ARTICLE

Physiologic Responses and Energy Expenditure of Kinect Active Video Game Play in Schoolchildren

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Objective: To evaluate the physiologic responses and energy expenditure of active video gaming using Kinect for the Xbox 360.

Design: Comparison study.

Setting: Kirkby Sports College Centre for Learning, Liverpool, England.

Participants: Eighteen schoolchildren (10 boys and 8 girls) aged 11 to 15 years.

Main Exposure: A comparison of a traditional sedentary video game and 2 Kinect activity-promoting video games, *Dance Central* and *Kinect Sports Boxing*, each played for 15 minutes. Physiologic responses and energy expenditure were measured using a metabolic analyzer.

Main Outcome Measures: Heart rate, oxygen uptake, and energy expenditure.

Results: Heart rate, oxygen uptake, and energy expenditure were considerably higher ($P < .05$) during activity-promoting video game play compared with rest and sedentary video game play. The mean (SD) corresponding oxygen uptake values for the sedentary, dance, and boxing video games were 6.1 (1.3), 12.8 (3.3), and 17.7 (5.1) $mL \cdot min^{-1} \cdot kg^{-1}$, respectively. Energy expenditures were 1.5 (0.3), 3.0 (1.0), and 4.4 (1.6) $kcal \cdot min^{-1}$, respectively.

Conclusions: *Dance Central* and *Kinect Sports Boxing* increased energy expenditure by 150% and 263%, respectively, above resting values and were 103% and 194% higher than traditional video gaming. This equates to an increased energy expenditure of up to 172 $kcal \cdot h^{-1}$ compared with traditional sedentary video game play. Played regularly, active gaming using Kinect for the Xbox 360 could prove to be an effective means for increasing physical activity and energy expenditure in children.

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LOW LEVELS OF PHYSICAL ACtivity have been associated with obesity risk.[1] Physical activity guidelines in the United Kingdom[2] state that children and young adults should undertake a range of moderate- to vigorous-intensity activities for at least 60 minutes per day, but most fall well below this recommendation.[3] Many factors are believed to contribute to the shortfall of activity levels in children, including an increase in competing sedentary activities, particularly television viewing and other electronic media use.[4] Video games, especially, are playing a greater part in the lives of young people in developed countries; in the United Kingdom alone it has been reported that up to 2 hours per day are dedicated to such activities.[5]

Video gaming has been attributed as a factor in reduced activity levels and childhood obesity risk[6]; however, the past decade has seen the development of activity-promoting gaming systems, most notably the Nintendo Wii, which was launched in 2006. Compared with traditional sedentary video game play, active video gaming encourages considerably more movement and could therefore help children increase their physical activity levels.[7]

Several previous studies[8-11] have examined the effects on physical activity levels and energy expenditures in children of several different active video games, such as *Dance Dance Revolution*, *EyeToy* games for the Sony PlayStation, and Nintendo Wii active sport simulations. In general, light to moderate increases in physical activity have been observed, as well as considerable increases in energy expenditure.

Recently, a new technology in active video gaming, Kinect for the Microsoft Xbox 360, has entered the active game play market. Unlike most previous forms of active video gaming, Kinect differs in that it uses a webcam-style sensor device and software technology that allows the player to inter-

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Table 1. Physical Characteristics of Study Participants

Characteristic	All (N = 18)	Boys (n = 10)	Girls (n = 8)
	Mean (SD)[a]		
Age, y	13.4 (1.2)	13.5 (1.5)	13.3 (0.7)
Height, cm	156.6 (10.6)	159.0 (12.3)	153.7 (7.7)
Weight, kg	52.9 (15.7)	53.5 (18.0)	52.2 (13.6)
BMI	21.3 (4.5)	20.7 (4.4)	22.0 (4.9)
BMI, percentile	59.7 (34.3)	56.4 (35.5)	63.8 (34.7)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

[a] Values in parentheses equal 1 SD.

act directly with the Xbox 360 without the need for a game controller. As such, this may promote more whole-body activity as opposed to just hand and arm movement.

This study was designed to evaluate the physiologic responses and energy expenditure requirement of this new video-gaming technology. It was hypothesized that active video game play using Kinect would generate considerably greater energy expenditures and physiologic responses compared with sedentary gaming.

METHODS

PARTICIPANTS

Eighteen children (10 boys and 8 girls) between the ages of 11 and 15 years were recruited for this study from Kirkby Sports College, a secondary education provider to 1200 local pupils aged 11 to 16 years in the Kirkby district of Liverpool, England. On completion of a health screening form, all participants were deemed healthy, with no condition that could affect normal physiologic responses to physical activity. Ethics approval for this study was obtained by the University of Chester's Faculty of Applied Sciences Research Ethics Committee. Informed consent forms were signed by the participant and a parent or guardian.

PROCEDURES

A repeated-measures design was used to compare physiologic and energy expenditure measurements during rest, sedentary gaming, and the 2 Kinect active video games, *Dance Central* and *Kinect Sports Boxing*, which all participants completed in the same order. Between-group measures were made to identify differences between the sexes.

Measurements

Height and weight were measured and body mass index (BMI) was calculated in accordance with standard anthropometric techniques (weight in kilograms divided by height in meters squared).[12] Participants' height and weight were recorded to the nearest 0.5 cm and 0.1 kg, respectively, and age- and sex-specific growth charts were used to calculate BMI percentiles.[13]

Physiologic Responses and Energy Expenditure

Oxygen uptake ($\dot{V}O_2$) and energy expenditure were measured at rest and during all video game play by a metabolic analyzer (K4 b^2; Cosmed). In accordance with validation by the analyzer,[14,15] an 18-mm flowmeter was used for measuring resting energy expenditure and a 28-mm flowmeter was used during physical activity. Before each testing session, the metabolic analyzer was calibrated in accordance with the manufacturer's recommendations.[16] The $\dot{V}O_2$ measurements were collected at 30-second intervals during rest and with each breath during both sedentary and active game play. Heart rate was measured continuously using chest strap telemetry (Polar Electro).

As in previous studies,[11,17] resting energy expenditure was measured for 20 minutes in a supine position. Participants had been instructed to fast and to abstain from caffeinated drinks and vigorous exercise for at least 2 hours before testing.

Video Game Activities

Three different video games were evaluated: *Project Gotham Racing 4*, a sedentary seated car-racing simulation game played using a handheld controller, and 2 Kinect active video games, *Dance Central* and *Kinect Sports Boxing*. In *Dance Central,* the participant mirrored the moves of an on-screen dancer, earning points in the process, and *Kinect Sports Boxing* placed the participant into a 3-round boxing bout against a computer opponent. Each of the 3 video games was played for 15 minutes, consistent with previous research,[17-19] with a 5-minute game familiarization period before data collection. After each game the participants rested for 5 minutes, during which time they could drink water. All games were completed in the same order as in previous studies,[9,11,17-19] beginning with the inactive car-racing game followed by *Dance Central* and *Kinect Sports Boxing*. The easiest difficulty level was selected for all games, which were projected onto a 178-cm screen in an exercise room. The Kinect sensor was recalibrated for each new participant before active video game play.

DATA ANALYSIS

Descriptive statistics, including mean (SD), were calculated for all key variables. Comparisons of descriptive data according to sex were made using independent, 2-tailed t tests for body weight and BMI and Mann-Whitney tests for age and weight, for which normal distributions were not observed. One-way repeated-measures analysis of variance was used to compare the cardiorespiratory and energy expenditure effects of different gaming conditions, with post hoc analysis using multiple paired t tests. Statistical significance was set at $P \leq .05$, and all statistical analysis was performed using commercial software (SPSS for Windows, version 17; SPSS Inc).

RESULTS

Demographic and anthropometric data are summarized in **Table 1**. The age- and sex-adjusted BMI percentile was 59.7 (34.3). Twelve of the children were considered to be of normal weight, 4 were obese, 1 was overweight, and 1 was underweight. No statistically significant differences between the sexes were noted.

Significant increases were observed in heart rate (**Figure 1**), $\dot{V}O_2$ (**Table 2**), and energy expenditure (**Figure 2**) during all gaming conditions compared with both rest and sedentary game play ($P \leq .05$).

Dance Central and *Kinect Sports Boxing* elicited mean heart rates of 118 beats · min^{-1} and 131 beats · min^{-1}, respectively. These were, respectively, 53% and 70% higher than resting heart rate ($P < .001$) and 34% and 48% higher than sedentary game play ($P < .001$). Heart rates were

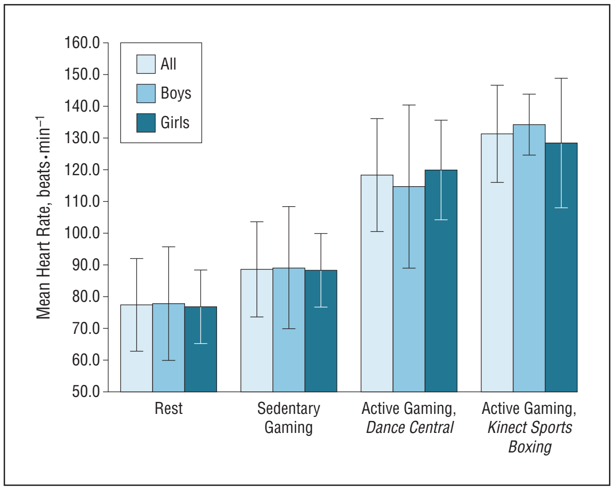

Figure 1. Mean heart rate during rest and game modes. Whiskers indicate standard deviation.

Table 2. $\dot{V}O_2$ During Test Conditions

	Mean (SD)			
	$\dot{V}O_2$, mL · min^{-1} · kg^{-1}			
Characteristic	Rest	Sedentary Project Gotham Racing	Active *Dance Central*	Active *Kinect Sports Boxing*
All	4.4 (0.8)	6.1 (1.3)	12.8 (3.3)	17.7 (5.1)
Boys	4.8 (0.7)	6.4 (1.2)	13.6 (2.9)	20.7 (2.7)
Girls	3.9 (0.7)[a]	5.8 (1.4)	12.0 (3.7)	13.9 (5.0)[a]

Abbreviation: $\dot{V}O_2$, oxygen uptake.
[a]Significantly lower in girls vs boys ($P \leq .05$).

11% greater during *Kinect Sports Boxing* compared with *Dance Central* (P = .03).

During *Dance Central*, the mean $\dot{V}O_2$ was 12.8 mL · min^{-1} · kg^{-1}, 191% higher than at rest ($P < .001$) and 110% higher than during sedentary gaming ($P < .001$). Compared with *Dance Central*, a considerably higher $\dot{V}O_2$ (P = .01) of 17.7 mL · min^{-1} · kg^{-1} was measured during *Kinect Sports Boxing*, which was 302% higher than at rest ($P < .001$) and 190% higher than during sedentary gaming ($P < .001$).

There were no significant sex differences in $\dot{V}O_2$ during *Dance Central*. However, $\dot{V}O_2$ was higher for boys at rest (P = .04) and during *Kinect Sports Boxing* (P = .003).

Mean energy expenditure increased from a mean resting value of 1.2 (0.3) kcal · min^{-1} to 1.5 (0.3) kcal · min^{-1} during sedentary video game play (P = .001). During active video game play, mean energy expenditures further increased to 3.0 (1.0) kcal · min^{-1} and 4.4 (1.6) kcal · min^{-1} during *Dance Central* and *Kinect Sports Boxing*, respectively ($P < .001$). Significant differences ($P < .001$) in energy expenditures were also observed between sedentary gaming and both active games, with respective increases of 103% and 194% for *Dance Central* and *Kinect Sports Boxing*.

Energy expenditure differences (P = .03) were also observed between sexes during the *Kinect Sports Boxing* active game, with an expenditure of 5.1 kcal · min^{-1} for the boys compared with 3.4 kcal · min^{-1} for the girls (Figure 2). This difference remained significant (P = .004) when caloric expenditure was normalized for body weight.

Energy expenditures normalized for body weight were 1.3 (0.3), 1.8 (0.4), 3.6 (0.9), and 5.1 (1.5) kcal · kg^{-1} · h^{-1}, respectively, during rest, sedentary gaming, *Dance Central*, and *Kinect Sports Boxing*.

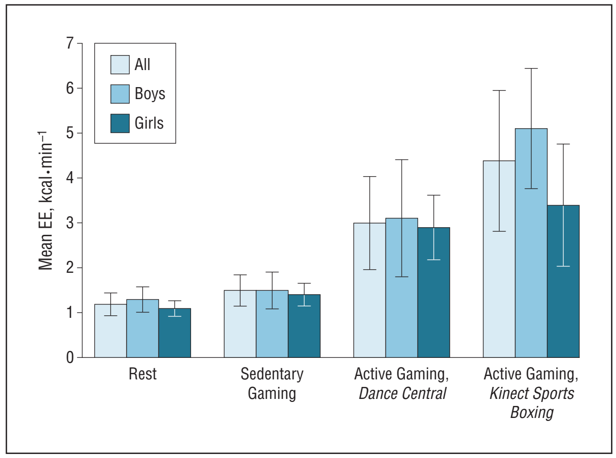

Figure 2. Mean energy expenditure (EE) during rest and game modes.

COMMENT

Video game play using Kinect for the Xbox 360 produced considerably higher heart rate and $\dot{V}O_2$ responses and, thus, energy expenditures compared with rest as well as sedentary game play. Sedentary video game play also generated marginal but statistically significant cardiorespiratory and energy cost increases from rest; however, as seen in previous research,[20,21] these responses did not achieve physical activity intensity recommendations.

The mean heart rate of 118 beats · min^{-1} observed during *Dance Central* was equivalent to 59% of adolescent-specific age estimated maximum heart rate (HRmax),[22] and this corresponded with heart rate responses during *Dance Dance Revolution* in other active game studies.[19,23] *Kinect Sports Boxing* generated the highest mean heart rate of 131 beats · min^{-1}, equivalent to 66% HRmax, and this is consistent with the range of 121 to 140 beats · min^{-1} reported in 5 studies[10,19,23-25] that examined physiologic responses during *Wii Boxing* active game play.

Whether such heart rates are adequate for increasing cardiovascular fitness is debatable. Although the American College of Sports Medicine criterion of a 55% to 65% HRmax has been cited[26] as sufficient for increasing cardiovascular fitness, a review[27] of endurance training in young people indicated that training intensities of more than 80% HRmax would be needed to improve cardiovascular fitness in children.

According to the classification of the energy costs of physical activity,[28] moderate to vigorous activity, as recommended for children on most days of the week, equates to an activity level of 3 to 6 metabolic equivalents (METs). Child-specific METs (child-METs), which have been measured by dividing the $\dot{V}O_2$ of the respective activity by resting oxygen consumption,[8] ranged from 2.0 to 5.0 child-

Table 3. Selected Sporting Activities With Comparable Physical Activity Levels to *Dance Central* and *Kinect Sports Boxing*[a]

3 METs	4 METs
Ballroom dancing	Cycling, <16 km/h
Body boarding	Gymnastics
Bowling	Horseback riding
Rowing, 3.2-6.2 km/h	Table tennis
Sailing	Volleyball
Stationary cycling, 50 W	Walking, 4.8 km/h
Walking, 3.2 km/h	Water aerobics

Abbreviation: METs, metabolic equivalents.
[a] Adapted from the Compendium of Physical Activities.[30]

METs during 17 different active video games in a recent systematic review[29] of activity-promoting video games. Predictions of child-METs for the video dance simulation *Dance Dance Revolution* have varied considerably in other studies, from less than 2 child-METs[23] to 3.9 child-METs.[8] *Dance Central* using Kinect was estimated as 2.91 child-METs, which is considered to be of light intensity and comparable to nongaming activities, such as ballroom dancing, bowling, and walking at 3.2 km/h (**Table 3**).

At 4.03 child-METs, *Kinect Sports Boxing* was deemed to be a moderate-intensity activity and comparable to playing table tennis, volleyball, or walking at 4.8 km/h. It is likely that a greater contribution of upper body and limb movement during *Kinect Sports Boxing* resulted in higher oxygen costs for this active video game compared with *Dance Central,* as has been similarly demonstrated during *Wii Boxing* compared with *Wii Bowling* and *Wii Tennis*.[10]

The oxygen demands of *Kinect Sports Boxing* were considerably greater than those of *Wii Boxing* in earlier studies.[10,19,23,25] The absence of a game controller could be a factor in the higher levels of physical activity exhibited during *Kinect Sports Boxing* compared with *Wii Boxing*. Higher activity levels have been reported for the boxing simulation *EyeToy Knockout*, at 5 child-METs[8]; however, this game was played for only 5 to 8 minutes, which could explain shorter but more intense bouts of activity.

An energy expenditure of 3.0 $kcal \cdot min^{-1}$ or 3.6 $kcal \cdot kg^{-1} \cdot h^{-1}$ demonstrated during *Dance Central* was 150% above resting values and similar to energy cost increases seen during *Dance Dance Revolution* in previous studies.[17,23,26] An energy expenditure of 4.4 $kcal \cdot min^{-1}$ or 5.1 $kcal \cdot kg^{-1} \cdot h^{-1}$ during *Kinect Sports Boxing* was 263% above resting values, significantly higher than reported for *Wii Boxing* in earlier studies.[10,19]

There have been considerable variances, in both absolute and weight-adjusted values, for the energy cost of active video game play in children, ranging from 1.6 to 6.5 $kcal \cdot min^{-1}$ and from 2.6 to 9.0 $kcal \cdot kg^{-1} \cdot h^{-1}$. Many confounding factors exist, however, such as game mode, level, and activity duration, as well as child weight in studies where energy expenditure has not been normalized for weight. Direct comparisons between studies, therefore, may not always be appropriate.

Although activity levels and energy expenditures during active gaming may be lower than during traditional sports,[18] it has been suggested that active video gaming could fill an energy gap[11] that may be responsible for the increase in childhood obesity.

With an increase of 1.5 $kcal \cdot min^{-1}$ and 2.9 $kcal \cdot min^{-1}$, respectively, over sedentary game play, the substitution of *Dance Central* or the more physically demanding *Kinect Sports Boxing* in place of traditional nonactive gaming would yield an additional 91 to 172 $kcal \cdot h^{-1}$. If claims are accurate that UK children spend, on average, 1.9 hours playing video games daily,[5] the conversion of daily sedentary gaming to *Dance Central* or *Kinect Sports Boxing* could expend an additional 173 to 326 $kcal \cdot d^{-1}$. The effect on weight of daily *Kinect Sports Boxing* play in place of sedentary game play could be up to 0.3 kg per week based on our sample. The substitution of 1 hour of traditional video game play daily with *Dance Central* could affect weight by a more conservative 0.08 kg per week.

If such virtual activities are to play a part in weight management interventions, they need to be adhered to long term. Whether children, particularly overweight children, are capable of sustaining active game play long enough and on a regular basis to elicit meaningful levels of physical activity, energy expenditure, and, potentially, weight loss are questionable. The few trials[31-34] that have considered the longer-term effects of active gaming on physical activity levels and energy expenditures in children have not extended beyond 28 weeks and have reported, at best, mixed results.

It has been suggested that active gaming may be more entertaining and enjoyable than traditional forms of physical activity[35]; however, further extensive research is required to examine active video game play adherence. Motivation to play, enjoyment, competition, social interaction, and network play as well as game sophistication and diversification may all be factors that influence long-term active game play. Such research may help to establish to what degree active video gaming may be used in the fight against childhood inactivity and obesity.

Although it is unlikely that active video game play can single-handedly provide the recommended amount of physical activity for children or expend the number of calories required to prevent or reverse the obesity epidemic, it appears from the results of this study that Kinect active game play can contribute to children's physical activity levels and energy expenditure, at least in the short term.

Although this study demonstrated significant increases in energy expenditures for Kinect active gaming, one limitation of this research was that the sample size was small; hence, the influence of other factors on the results, such as age, cannot be discounted. The activities were also not randomized, and it could be argued that some order effect exists with this method. Furthermore, the study was not conducted in the home environment; however, there is no reason to believe that the results would have been different if this had been the case.

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Conflict of Interest Disclosures: None reported.

Online-Only Material: Listen to an author interview about this article, and others, at http://bit.ly/MW1WVH.

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