the participants immediately before the condition, and they were instructed to do their best.

One at a time, on 3 separate occasions 1–4 wk apart, the participants arrived at the laboratory at 0730 after fasting for 12 h. An accelerometer was attached immediately on arrival. Visual analog scales (VASS) were used to record subjective measures of appetite at 0745 (and at other time points during the day), and the participant was provided a standardized breakfast at 0800. The participant then refrained from eating until the ad libitum lunch. The 1-h experimental intervention consisted of 1 of the 3 conditions, starting at 1020. Participants were asked to relax on a comfortable chair between the end of the breakfast and the beginning of the testing condition. Energy expenditure was measured during the condition with the use of a portable indirect calorimeter. The participant thereafter was given an ad libitum test lunch to evaluate spontaneous food intake. A food menu was used to assess food intake for the remainder of the day. Finally, the participant was required to fill out a 3-d dietary record and wear the accelerometer for 3 d after each experimental condition. A schematic overview of the study protocol is presented in **Figure 2**.

### Anthropometric measurements

Body weight was measured without shoes while wearing scrubs, after voiding, to the nearest 0.1 kg on a calibrated electronic scale (Tanita). Height was measured, again without shoes, after a deep inspiration, to the nearest 0.1 cm with the participant standing with feet together and head in the Frankfort plane against a wall-mounted stadiometer. BMI was determined and interpreted with the WHO BMI-for-age growth charts (22).

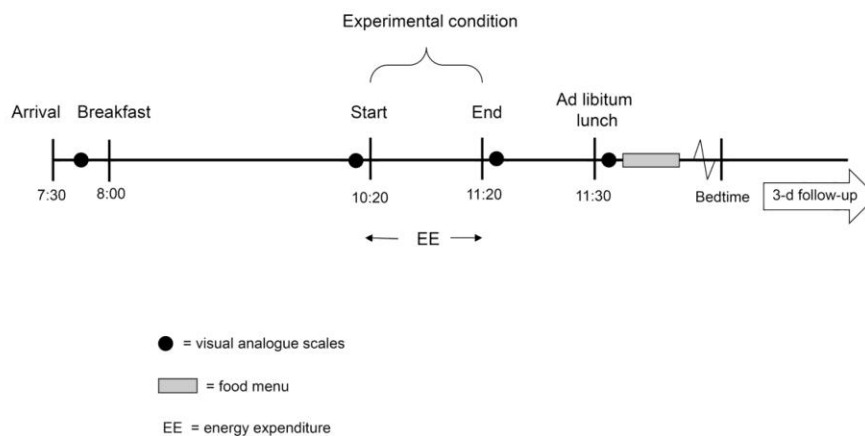


**FIGURE 1** Flowchart of participants during the active video game intervention study.

Waist circumference was measured to the nearest 0.1 cm by using a nonextendable linen tape and measured midway between the lower border of the last rib and the upper border of the iliac crest at the end of a normal expiration.

#### Breakfast

A standardized breakfast was given to the participants at 0800 am, which consisted of 2 pieces of whole-wheat bread (78 g, 837 kJ; D'Italiano), peanut butter (18 g, 452 kJ; Kraft Smooth Peanut



**FIGURE 2** Overview of the study protocol. Black dots = visual analog scales; gray rectangle = food menu. EE, energy expenditure.

Butter), raspberry jam (16 mL, 218 kJ; Kraft Pure Raspberry), cheddar cheese (21 g, 335 kJ; Kraft Cracker Barrel Marble), and orange juice (200 mL, 418 kJ; Minute Maid 100% Orange Juice). Participants ate alone in a room with no distractions, and all of the participants consumed the entire breakfast within 15 min.

#### **Ad libitum lunch**

Spontaneous food intake, including liquids, was assessed by using an ad libitum food menu immediately after each experimental condition, which allowed us to assess both total energy intake and macronutrient preference (23). The food menu contains a variety of meal-type foods (both hot and cold), beverages, and snacks differing in macronutrient composition (74 items in total). The foods were offered in large amounts, and the participants were instructed to eat ad libitum, alone, in a room without distractions, with no restrictions on the amount consumed. The participants were given 30 min for this meal, and all foods were measured to the nearest 0.1 g before and after ingestion. Ad libitum energy intake was measured by a food technician using calculations performed on the amount of the meal consumed. Furthermore, the food menu was used to measure energy intake for the remainder of the day. Briefly, participants self-selected what they wanted to eat for the rest of the day (until bedtime), and all selected foods were packed into coolers for them to take home. Participants were asked to return all leftovers, wrappings, and peels and to put them into their original containers when applicable. For both the in-laboratory and out-of-laboratory sessions, 2 portions of each of the food and beverage items selected were prepared and served (or packed into the portable cooler). The specific quantity (portions) of each food and beverage item provided or served to the participants was reported previously (23). This type of food menu, which has a high appreciation of food items on the menu, has been shown to produce a reliable measure of energy intake inside and outside the laboratory in both adults and adolescents (23, 24).

#### **Appetite sensations**

For each condition, the participants were instructed to complete 9 VASs for their sensations of hunger, satiety, prospective food consumption, fullness, and desire to eat something sweet, salty, or rich in fat. They also rated their opinion on the general appreciation of the meal and on the overall perceived mental workload of the experimental conditions, from “not cognitively challenging at all” to “extremely challenging.” The VAS, 100 mm in length, contained statements anchored at each end expressing the most positive and most negative rating of the participants’ appetite sensations. The VAS has been shown to be both reproducible and valid for the measurement of appetite sensations in a laboratory setting (25). The VASs were completed during each experimental condition: at fasting (0745), before the experimental condition (1015), immediately after the experimental condition (1125), and immediately after the ad libitum lunch (1215).

#### **Dietary record**

All participants were instructed to complete a 3-d dietary record, with help from the parents, after each experimental

condition to evaluate the degree of potential compensation in the following days (26). According to exercise intervention studies, the time frame for compensation (if it occurs) has not yet been clearly established but can range from hours to over several days (9–11, 15). Participants were instructed on how to complete the dietary record and on how to measure quantities of ingested foods. The 3-d food records were reviewed with each participant upon their return to improve the validity of the information provided. Mean energy and macronutrient intakes were calculated by using the Food Processor SQL software (version 9.6.2; ESHA Research).

#### **Resting metabolic rate measurement**

Resting metabolic rate (RMR) was measured during the preliminary visit by indirect calorimetry (Vmax 229 series metabolic cart; SensorMedics). RMR was measured for 30 min after a 30-min rest period and a 12-h overnight fast. The first and last 5 min were excluded from the calculations; thus, minutes 6–25 were used in the calculation. Mean RMR was calculated by using the Weir equation (27). The CV and reliability coefficient for the determination of RMR with this metabolic cart in our laboratory are 2.3% and  $r = 0.98$ , respectively, as determined in 12 healthy participants.

#### **Physical activity energy expenditure compensation**

Changes in physical activity after each condition were assessed by using an Actical accelerometer (Philips Respironics). The accelerometer, on an elastic belt, was positioned on the right iliac crest in midaxillary position immediately on arrival at the laboratory (0730) and worn for a 3-d period to ensure adequate follow-up. The Actical measures and records time-stamped acceleration in all directions (omnidirectional), and the digitized values are summed over a user-specified interval of 1 min. The Actical has been validated to measure physical activity in children and adolescents (28) and has better instrument reliability than other accelerometer models (29). Accelerometry data underwent standardized quality control and data reduction procedures, as previously reported (30). Physical activity energy expenditure (PAEE) was determined from the Actical by using validated equations (28).

#### **Energy expenditure of experimental conditions**

Energy expenditure of each 1-h experimental condition (control, seated video gaming, and AVG) was measured with the use of a portable metabolic analyzer (Cosmed K4b2), as described in detail elsewhere (31). The energy expenditure measurements were performed during the entire duration of each condition. On the basis of our experience, this assessment is well tolerated by adolescents and does not interfere with the game played. The device comprises a mask and a small data unit, and the data are transmitted by telemetry, reducing instrumentation. The Cosmed K4b2 portable metabolic system has been shown to be accurate in measuring the metabolic costs of daily life activities (32–34). The metabolic rate measurements as performed in our facilities provide a reliability coefficient of 0.9 and a CV of <5%.

### Questionnaires

To better characterize the adolescents, some questionnaires were administered during the preliminary visit. The 51-item Three-Factor Eating Questionnaire (35) was used to verify that the participants were not restrained eaters (those with a score  $\geq 12$  for cognitive dietary restraint were not eligible). The purpose of this questionnaire is to assess 3 factors related to cognition and eating behaviors: cognitive dietary restraint (intent to control food intake), disinhibition (overconsumption of food in response to cognitive or emotional cues), and susceptibility to hunger (food intake in response to feelings and perceptions of hunger). This questionnaire has been validated, and its 3 scales have been reported to show good test-retest reliability (36). In addition, participants completed the Pittsburgh Sleep Quality Index (37), a self-rated questionnaire that assesses sleep quality and disturbances over the preceding month. Sleep hygiene was assessed in this study because sleep duration has been shown to influence appetite sensations (38). A total score  $>5$  is associated with poor sleep. The physical activity pattern of participants was assessed by using the Physical Activity Questionnaire for Adolescents, a self-report measure of physical activity that has been validated in white Canadian samples (39). A score of 1 and a score of 5 indicate low and high physical activity participation, respectively. The pubertal status of adolescents was evaluated with a self-assessment questionnaire that aims to measure pubertal status by using line drawings of the Tanner puberty stages (40). Finally, Cohen's Perceived Stress Scale (41) was completed to evaluate the amount of stress in the participant's daily life. This questionnaire contains 10 questions and a score  $<10$  indicates good stress management.

### Outcome measures

The primary outcomes were acute (immediately after the conditions and 24-h) and short-term (3-d) energy intake and expenditure. The food intake outcome was assessed by using the ad libitum test meal immediately after the conditions, the food menu for the remainder of the day, and the dietary record for the subsequent 3-d period. The energy expenditure outcome was assessed by using indirect calorimetry during the conditions and with the Actical accelerometer for the subsequent 3-d period. Total energy expenditure (TEE) was calculated by using the following formula (42):

$$TEE = (\text{PAEE from the Actical} + \text{RMR}) \times 1.11 \quad (1)$$

where the thermic effect of food is fixed at 10% of TEE. The secondary outcome measures were appetite sensations (VAS).

### Sample size calculation

Previous results on the effects of seated video games on energy balance (3) have shown that 18 participants was a sufficient number to detect a significant energy balance difference of 246 kJ (SD: 210 kJ) between the seated video game and the control conditions (repeated-measures ANOVA). It was thus estimated that a sample size of 26 participants would provide at least 90% power at a 5% level of significance (2-sided) to detect a minimal group difference of 200 kJ, assuming an SD of 400 kJ. We used a conservative SD estimate because large variability is generally observed for energy intake (especially with the use of dietary

records) and to increase the likelihood of detecting a significant difference between conditions.

### Statistical analysis

Before statistical analysis, all data were tested for normality by using the Shapiro-Wilk W test and variance homogeneity and log-transformed if necessary. A 2-factor repeated-measures ANOVA was used to assess the effects of the intervention on outcome measures. Tukey's post hoc test was used to contrast mean differences. Effect sizes were examined by using Cohen's *d* method, reflecting the magnitude of the difference between groups in SD units. Cohen's *d* is computed by subtracting the average score of the control group from the average score of the intervention group and then dividing the difference by the pooled SD. Effect sizes are considered negligible if  $<0.2$ , small if between 0.2 and 0.5, moderate if between 0.5 and 0.8, and important if  $>0.8$ . Data are presented as means and SDs unless otherwise indicated. All statistical analyses were performed by using SPSS Statistics 22.0.

## RESULTS

### Participant characteristics

Table 1 shows the descriptive characteristics of participants enrolled in the present study. Participants were, on average, of normal weight, with 7 (27%) being either overweight or obese. None of the participants were restrained eaters, and all had low disinhibition and susceptibility to hunger scores. Puberty levels were self-reported to be in the mid to later stages of development. Physical activity levels were somewhat low but consistent between the participants. In addition, they generally had a fairly good sleep quality but had high levels of perceived stress in their daily lives.

### Energy expenditure

We observed that energy expenditure was significantly higher during the AVG condition than with the control and seated video

**TABLE 1**  
Descriptive characteristics of participants ( $n = 26$ )<sup>1</sup>

Variable	Value
Age, y	14.5 $\pm$ 1.4
Height, cm	170.9 $\pm$ 7.7
Body weight, kg	64.7 $\pm$ 19.2
BMI, kg/m <sup>2</sup>	21.8 $\pm$ 5.0
Waist circumference, cm	74.1 $\pm$ 12.7
Resting metabolic rate, kJ/d	7101 $\pm$ 1224
Tanner puberty stages (self-assessed)	
Genitals	3.5 $\pm$ 0.9
Pubic hair	3.6 $\pm$ 0.9
Physical Activity Questionnaire score	2.3 $\pm$ 0.5
Cohen's Perceived Stress Scale score	13.0 $\pm$ 5.4
Pittsburgh Sleep Quality Index score	4.8 $\pm$ 2.3
Three-Factor Eating Questionnaire	
Cognitive dietary restraint	1.5 $\pm$ 1.8
Disinhibition	1.0 $\pm$ 1.0
Susceptibility to hunger	2.4 $\pm$ 1.8

<sup>1</sup>Values are means  $\pm$  SDs.

game conditions ( $P < 0.001$ ; **Figure 3**). However, no significant differences were observed between the conditions over 24 h ( $P > 0.49$ ; **Figure 4**) and for the 3 d postintervention ( $P > 0.82$ ; **Figure 5**). The results did not change when adjusting for BMI (data not shown). In **Figure 3**, the effect size was large for the difference in energy expenditure between the AVG condition and the seated video game condition (Cohen's  $d$ : 4.27) and between the AVG condition and the control (Cohen's  $d$ : 4.28). Over 24 h, effect sizes were all small between conditions (Cohen's  $d$  between 0.27 and 0.31). Effect sizes for energy expenditure were negligible for the 3 d after the intervention.

### Energy intake

We observed no significant differences between conditions in energy intake immediately after the intervention ( $P > 0.94$ ; **Figure 3**) or 24 h ( $P > 0.63$ ; **Figure 4**) or 3 d ( $P > 0.53$ ; **Figure 5**) postintervention. Furthermore, no significant differences were found between conditions when energy intake was examined with respect to macronutrient composition (data not shown). In addition, these findings were not altered after BMI was controlled in our analyses (data not shown). The effect size was small for energy intake over 24 h between the AVG condition and the seated video game condition (Cohen's  $d$ : 0.24). All other effect sizes for energy intake were considered negligible.

### Appetite sensations

There were no significant differences in the VASs (all time points) between conditions (data not shown).

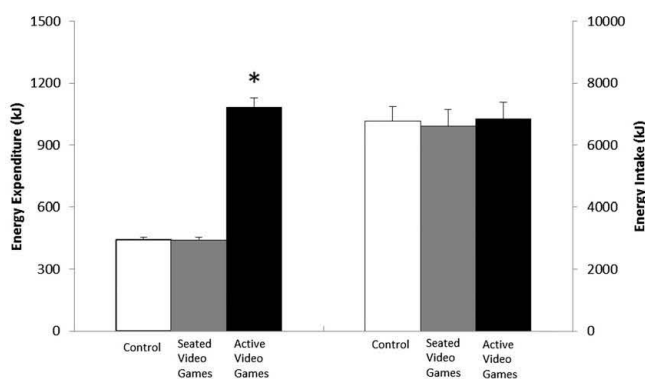
### DISCUSSION

Our data show that 1 h of Kinect AVG play results in higher energy expenditure than do seated video games and resting in a seated position; however, this increase in energy expenditure was accompanied by a compensatory adjustment afterward so that PAEE was similar after 24 h. In addition, we observed that 1 h of Kinect AVG play does not result in increased appetite sensations or in increased food intake when compared with seated video gaming or the resting control. Collectively, these results

suggest that the benefits of Kinect in increasing energy expenditure are offset within 24 h in male adolescents. Randomized controlled trials spanning several months will be needed to confirm our findings on short-term energy balance.

The significantly higher energy expenditure during the 1-h AVG condition (1084 kJ) than during the seated video game (440 kJ) and resting control conditions (441 kJ) is consistent with results from other studies in the field (20). The increase in acute energy expenditure is even greater with the use of Kinect compared with previous AVG systems because its webcam-style sensor device and software technology allow the player to interact directly with the Xbox 360 without the need for a game controller, thereby promoting more whole-body activity as opposed to only hand and arm movements (21). However, active gaming with the use of the Kinect would be an effective means of increasing physical activity and energy expenditure only if it is maintained over time. The present study supports our hypothesis that a compensatory adaptation in spontaneous physical activity occurs subsequent to playing Kinect, resulting in no significant differences in net energy expenditure over the course of 24 h. This compensation in PAEE after engaging in AVGs is consistent with results from exercise trials that showed that individuals tend to compensate for physical activity interventions by decreasing subsequent spontaneous physical activity levels (14–16).

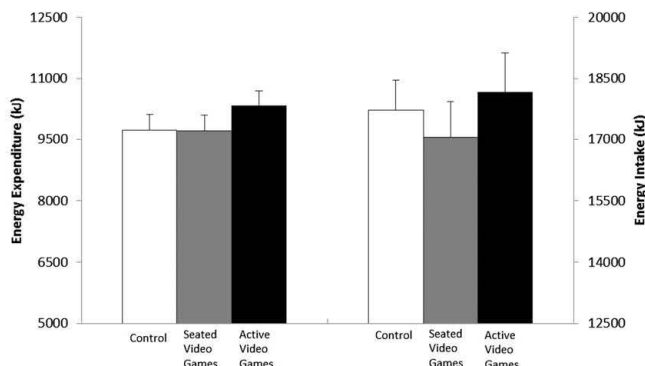
In contrast, we did not observe an increase in food intake after the AVG condition. Indeed, spontaneous food intake was not significantly different between the 3 conditions after the interventions, suggesting that individuals consume the same quantity of food regardless of whether they are resting, playing seated video games, or playing AVGs. This finding is contrary to previous studies in adolescents and adults that showed an increase in spontaneous energy intake when playing either seated video games (3) or AVGs (13) compared with a resting control condition. Reasons for this conflicting finding may include the use of a different AVG console and differing availabilities of and access to food. Different AVG consoles elicit different levels of energy expenditure and intensity, both between consoles and within consoles depending on the game requirements (20). In addition, the availability of food items while gaming may increase energy intake because of the distracted nature of eating (4). The study by



**FIGURE 3** Energy expenditure during the three 1-h experimental conditions and spontaneous energy intake from the ad libitum lunch offered on completion of each condition. Values are means  $\pm$  SEMs;  $n = 26$ . Comparisons between groups were analyzed by ANOVA for repeated measures, and Tukey's post hoc test was used to contrast mean differences. \*Different from the control and seated video game condition,  $P < 0.001$ .

## ACTIVE VIDEO GAMES AND ENERGY BALANCE

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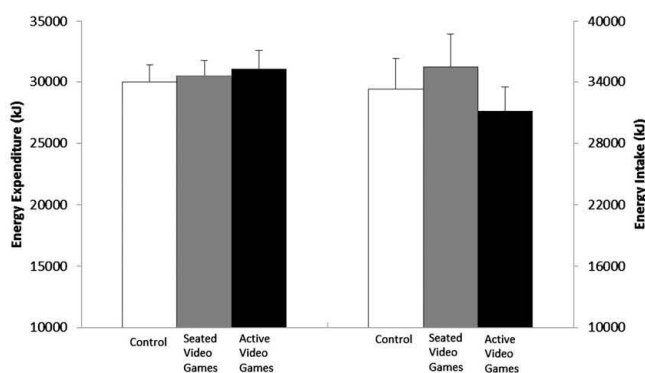
**FIGURE 4** Twenty-four-hour energy expenditure and intake associated with the 3 experimental conditions. Values are means  $\pm$  SEMs;  $n = 26$ . Comparisons between groups were analyzed by ANOVA for repeated measures, and Tukey's post hoc test was used to contrast mean differences. There were no significant differences between conditions.

Lyons et al. (13) in adults occurred during typical meal times and used a different AVG console (hand-held motion-controlled video games) than the Xbox Kinect used in the current study. The adult participants also had ad libitum access to high-calorie-content snack food items while playing (13), whereas in our study adolescent participants were not allowed to consume food until after playing. This last point is important, because distracted eating often leads to increased energy intake as seen with television viewing (4). Another explanation may lie in the fact that "mental stress" was significantly increased in the previous study by Chaput et al. (3), whereas no differences were observed in the present study. Cognitively challenging activities have been reported to increase food intake in the absence of hunger in previous experiments (43, 44). However, our results are in line with a recent trial that examined diet patterns through 3-d dietary recalls during a 6-mo intervention comparing the GameBike (Game Bike Fitness) to a cycle ergometer with music in adolescents (45).

Given the observation that energy intake was not significantly different between the 3 conditions, the finding that subjective measures of appetite sensations were not different is logical. The

lack of a significant difference in appetite sensations between the conditions is in line with previous research that showed that seated video games do not increase hunger sensations (3) and that appetite sensations also do not differ after exercise interventions in adolescents (11). The addition of measures of appetite hormones in the current study would allow for further exploration of these results.

With the current promotion by the manufacturers of AVGs as a replacement for traditional physical activity, future research should focus on comparing the effects of AVGs on energy balance, body composition, and physical fitness with "authentic" exercise. By using a traditional exercise group for comparison (matched for energy expenditure), future studies will be able to determine whether the compensatory changes in energy balance differ (and to what extent) between AVGs and traditional physical activity. It was shown that AVGs result in a significantly higher maximal oxygen uptake ( $\text{VO}_2$ ) and heart rate than does light treadmill walking (1.5 miles/h); however, the intensity of AVGs was not high enough to alter cardiorespiratory fitness in children (46) or to meet daily physical activity requirements (20). Also, the long-term relation between AVGs and energy



**FIGURE 5** Energy expenditure and intake for 3 d after the experimental conditions. Values are means  $\pm$  SEMs;  $n = 26$ . Comparisons between groups were analyzed by ANOVA for repeated measures, and Tukey's post hoc test was used to contrast mean differences. There were no significant differences between conditions.

intake will need to be examined along with the adoption and adherence rate of AVG play over seated video games in adolescents. In the meantime, manufacturers should produce more entertaining AVGs that would promote sustained game play over seated video games and scientists should try to keep up with the advancements in technology to provide evidence-informed answers to the potential benefits and harms of AVGs.

The main limitation of this study is that it was conducted in a controlled laboratory setting in which only male adolescents were recruited, thereby limiting the generalizability of the findings. A comparison of normal-weight vs. obese adolescents would be of value because obese individuals have been shown to be more likely than their normal-weight peers to reduce their normal daily activities after an exercise intervention (9, 47). In addition, adolescents usually play video games for longer than 1 h and have access to food while playing under free-living conditions, not just immediately afterward. This easy access to food while playing could lead to higher energy intakes, as seen with television viewing, because they are distracted during this time (4). However, recent studies suggested that the energy intake increase when individuals have access to food while playing AVGs is not as much as the increase seen with seated video games, especially because of the physical involvement of the player and the detrimental effect eating has on game performance (13). In the present study, measuring food intake during AVG play was not possible because participants had to wear a face mask for the measurement of energy expenditure. Future studies with food available during the exposure will be needed to better examine compensatory changes in energy intake after AVG interventions. Finally, the level of compensation in energy expenditure after playing AVGs is difficult to evaluate in the present study and is influenced by the precision of methods used. Indeed, the metrics used for 24-h energy expenditure are based on accelerometer counts with regression-based conversions to project energy expenditure, whereas indirect calorimetry was used during the 1-h intervention.

In conclusion, our results suggest that the increase in energy expenditure promoted by a single session of Kinect AVG play is not accompanied by an increase in food intake and results in no measurable change in PAEE after 24 h. These results suggest that the increased energy expenditure promoted by Kinect is offset within 24 h in male adolescents. Randomized controlled trials will be needed to confirm our findings.

The authors' responsibilities were as follows—MST and J-PC: designed the research; AG: conducted the research and analyzed the data; JM and OJ: provided essential materials and support; AG and J-PC: wrote the manuscript; and J-PC had primary responsibility for the final content. All authors read and approved the final manuscript. None of the authors declared a conflict of interest.

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### **PART 3 – Global Discussion**

As discussed in Part 1 of the thesis, very little is known regarding the effects of AVG on short term energy balance in adolescents (LeBlanc, et al., 2013); hence, the purpose of this thesis was to examine these effects. The descriptive characteristics of our participants and results of energy expenditure and energy intake are contained within Part 2. All other results can be found in Part 5.

The results of this study illustrate that AVG significantly increase energy expenditure when compared to rest and seated video games; however, the increase in physical activity expenditure is compensated for by a decrease in spontaneous physical activity levels for the remainder of the day such that there was no net benefit. Energy expenditure over a three-day period was not significantly different between the three conditions. This suggests that the benefits of increased energy expenditure from AVG are offset within a 24-hour period in male adolescents. The energy expenditure from the conditions are in line with previous research illustrating that AVG have the potential to increase energy expenditure up to two fold when compared to seated video games and rest (Smallwood, Morris, Fallows, & Buckley, 2012). However, the energy expenditure from the conditions are not in line with Chaput *et al's* (2011) crossover study showing that seated video games result in increased energy expenditure when compared to a resting control, even though energy expenditure during the seated video game condition was comparable. The compensatory effect of decreasing subsequent physical activity levels seen after the AVG condition is consistent with exercise interventions in this population (Frémeaux, et al., 2011; King, et al., 2007; Ridgers, Timperio, Cerin, & Salmon, 2014). Randomized controlled trials will be needed in order to confirm our results.

In contrast to our other hypothesis, the increase in energy expenditure promoted by AVG was not compensated for by an increase in food intake. AVG did not lead to an increase in spontaneous, 24 hour or 3 day energy intake when compared to resting or seated video gaming. Logically, appetite sensations were also seen to be non-significant between the three conditions. This suggests that the same amount of food is consumed regardless of the condition performed beforehand. Our results of spontaneous energy intake are not consistent with previous trials in adolescents and adults showing that spontaneous energy intake is increased after seated video game play (Chaput, et al., 2011) or AVG play (Lyons, Tate, Ward, & Wang, 2012) compared to a resting control. Reasons for this could be related to the levels of mental stress elicited by the condition or the type and availability of the food during the experiment. Food intake is known to increase with mental stress (Chaput & Tremblay, 2007), contrary to Chaput *et al* (2011) the current study did not observe increased stress levels during the seated video game or AVG condition. The similar stress levels between conditions observed in the current study may explain why a significant difference in energy intakes between conditions was not observed. *Ad libitum* access to high caloric content food while playing video games could explain higher energy intake levels, as seen in television viewing, due to the distracted nature of eating (Bellisle, Dalix, & Slama, 2004). Unlike, Lyons *et al* (2012), the current study did not offer access to food during game play, therefore the increased energy intakes as a result of distracted eating from video games would not affect the energy intake in the present study. Our energy intake results are however consistent with a previous trial which compared short (3 days) and long term (6 months) energy intake levels through food diaries in adolescents between cycling on an ergometer with music and the GameBike (Adamo, Rutherford, & Goldfield, 2010). The unchanged subjective appetite sensations between the three conditions in our study is also

consistent with previous research showing that hunger sensations remain unaffected by video games (Chaput, et al., 2011) and exercise interventions in adolescents (Thivel & Chaput, 2014). The addition of measures of appetite hormones would have provided more evidence to support these self-reported appetite sensation findings.

Our results from the PANAS showed that there were no significant differences in positive or negative affect between the three conditions (see Appendix). These results agree and conflict with previous research, which showed that positive affect did not differ but negative affect decreased after playing AVG when compared to seated video games (Russell & Newton, 2008). Interestingly, the experience level of the participants did not affect their mood states (Russell & Newton, 2008). Post condition, AVG were seen to significantly lower anger when compared to seated video games, and significantly raise vigour on the Brunel mood scale when compared to the resting control condition. These results are in line with studies in adults, which showed that mood is significantly enhanced after exercise (Lane, Crone-Grant, & Lane, 2002; Milton, Lane, & Terry, 2005; Lane, Jackson, & Terry, 2005).

As expected and based on previous research (Finlayson, King, & Blundell, 2007; Finlayson, King, & Blundell, 2008; McNeil, Cadieux, Finlayson, & Doucet, 2015), our results showed that explicit wanting and liking, and implicit wanting for high versus low fat foods were significantly less after the *ad libitum* lunch (see Appendix). Interestingly, only implicit wanting for sweet versus savoury foods was significantly different after the *ad libitum* lunch, suggesting that the participants' desire for sweet foods was unaffected by the *ad libitum* lunch. Overall, between the conditions, the relative preference for high versus low fat foods and the implicit wanting for sweet versus savoury foods were significantly different. AVG were found to significantly lower explicit wanting and relative preference for high versus low fat foods

compared to the resting control condition, and seated video games were found to significantly lower the implicit wanting for sweet versus savory foods compared to the resting control condition. This is in line with a previous study, which found that exercise decreased the relative preference for high versus low fat foods (McNeil, Cadieux, Finlayson, & Doucet, 2015). Similar to previous studies examining the effects of exercise on food reward and energy intake (McNeil, Cadieux, Finlayson, & Doucet, 2015; Balaguera-Cortes, Wallman, Fairchild, & Guelfi, 2011; Laan, Leidy, Lim, & Campbell, 2010), the increase in the hedonic component of eating was observed without increased energy intake between conditions.

Collectively, our results somewhat support our hypothesis in that compensation did occur with the AVG condition. Although AVG are not compensated for by an increase in energy intake either spontaneously or over a 24 hour period, their benefit of an increased activity energy expenditure is compensated for afterwards so that the net energy expenditure over a 24 hour period is unchanged compared to rest or seated video games. This means that although AVG offer the opportunity to significantly increase energy expenditure compared to sedentary activities while doing the activity, their benefit is compensated for so that the net effect on daily energy expenditure remains unchanged. Although more studies will be needed to confirm our findings, this observation does not speak in favour of an anti-obesity effect of AVG and caution must be exercised when we prescribe them if the goal is to impact body weight.

Although this compensation has also been seen in exercise interventions, composing of low to moderate intensities (Frémeaux, et al., 2011; King, et al., 2007; Ridgers, Timperio, Cerin, & Salmon, 2014), AVG should not be considered as a replacement for “authentic” exercise. Although AVG play has been shown to elicit a significantly higher  $VO_2$  and heart rate than walking on a treadmill at 1.5 miles/hour, their intensity was not enough to alter cardio-

respiratory fitness in children (Penko & Barkley, 2010). In addition, AVG were unable to induce significant changes in cardio-metabolic health indicators, such as high density lipoprotein and low density lipoprotein concentrations (Murphy, et al., 2009). These findings may be explained by the fact that AVG produce differing levels of physical activity expenditure, from low to moderate intensities (LeBlanc, et al., 2013), and that typically moderate to vigorous intensities are required to promote the physiological adaptations that result in a marked improvement in cardio-metabolic health in adolescents (Janssen & LeBlanc, 2010). Collectively, these findings may help to rationale why, in recent randomized controlled trials, AVG, due to their inability to create a significant energy deficit, have not been able to significantly alter body composition and increase 24 hour physical activity in children under free-living conditions (Maddison, et al., 2011; Baranowski, et al., 2012).

Although AVG do not seem useful in altering body composition, AVG could be a useful tool in promoting physical activities, over sedentary ones, during the winter months in Canada. It has been reported that poor weather and seasonality negatively affect levels of physical activity levels in adolescents, with children in the United Kingdom showing lower levels of physical activity during the winter months; however, these affects seem to be regionally dependent (Rich, Griffiths, & Dezaux, 2012). In Canada, similar effects have been reported, with snow, less daylight hours, high winds, and cold weather reported as barriers to physical activity in youth (Tucker & Gilliland, 2007). The effect of seasonality on physical activity levels could be mitigated by promoting and increasing ease of access to physical activity opportunities within indoor facilities (Tucker & Gilliland, 2007). In addition to the decrease in physical activity levels during the autumn and winter it has been reported that adolescents engage in more screen time, including video game play, during these months (Devis-Devis, Peiró-Velert, Beltrán-

Carrillo, & Tomás, 2009). Therefore, replacing the increased sedentary screen time with AVG during the winter months could at least allow for the possibility of reducing sitting time, but not as a means to improve cardio-metabolic health or body composition.

With the current promotion of AVG as a replacement for traditional physical activity, future research should focus on establishing the effects of AVG on energy balance, body composition, and physical fitness compared to “authentic” exercise. Along with the long-term effects of AVG on energy intake, their adoption and adherence rate over seated video games in adolescents is important to include. It is currently estimated that adolescents spend half the amount of time playing AVG compared to their time spent playing seated video games (Simons, de Vet, Brug, Seidell, & Chinapaw, 2014), and that AVG play tends to significantly decrease over time (LeBlanc, et al., 2013). At the population level, this is important to consider when assessing the effectiveness AVG based interventions on levels of overweight and obesity.

The main limitation of this study was that it was conducted in a controlled laboratory setting using only adolescent males, limiting the generalizability of our results. Although the prevalence of video gamers is high in adolescent males, females also play video games with increasing prevalence (Rideout, Roberts, & Foehr, 2005; Rideout, Foehr, & Roberts, 2010), and examining and contrasting the effects of AVG on both female and male adolescents would have been beneficial. Under free-living conditions adolescents typically engage in video games for longer than one hour and have *ad libitum* access to palatable foods. The availability of foods while playing video games has been suggested to result in an increase in energy intake, similar to television viewing, due to the distracted nature of eating (Bellisle, Dalix, & Slama, 2004). Based on the levels of overweight and obesity in Canada and the daily physical activity and screen time of the Canadian adolescent population, it would be reasonable to postulate that food availability

may be a driving force of overweight and obesity in this age group. The increase in energy intake with the use of AVG has been found to be less than the increase from seated video game play, due to the detrimental affect eating has on game performance (Lyons, Tate, Ward, & Wang, 2012). The ability to examine the effects of AVG on obese adolescents would have been interesting as obese individuals are more likely to decrease their normal daily activities following an exercise intervention when compared to their normal weight peers (King, et al., 2012; Colley, Hills, King, & Byrne, 2010). Furthermore, longer term studies with energy balance assessments at multiple time points would provide a better picture of the effects AVG have than relying on short term experiments. However, such interventions are difficult to conduct and the assessment of energy intake is complex and less accurate than the assessment of energy expenditure.

The main strength of this study was its randomized crossover design, eliminating any individuality effects. Measurement tools for the primary outcomes were specifically selected due to their accuracy, ease of measurement with respect to the protocol, and tolerance. The use of a food menu, over self report, provided a more accurate and controlled measurement of acute energy intake (McNeil, Riou, Razmjou, Cadieux, & Doucet, 2012; Chaput, et al., in press). Self-reported food diaries were used for the 3 day follow-up period with all the limitations associated with this tool. The use of indirect calorimetry allowed for an accurate measurement of energy expenditure during the experimental conditions. A portable unit was utilized to not affect the performance during the AVG condition. The use of an Actical accelerometer attached at the hip was used to measure energy expenditure from physical activities for the 3 days post condition. The Actical is one of the most reliable accelerometers available validated in adolescents (Puyau, Adolph, Vohra, Zakeri, & Butte, 2004; Esliger & Tremblay, 2006). Hip placement was chosen

to capture whole body movements, rather than just limb movements, as is the case with wrist or leg placement (Rosenkranz, Rosenkranz, & Weber, 2011).

In conclusion, the results from this study suggest that the increased energy expenditure from a single session of AVG is not accompanied for by an increase in energy intake, but is compensated for by a decrease in subsequent physical activity so that the beneficial effects are offset within 24 hours in male adolescents. AVG were not seen to significantly affect appetite sensations, but did have a positive effect on mood as AVG decreased anger and increased vigour. Participants were also seen to have a significantly lower preference for high fat foods. Randomized controlled trials will be necessary to confirm our findings; however, our results suggest that caution must be exercised when prescribing AVG for use in interventions hoping to prevent and/or treat obesity.

## PART 4

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**Ethics Approval**

Université d'Ottawa

University of Ottawa

Bureau d'éthique et d'intégrité de la recherche

Office of Research Ethics and Integrity

**Ethics Approval Notice****Health Sciences and Science REB****Principal Investigator / Supervisor / Co-investigator(s) / Student(s)**

<u>First Name</u>	<u>Last Name</u>	<u>Affiliation</u>	<u>Role</u>
Jean-Philippe	Chaput	Medicine / Medicine	Principal Investigator
Aidan	Gribbon	Health Sciences / Human Kinetics	Co-investigator

**File Number:** H11-12-02**Type of Project:** Independent Study Project**Title:** Active Video Games and Appetite Control in Adolescents

<b>Renewal Date (mm/dd/yyyy)</b>	<b>Expiry Date (mm/dd/yyyy)</b>	<b>Approval Type</b>
12/05/2014	12/04/2015	Ia

**(Ia: Approval, Ib: Approval for initial stage only)****Special Conditions / Comments:**

N/A



# Université d'Ottawa

# University of Ottawa

Bureau d'éthique et d'intégrité de la recherche

Office of Research Ethics and Integrity

This is to confirm that the University of Ottawa Research Ethics Board identified above, which operates in accordance with the Tri-Council Policy Statement (2010) and other applicable laws and regulations in Ontario, has examined and approved the ethics application for the above named research project. Ethics approval is valid for the period indicated above and subject to the conditions listed in the section entitled "Special Conditions / Comments".

During the course of the project, the protocol may not be modified without prior written approval from the REB except when necessary to remove participants from immediate endangerment or when the modification(s) pertain to only administrative or logistical components of the project (e.g., change of telephone number). Investigators must also promptly alert the REB of any changes which increase the risk to participant(s), any changes which considerably affect the conduct of the project, all unanticipated and harmful events that occur, and new information that may negatively affect the conduct of the project and safety of the participant(s). Modifications to the project, including consent and recruitment documentation, should be submitted to the Ethics Office for approval using the "Modification to research project" form available at:

<http://www.research.uottawa.ca/ethics/forms.html>.

Please submit an annual report to the Ethics Office four weeks before the above-referenced expiry date to request a renewal of this ethics approval. To close the file, a final report must be submitted. These documents can be found at: <http://www.research.uottawa.ca/ethics/forms.html>.

If you have any questions, please do not hesitate to contact the Ethics Office at extension 5387 or by e-mail at:

[ethics@uOttawa.ca](mailto:ethics@uOttawa.ca).

## Signature:

Ethics Coordinator

For, Director of the Office of Research Ethics and Integrity



## Research Ethics Board 2014 Annual Renewal (Delegated)

**Principal Investigator:** Dr. Jean-Philippe Chaput  
**REB Protocol No:** 12/130X  
**Romeo File No:** 10001499  
**Project Title:** CHEOREB#12/130X - Active Video Games and Appetite Control in Adolescents  
**Primary Affiliation:** HALO\HALO  
**Protocol Status:** Active  
**Approval Date:** October 14, 2014  
**Approval Valid Until:** October 15, 2015  
**Annual Renewal Submission Deadline:** September 15, 2015

### Documents Reviewed & Approved:

Document Name	Comments	Version Date
Consent Form	Child Consent Form - Active Video Game Study - Version 2 - Annual Renewal 2014	2012/10/16
Consent Form	Informed Consent Form - Active Video Game Study - Version 2 - Annual Renewal 2014	2014/10/16

This is to notify you that the CHEO REB has granted approval to the renewal for the above named research study for a period of one year. The renewal was reviewed and approved by the Chair only. Decisions made by the Chair under delegated review are ratified by the full Board at its subsequent meeting.

In fulfilling its mandate, the CHEO REB is guided by: Tri-Council Policy Statement; ICH Good Clinical Practice Practices: Consolidated Guideline; Applicable laws and regulations of Ontario and Canada (e.g., Health Canada Division 5 of the Food and Drug Regulations & the Food and Drugs Act - Medical Devices Regulations).

Approval is granted with the understanding that the investigator agrees to comply with the following requirements:

1. The investigator must conduct the study in compliance with the protocol and any additional conditions set out by the Board.
2. The investigator must not implement any deviation from, or changes to, the protocol without the approval of the REB except where necessary to eliminate an immediate hazard to the research subject, or when the change involves only logistical or administrative aspects of the study (e.g., change of telephone number or research staff). As soon as possible, however, the implemented deviation or change, the reasons for it and, if appropriate, the proposed protocol amendment(s) should be submitted to the Board for review.
3. The investigator must, prior to use, submit to the Board changes to the study documentation, e.g., changes to the informed consent letters, recruitment materials. Should major revisions to the consent form be made, the investigator agrees to re-consent those subjects who have originally consented to the study and who wish to continue on the study.
4. For clinical drug or device trials, investigators must promptly report to the REB all adverse events that are both serious and unexpected (SAEs). For SAE reports on CHEO patients, the investigator must also comply with the hospital-wide Policy regarding, Procedures For Considering Medical Error In The Differential Diagnosis of Severe Adverse Events (SAE) Associated with the Drugs Administered in a Clinical Trial (see [http://cheonet/data/1/rec\\_docs/3792\\_Medical%20Error%20Policy%20revised%20january%2020061.doc](http://cheonet/data/1/rec_docs/3792_Medical%20Error%20Policy%20revised%20january%2020061.doc)).
5. For all other research studies, investigators must promptly report to the REB all unexpected and untoward occurrences (including the loss or theft of study data and other such privacy breaches).
6. Investigators must promptly report to the REB any new information regarding the safety or research subject (e.g., changes to the product monograph or investigator's brochure of drug trials). Where available, any reports produced by Data Safety Monitoring Board should be submitted to the REB.
7. Investigators must notify the REB of any study closures (temporary, premature or permanent), in writing along with an explanation of the rationale for such action.
8. Investigators must submit an annual renewal report to the REB 30 days prior to the expiration date stated on the final approval letter.
9. Investigators must submit a final report at the conclusion of the study.
10. Investigators must provide the Board with French version of the consent form, unless a waiver has been granted.

If you have any questions, pertaining to this letter, please contact  
office at (613) 737-7600,

, Research Ethics Board

Regards,

**Chair, Research Ethics Board**  
**Présidente, Comité d'éthique de la recherche**  
**401 Smyth Road, Ottawa, ON K1H 8L1**

## Appendices

**Table 2a.** Results, in mm, from the visual analogue scales administered at 7:45.

	1	2	3	4	5	6	7	8	9
Control	58 ± 19	30 ± 19	24 ± 23	69 ± 23	38 ± 27	42 ± 26	38 ± 28	NA	22 ± 17
Seated video games	57 ± 23	28 ± 18	22 ± 19	67 ± 19	44 ± 31	43 ± 24	38 ± 28	NA	21 ± 18
Active video games	59 ± 23	28 ± 18	20 ± 18	70 ± 18	52 ± 29	42 ± 27	44 ± 25	NA	21 ± 17

Data are mean ± SD. Not significantly different between the conditions.  $n=26$ . Note: 1= How hungry do you feel?, 2= How satisfied do you feel?, 3= How full do you feel?, 4= How much do you think you can eat?, 5= Would you like to eat something sweet?, 6= Would you like to eat something salty?, 7= Would you like to eat something fatty?, 8= Did you like your meal?, 9= How did you perceive the mental effort of the experimental condition?

**Table 2b.** Results, in mm, from the visual analogue scales administered at 10:15.

	1	2	3	4	5	6	7	8	9
Control	39 ± 20	48 ± 20	44 ± 20	57 ± 24	46 ± 28	43 ± 25	40 ± 27	61 ± 20	20 ± 17
Seated video games	38 ± 25	47 ± 25	43 ± 26	54 ± 25	44 ± 26	46 ± 27	36 ± 26	59 ± 19	25 ± 25
Active video games	44 ± 23	49 ± 20	43 ± 22	57 ± 24	51 ± 25	46 ± 25	46 ± 28	62 ± 17	22 ± 20

Data are mean ± SD. Not significantly different between the conditions.  $n=26$ . Note: 1= How hungry do you feel?, 2= How satisfied do you feel?, 3= How full do you feel?, 4= How much do you think you can eat?, 5= Would you like to eat something sweet?, 6= Would you like to eat something salty?, 7= Would you like to eat something fatty?, 8= Did you like your meal?, 9= How did you perceive the mental effort of the experimental condition?

**Table 2c.** Results, in mm, from the visual analogue scales administered at 11:25.

	1	2	3	4	5	6	7	8	9
Control	61 ± 22	28 ± 18	26 ± 18	74 ± 17	50 ± 28	55 ± 26	49 ± 30	57 ± 21	20 ± 19
Seated video games	61 ± 23	33 ± 20	27 ± 17	70 ± 16	49 ± 28	53 ± 26	44 ± 30	63 ± 22	29 ± 25
Active video games	63 ± 18	29 ± 16	27 ± 17	76 ± 16	50 ± 30	55 ± 28	49 ± 32	69 ± 17	32 ± 28

Data are mean ± SD. Not significantly different between the conditions.  $n=26$ . Note: 1= How hungry do you feel?, 2= How satisfied do you feel?, 3= How full do you feel?, 4= How much do you think you can eat?, 5= Would you like to eat something sweet?, 6= Would you like to eat something salty?, 7= Would you like to eat something fatty?, 8= Did you like your meal?, 9= How did you perceive the mental effort of the experimental condition?

**Table 2d.** Results, in mm, from the visual analogue scales administered at 12:15.

	1	2	3	4	5	6	7	8	9
Control	10 ± 14	88 ± 18	90 ± 17	15 ± 16	21 ± 28	17 ± 24	12 ± 20	90 ± 11	19 ± 21
Seated video games	10 ± 15	87 ± 14	87 ± 13	15 ± 16	24 ± 24	17 ± 20	12 ± 15	79 ± 21	22 ± 21
Active video games	8 ± 10	89 ± 13	91 ± 14	14 ± 19	19 ± 26	14 ± 17	10 ± 16	80 ± 23	18 ± 19

Data are mean ± SD. Not significantly different between the conditions.  $n=26$ . Note: 1= How hungry do you feel?, 2= How satisfied do you feel?, 3= How full do you feel?, 4= How much do you think you can eat?, 5= Would you like to eat something sweet?, 6= Would you like to eat something salty?, 7= Would you like to eat something fatty?, 8= Did you like your meal?, 9= How did you perceive the mental effort of the experimental condition?

**Table 3.** Results from the Positive Affect Negative Affect Scale before and after engaging in the experimental conditions.

	Pre-condition		Post-condition	
	Positive Affect	Negative Affect	Positive Affect	Negative Affect
Control	19.6 ± 6.1	11.0 ± 1.9	18.3 ± 5.7	10.9 ± 1.8
Seated video games	19.7 ± 6.8	11.5 ± 3.4	20.0 ± 6.5	10.6 ± 1.1
Active video games	20.2 ± 6.5	11.6 ± 2.8	20.4 ± 6.4	10.6 ± 0.9

Data are mean ± SD. Not significantly different between the conditions.  $n=26$ .

**Table 4.** Results from the Brunel mood scale before and after engaging in the experimental conditions.

	Pre-condition			Post-condition		
	Control	Seated video games	Active video games	Control	Seated video games	Active video games
Anger	0.1 ± 0.2	0.1 ± 0.2	0.1 ± 0.2	0.07 ± 0.20	0.1 ± 0.3	0.02 ± 0.07*
Confusion	0.1 ± 0.2	0.2 ± 0.3	0.3 ± 0.4	0.1 ± 0.2	0.2 ± 0.3	0.1 ± 0.20
Depression	0.1 ± 0.4	0.2 ± 0.5	0.1 ± 0.5	0.1 ± 0.4	0.1 ± 0.3	0.07 ± 0.30
Fatigue	0.8 ± 0.5	0.8 ± 0.8	1.2 ± 0.8	0.8 ± 0.8	0.5 ± 0.7	0.9 ± 0.9
Tension	0.3 ± 0.6	0.3 ± 0.7	0.3 ± 0.6	0.2 ± 0.5	0.1 ± 0.3	0.1 ± 0.4
Vigour	1.0 ± 0.7	0.9 ± 0.8	1.0 ± 0.8	0.9 ± 0.8	1.0 ± 0.7	1.5 ± 0.9**

Data are mean ± SD. \*Significantly different from the seated video game condition ( $P=0.04$ ).

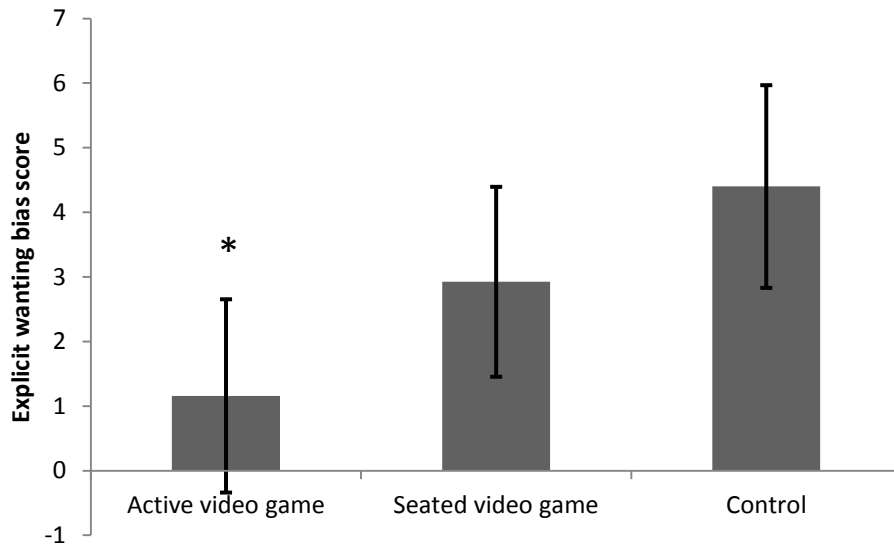
\*\*Significantly different from the control condition ( $P=0.02$ ).  $n=26$ .

**Table 5.** Explicit liking, wanting, implicit wanting, and choice frequency of high vs. low fat foods, and sweet vs. savoury foods across conditions, time (pre vs. post lunch), and condition x time interactions.

	Control	Seated video games	Active video games	Condition effect	Time effect	Condition x Time interaction
<b>Explicit liking</b>						
Fat bias				$P = 0.65$	$P = 0.002$	$P = 0.04$
Before lunch	$8.1 \pm 11.8$	$7.0 \pm 11.2$	$4.6 \pm 10.1$			
After lunch	$0.9 \pm 7.9$	$0.3 \pm 6.7$	$1.9 \pm 6.4$			
Taste bias				$P = 0.62$	$P = 0.68$	$P = 0.89$
Before lunch	$2.1 \pm 13.6$	$0.2 \pm 18.2$	$1.5 \pm 22.1$			
After lunch	$3.9 \pm 9.0$	$2.9 \pm 12.3$	$2.4 \pm 13.1$			
<b>Explicit wanting</b>						
Fat bias				$P = 0.13$	$P = 0.001$	$P = 0.54$
Before lunch	$7.9 \pm 11.5$	$6.4 \pm 12.2$	$3.6 \pm 10.0$			
After lunch	$0.9 \pm 6.4$	$-0.5 \pm 7.2$	$-0.5 \pm 8.1$			
Taste bias				$P = 0.62$	$P = 0.68$	$P = 0.60$
Before lunch	$0.6 \pm 12.3$	$0.08 \pm 16.2$	$0.6 \pm 20.8$			
After lunch	$3.9 \pm 10.7$	$1.2 \pm 13.6$	$1.2 \pm 12.0$			
<b>Implicit wanting</b>						
Fat bias				$P = 0.36$	$P = 0.01$	$P = 0.09$
Before lunch	$7.5 \pm 36.9$	$47.6 \pm 116.8$	$12.3 \pm 35.9$			
After lunch	$-6.9 \pm 73.5$	$-14.3 \pm 56.4$	$-9.1 \pm 52.7$			
Taste bias				$P = 0.06$	$P = 0.07$	$P = 0.30$
Before lunch	$3.9 \pm 50.3$	$-49.1 \pm 200.8$	$-3.7 \pm 45.2$			
After lunch	$39.4 \pm 78.6$	$13.2 \pm 69.3$	$6.1 \pm 96.0$			
<b>Choice frequency</b>						
Fat bias				$P = 0.07$	$P = 0.01$	$P = 0.73$
Before lunch	$5.8 \pm 7.9$	$4.5 \pm 8.3$	$4.1 \pm 8.0$			
After lunch	$1.8 \pm 9.1$	$-0.8 \pm 8.4$	$-0.2 \pm 10.1$			
Taste bias				$P = 0.39$	$P = 0.21$	$P = 0.63$
Before lunch	$-0.3 \pm 12.1$	$-2.4 \pm 10.2$	$0.1 \pm 14.2$			
After lunch	$2.2 \pm 8.8$	$2.0 \pm 9.9$	$3.9 \pm 11.5$			

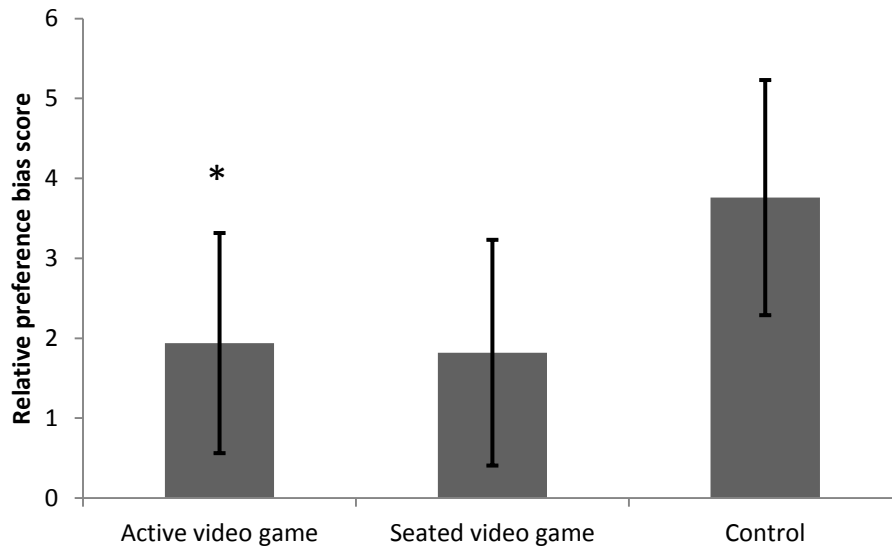
Note: A positive score indicates a relative preference for high vs. low fat foods, or sweet vs. savoury foods. A negative score indicates a relative preference for low vs. high fat foods, or savoury vs. sweet foods. A score of zero indicates an equal preference. Data are mean  $\pm$  SD.

**Figure 6.** Explicit wanting bias for high fat vs. low fat foods between experimental conditions.



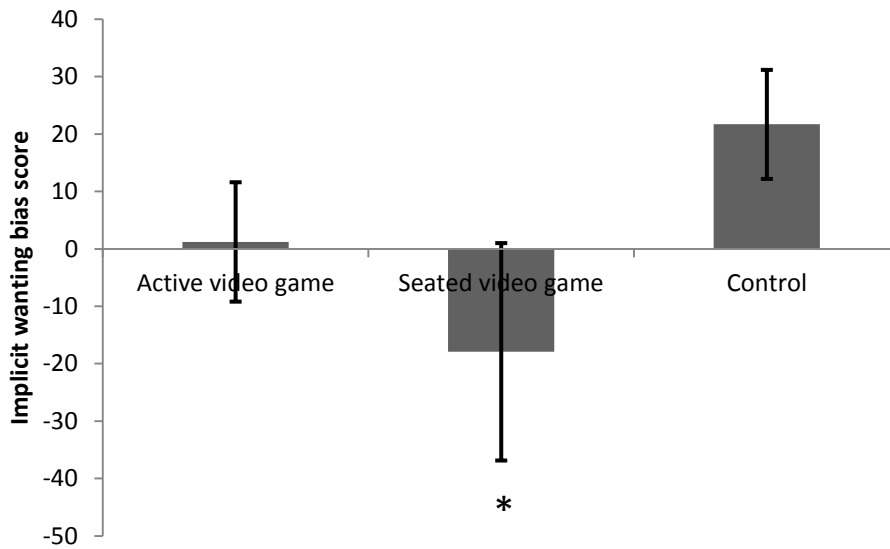
Data are expressed as mean  $\pm$  SEM. Comparisons between groups were measured by ANOVA for repeated measures. \*Significantly different from control condition ( $P = 0.04$ ).  $n = 25$ . Note: A positive score indicates a relative preference for high vs. low fat foods. A negative score indicates a relative preference for low vs. high fat foods. A score of zero indicates an equal preference.

**Figure 7.** Choice frequency bias for high fat vs. low fat foods between experimental conditions.



Data are expressed as mean  $\pm$  SEM. Comparisons between groups were measured by ANOVA for repeated measures. \*Significantly different from control condition ( $P = 0.03$ ).  $n = 25$ . Note: A positive score indicates a relative preference for high vs. low fat foods. A negative score indicates a relative preference for low vs. high fat foods. A score of zero indicates an equal preference.

**Figure 8.** Implicit wanting bias for sweet vs. savoury foods between experimental conditions.



Data are expressed as mean  $\pm$  SEM. Comparisons between groups were measured by ANOVA for repeated measures. \*Significantly different from control condition ( $P = 0.04$ ).  $n = 25$ . Note: A positive score indicates a relative preference for sweet vs. savoury fat foods. A negative score indicates a relative preference for savoury vs. sweet fat foods. A score of zero indicates an equal preference.