Active video games and energy balance in male adolescents: a randomized crossover trial

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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 ± SD age: 14.5 ± 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 (~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 (~6%; $P > 0.49$) and 3 d after the experimental conditions (~3%; $P > 0.82$). No significant differences were observed in absolute energy intake immediately after the conditions (~2%; $P > 0.94$) or in absolute energy intake 24 h (~5%; $P > 0.63$) and 3 d (~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 as NCT01655901.

Keywords: exergaming | appetite | energy intake | energy expenditure | food | obesity | teenagers

Article:

ABBREVIATIONS: AVG, active video game; PAEE, physical activity energy expenditure; RMR, resting metabolic rate; TEE, total energy expenditure; VAS; visual analog scale

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)[4] 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).

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 (±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 ≥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.

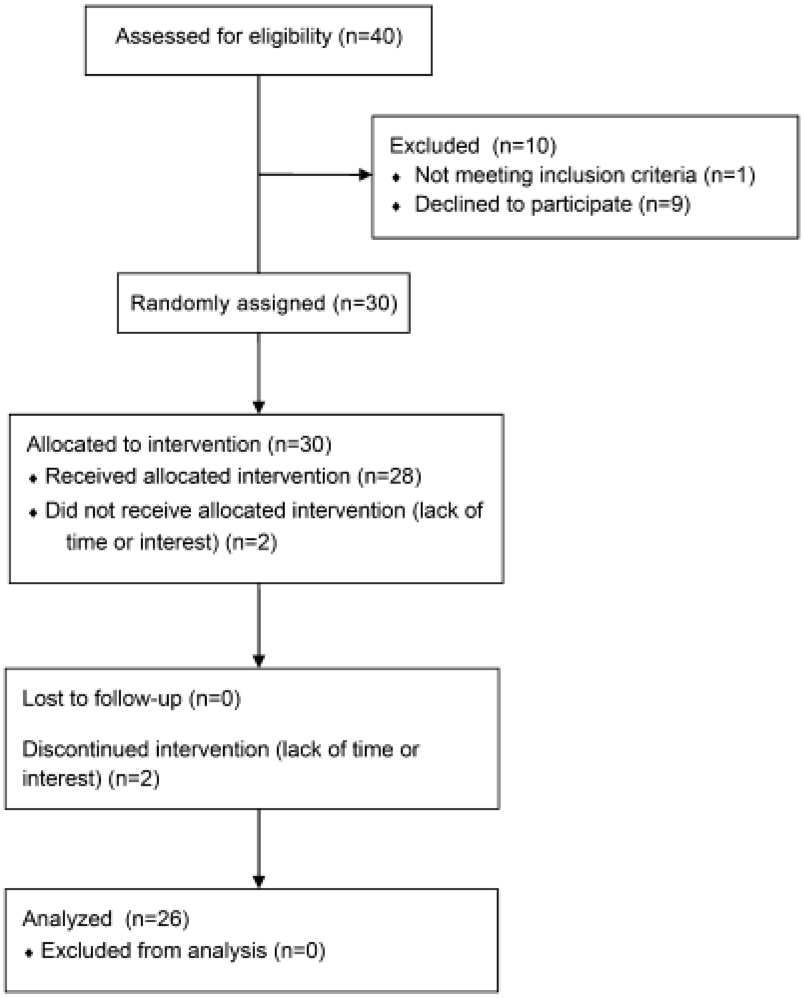

FIGURE 1. Flowchart of participants during the active video game intervention study.

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.

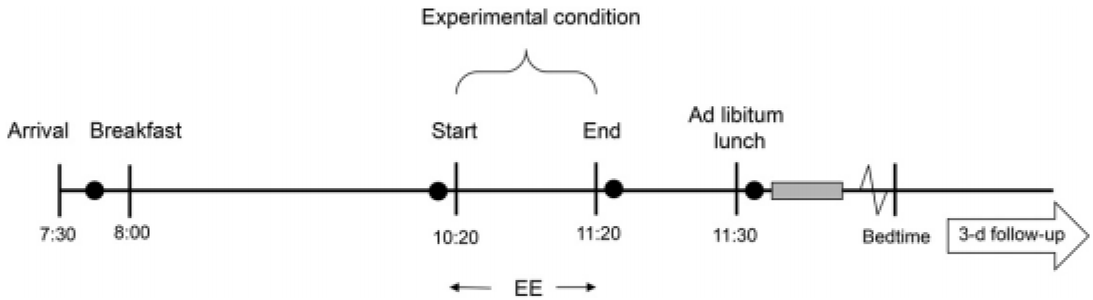

FIGURE 2. Overview of the study protocol. Black dots = visual analog scales; gray rectangle = food menu. EE, energy expenditure.

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). 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 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 ≥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):

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

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.

TABLE 1. Descriptive characteristics of participants (*n* = 26)[1]

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

[1] Values are means ± SDs.

Energy expenditure

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

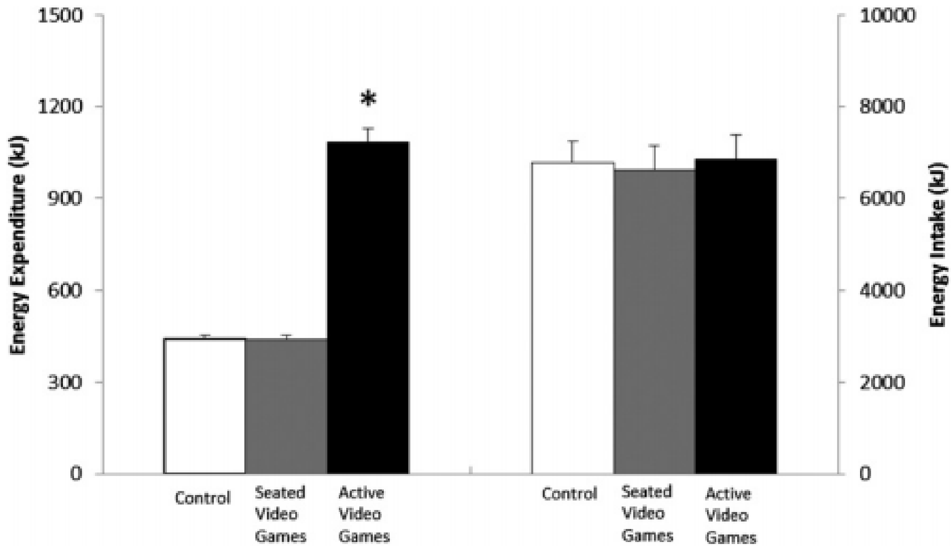

FIGURE 3. Energy expenditure during the three 1-h experimental conditions and spontaneous energy intake from the ad libitum lunch offered on completion of each condition. Values are means ± SEMs; $n = 26$. Comparisons between groups were analyzed by ANOVA for repeated measures, and Tukey's post hoc test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

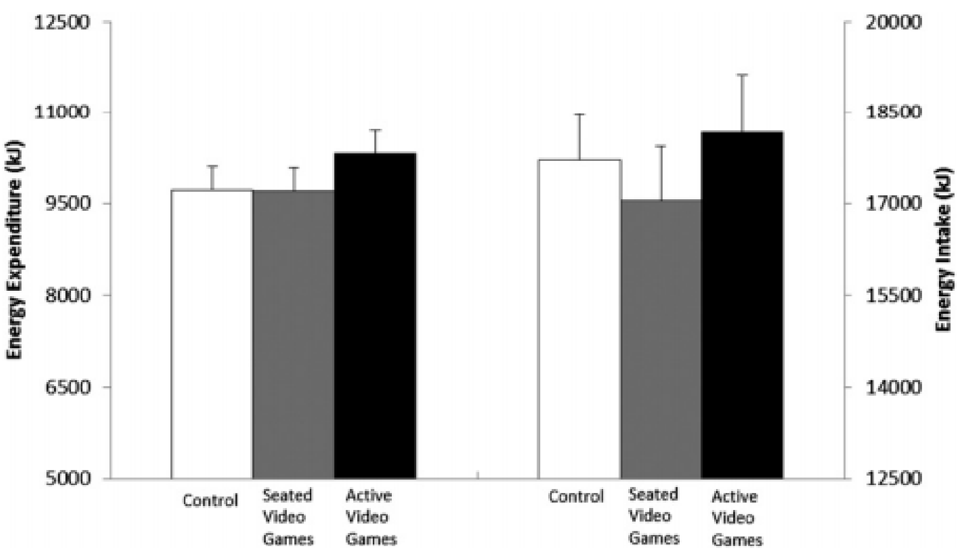

FIGURE 4. Twenty-four-hour energy expenditure and intake associated with the 3 experimental conditions. Values are means ± SEMs; $n = 26$. Comparisons between groups were analyzed by ANOVA for repeated measures, and Tukey's post hoc test was used to contrast mean differences. There were no significant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

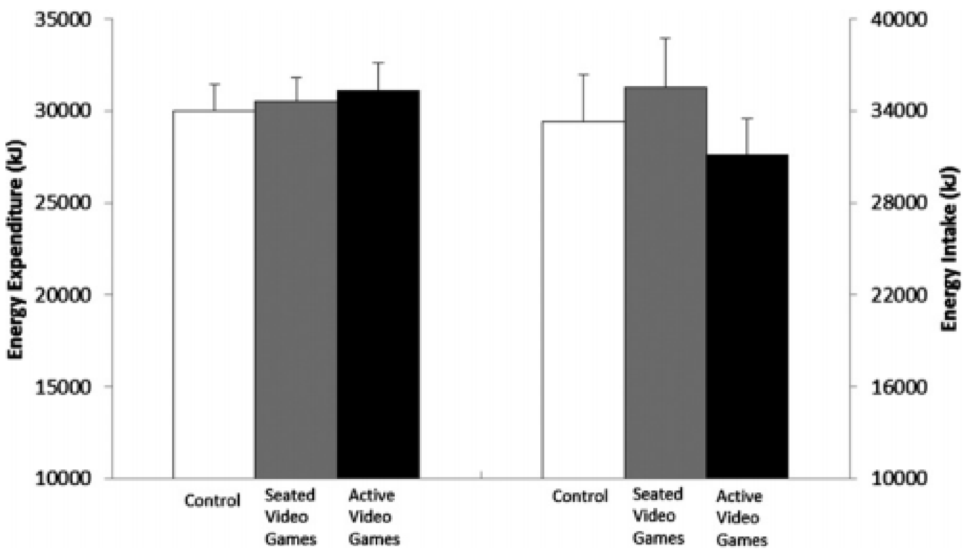

FIGURE 5. Energy expenditure and intake for 3 d after the experimental conditions. Values are means ± SEMs; *n* = 26. Comparisons between groups were analyzed by ANOVA for repeated measures, and Tukey's post hoc test was used to contrast mean differences. There were no significant differences between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

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 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 (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 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.

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