ARCHIVES
of Exercise in Health and Disease

Original Research Manuscript

Comparing the Physiological Cost of Step-Powered Video Gaming, Sedentary Video Gaming, and Self-Paced Ambulatory Activity in University Students

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Objectives: Methods intended to convert inactive video gaming to active video gaming have gained popularity in recent years. This study compared the physiological cost of a new peripheral device that uses interactive steps to provide movement within a video gaming system against sedentary video gaming and self-paced ambulatory activity in university students (i.e., ages 19 to 29 years). ***Methods:*** Nineteen adults (i.e., 9 males and 10 females) performed six 10-minute activities, namely, self-paced leisurely walking, self-paced brisk walking, self-paced jogging, two forms of sedentary video gaming, and step-powered video gaming. Each participant performed the activities in a random order. The physiological cost of each activity was measured using Actiheart. ***Results:*** The energy expenditure of step-powered video gaming (i.e., 388.8 $kcal.h^{-1}$) was comparable to the energy expended during brisk walking (i.e., 373.8 $kcal.h^{-1}$); additionally, step-powered video gaming used a higher amount of energy than sedentary video gaming (i.e., 124.1 $kcal.h^{-1}$) and a lower amount of energy than jogging (i.e., 694.5 $kcal.h^{-1}$). ***Conclusion:*** Overall, step-powered video gaming could be used as an entertaining and appealing tool to increase physical activity, but it should not be used as a complete substitute for traditional aerobic exercise, such as jogging. *Arch Exerc Health Dis* 2 *(1):81-88, 2011*

Key Words: video gaming; physical activity; general ergonomics; physical work capacity; Actiheart

INTRODUCTION

Based on current recommendations by the healthcare community, adults should engage in at least 30 minutes of moderate intensity physical activity on a minimum of 5 days per week (7) or accrue a minimum physical activity based energy expenditure of 150 kilocalories (kcal) per day (i.e., 1,000 kcal per week) (11). However, only 6% of men and 4% of women in the United Kingdom (UK) achieve these recommended guidelines when the physical activity is measured using accelerometry-based monitors (5). Interest in promoting physical activity to different populations through the conversion of typically sedentary leisure behaviours to more physically active pursuits has been growing (6). In the UK, 3.4 million (i.e., 54%) of 16 to 24 year old individuals play sedentary video games three to seven times per week with each session lasting an average of 1.6 hours (17). The combination of video games and exercise appears to be one approach that could encourage university students to be more active and increase energy expenditures during typically sedentary activities.

A body of research supports the energy expending potential of physically active video games over sedentary equivalents for children and adults (8, 9, 10, 14, and 19). For example, as compared to rest, energy expenditure in participants increased by 273 kJ/hr and 382 kJ/hr when using active games, such as the EyeToy (Sony, Tokyo, Japan) and Dance Dance Revolution (DDR; Konami Digital Entertainment, CA, USA), respectively (12). Maddison et al. (14) found that active video gaming increased energy expenditure by 1.3 to 4.9 kcal/min as compared to inactive gaming, but the amount of increase depended on the console and the game used. Lastly, Graves et al. (8) reported energy expenditure during active video gaming using Nintendo Wii Sports (Nintendo Co Ltd, Minami-ku Kyoto, Japan) was 51% greater than that of sedentary gaming; however, active gaming used less energy than

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authentic versions of bowling and tennis.

While this research is promising, it tends to focus on games used on specific consoles. Individuals may potentially lose motivation for sustained use of such games due to over familiarisation with a game, thereby impacting any associated health benefits (16). A newly developed peripheral device, jOG (New Concept Gaming Co., Ltd., Liverpool, United Kingdom), which encourages step-powered video gaming, may negate such over-familiarisation because it is compatible with multiple video games that can be used on the PlayStation 2, PlayStation 3 (Sony Co, Tokyo, Japan), and Nintendo Wii video game consoles. However, no published research has evaluated the physiological response of adults to step-powered gaming with jOG. In addition, no comparisons have been made to other forms of inactive and active gaming or typical ambulatory activities within the young adult population.

Therefore, the aim of this study was to compare the physiological cost of step-powered video gaming, sedentary video gaming, and self-paced ambulatory activity with university students.

METHODS

Participants

A convenience sample of nineteen university students (i.e., 9 males and 10 females) ages 19 to 29 years (mean age = 23.6 ± 3.4 years) provided informed written consent to participate in this study (Table 1). All participants were free from illness and movement impairments, which were the exclusion criteria in this study, and were recruited via word of mouth. The study also received institutional ethical approval. The data was collected between October and December 2008.

Procedures

Anthropometry

Body mass (to the nearest 0.1 kg) and stature (to the nearest 0.1 cm) were measured using a calibrated mechanical flat scale (Seca Ltd, Birmingham, UK) and a portable stadiometer (Leicester Height Measure, Seca Ltd, Birmingham, UK), respectively. Using standardised anthropometric techniques, these measurements were taken while the participants were wearing light clothing and no shoes (13).

Familiarisation

On a different day prior to the experimental trial and following 2 hours of fasting and 5 minutes of supine rest, resting energy expenditure (REE) and resting heart rate (RHR) were measured for 10 minutes using an Actiheart sensor (Cambridge Neurotechnology Ltd, Papworth, UK). Once the resting measurements had been completed, participants were familiarised with the video games that were used in the experimental trial both in the sedentary and step-powered modes.

Since all of the participants were right handed, the video game consoles were set up to accommodate this preference. For sedentary video gaming, seated participants practiced using a snowboarding game (SSX3; Electronic Arts, San Mateo, California, USA) on the PlayStation 2 and *Lego Indiana Jones: The Original Adventures* (LucasArts, San Diego, California, USA) on the Nintendo Wii. For the step-powered video gaming (i.e., using the jOG system), standing participants practised using *Lego Indiana Jones*. In a randomised order, participants practiced each game for 5 minutes. Participants also wore an Actiheart sensor during familiarisation.

Experimental trial

In randomised order, participants completed six 10-minute activities with 5 minutes of seated rest between each activity. The activities included self-paced leisurely walking, self-paced brisk walking, self-paced jogging, sedentary video gaming (i.e., with SSX3 for PlayStation 2), sedentary video gaming (i.e., with *Lego Indiana Jones* for Nintendo Wii) and step-powered video gaming (i.e., with *Lego Indiana Jones* for Nintendo Wii). All activities were performed in an air-conditioned indoor laboratory facility at the university. For the self-paced ambulatory activities, participants were instructed to walk leisurely, walk briskly, and jog on a 20 m running track that is similar to an outdoor athletic track in terms of design and surface at a pace that they could maintain for 10 minutes. The time in seconds necessary for participants to get from the bottom of the running track to the top was measured throughout the 10-minutes, and speed was calculated by dividing distance (i.e., 20 m) by time. The average speed for each participant was obtained and converted into $km \cdot h^{-1}$. The total time spent in the self-paced activities was 30 minutes.

For the sedentary video gaming, i.e., using a PlayStation 2 snowboarding video game, participants used a standard handheld controller to manipulate the onscreen character movements. Participants competed against opponents supplied by the computer game in a downhill race, which was one specific mode in the game; thus, the game was externally paced. When a race finished, participants were instructed to restart the race and repeat this process for the duration of the trial. For sedentary and step-powered video gaming using *Lego Indiana Jones* on the Nintendo Wii, participants played the same predetermined level, which was identified in advance. The game required participants to use a handheld controller to manipulate a character through a level of game play whilst destroying enemies provided by the computer game and collecting points. During step-powered gaming, participants were additionally required to step on the spot in order to activate the video game controller and thus manipulate the movements of the onscreen character. Game play on *Lego Indiana Jones* was self-paced, and participants used the Wii remote and nunchuk attachment as specified in the game instructions and previously described (9). Total video gaming time for each participant was 30 minutes.

Peripheral device (jOG)

The investigated peripheral device is the jOG system, which is compatible with the Nintendo Wii. The standard set-up for the Nintendo Wii was used, and the console was connected to an overhead projector and displayed on a wall screen in front of the participants. The jOG peripheral device links a pedometer that is worn on the hip to the nunchuk controller and requires gamers to step in place in order to use the directional controls to generate onscreen character movement within the video game. For every step recorded by the pedometer, the gamer obtains 1-second of onscreen movement. Consequently, for continuous game play, sustained stepping is required.

Instrumentation

Actiheart

REE and physical activity energy expenditure (PAEE) were measured using an Actiheart monitor. The Actiheart monitor is a one-piece combined heart rate (HR) and movement sensor that has the primary purpose of predicting PAEE based on measurements of acceleration and HR (3). The sensor has a mass of 8 g and consists of two components, i.e., one component that is 7 mm thick with a diameter of 33 mm and another component that measures 5 x 11 x 22 mm. The two components are connected by a thin, flexible wire that is 100 mm in length. According to previous research, Actiheart is a reliable and valid tool for measuring HR and movement in adults during rest, walking, and running (3).

In the present study, an Actiheart monitor was attached to each participant with two electrocardiography (ECG) electrodes (52 x 54 mm; AgC1, Red Dot 2570, 3M). The medial electrode was attached to the skin at the base of the sternum, and the lateral electrode was place horizontally to the left side. The Actiheart wire connecting the two components was placed in a straight position but not taut. Prior to electrode attachment, participants prepared the skin at the electrode sites based on the Actiheart manufacturer guidelines (4). Specifically, each participants used a towel to rub the skin with enough vigour to remove the top layer. Normal redness was apparent but of no concern, and this process ensured sufficient detection of R wave signals by the sensor. Before each measurement period, the manufacturer recommended signal test was conducted to ensure that the HR signal was adequately detected. The Actiheart was set to the short-term recording mode, which records continuously over 15-second intervals during resting periods and experimental trials. The same monitor was used for all participants. The data was downloaded after each trial using a reader interface unit and analysed using the manufacturer's software (Actiheart v4.0.7, Cambridge Neurotechnology Ltd, Cambridge, UK).

Statistical analysis

REE ($j.kg^{-1}.min^{-1}$) and RHR (bpm) were averaged based on recorded measurements from the last 2 ½ minutes of collected data during the resting phase (9). For each activity and each participant, HR was measured and PAEE ($j.kg^{-1}.min^{-1}$) was estimated from the data collected by the Actiheart monitor using the Actiheart software (Actiheart version 4.0.7; 1). HR and PAEE were calculated using all data during the full 10 minutes of each activity. Total energy expenditure (TEE) was then calculated from PAEE by adding REE. Participant-specific metabolic equivalents (METS) were calculated for each trial by using the following formula: METS = TEE/REE (1). The estimated energy expenditure as calculated from the measurements from the Actiheart monitor was also used to estimate the number of kcal expended when participating in each activity for one hour by using the following formula: TEE X mass/1000/4.18 (15). Maximum HR (HR_{max}) was estimated for each participant by using the following formula: 205.8 – 0.685(age); this formula has been reported as the most accurate general equation for estimating HR_{max} in adults (18).

All data was statistically analysed using SPSS version 17. Initially, independent t-tests were conducted to investigate gender differences in the anthropometric data. The main analysis consisted of a repeated measures analysis of variance (gender (2) x trial (6)) for HR, TEE, METS, and kcal. Where needed, corrections for violations of sphericity were made using the Huynh-Feldt ($\varepsilon > 0.75$) or Greenhouse-Geisser epsilon ($\varepsilon < 0.75$). The α-level for determining

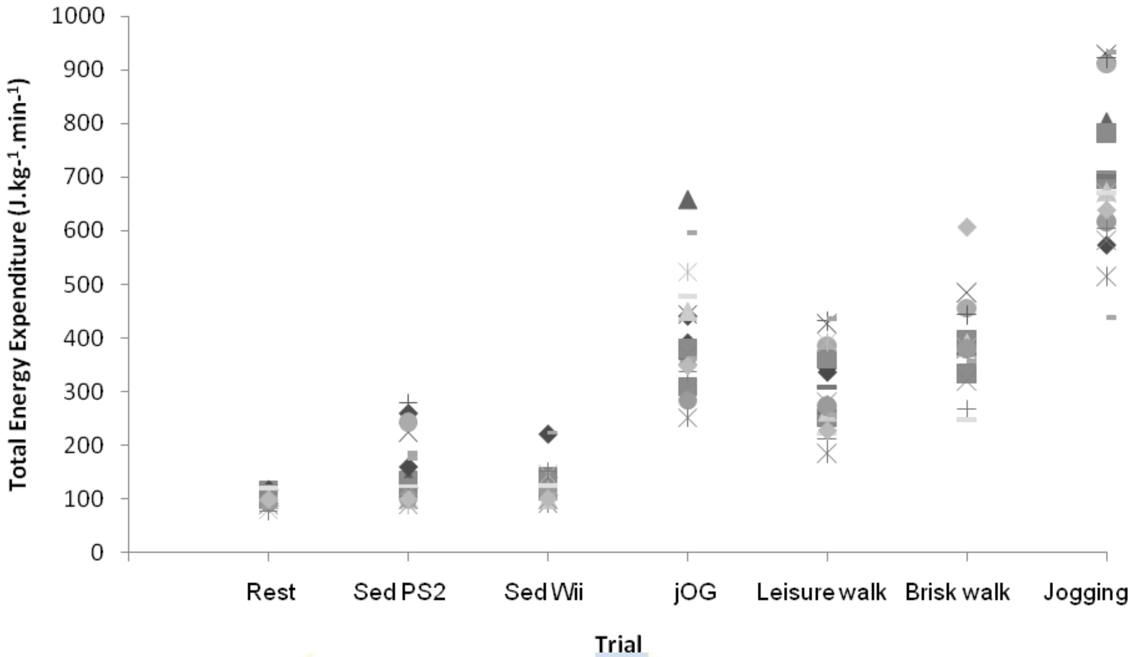

Figure 1: Variability in TEE across activities.

statistical significance was set at $p \leq 0.05$.

RESULTS

Descriptive Data

Several gender differences were observed in the data (Table 1). Males were taller, had a greater body mass, and jogged at a faster speed than females ($p < 0.01$). Male RHR was significantly lower than females ($p < 0.05$). No other significant differences were observed in the descriptive data.

Total Energy Expenditure (TEE)

Figure 1 shows the variability in TEE across the different trials. A significant trial main effect was observed ($p < 0.001$). Post hoc analyses revealed that TEE during step-powered video gaming was significantly higher than that during the other video gaming activities ($p < 0.01$). However, TEE during step-powered video gaming was significantly lower than jogging ($p < 0.01$). Step-powered video gaming expended 257.1 $j.kg^{-1}.min^{-1}$ and 278 $j.kg^{-1}.min^{-1}$ more TEE than sedentary PlayStation and sedentary Wii video gaming, respectively ($p < 0.01$).
The trial x gender interaction was also significant ($p < 0.01$). Contrast revealed that, compared to rest, male TEE was 69.2 $j.kg^{-1}.min^{-1}$ greater during sedentary PlayStation video gaming ($p < 0.01$) and 190.6 $j.kg^{-1}.min^{-1}$ greater during self-paced jogging ($p < 0.01$) as compared to that of females.

Metabolic Equivalents (METs) and kilocalories (kcal)

A significant trial main effect for METs ($p < 0.01$) and kcal ($p < 0.01$) was observed. Post hoc analyses indicated that the MET values and kcal expended during step-powered video gaming were significantly higher as compared to that of sedentary PlayStation video gaming, sedentary Wii video gaming, and leisurely walking; yet, it was significantly lower than that of jogging ($p < 0.01$). METs during step-powered interactive gaming were 2.7 and 2.9 METs higher than that of sedentary PlayStation and sedentary Wii video gaming, respectively, and comparable to brisk walking (4.0 METs; Table 2). Therefore, based on the results, one hour of step-powered video gaming would expend an extra 243.4 and 268.1 $kcal.h^{-1}$ as compared to sedentary PlayStation video gaming and sedentary Wii video gaming, respectively ($p < 0.01$; Table 3).
The trial x gender interaction for METs ($p < 0.05$) and kcal expended ($p < 0.001$) were also significant. Further investigation revealed that when compared to sedentary PlayStation video gaming, the MET values and kcal expended by males were lower during sedentary Wii gaming ($p < 0.05$) and higher during jogging (METS: $p < 0.05$; kcal: $p < 0.001$) as compared to those of females.

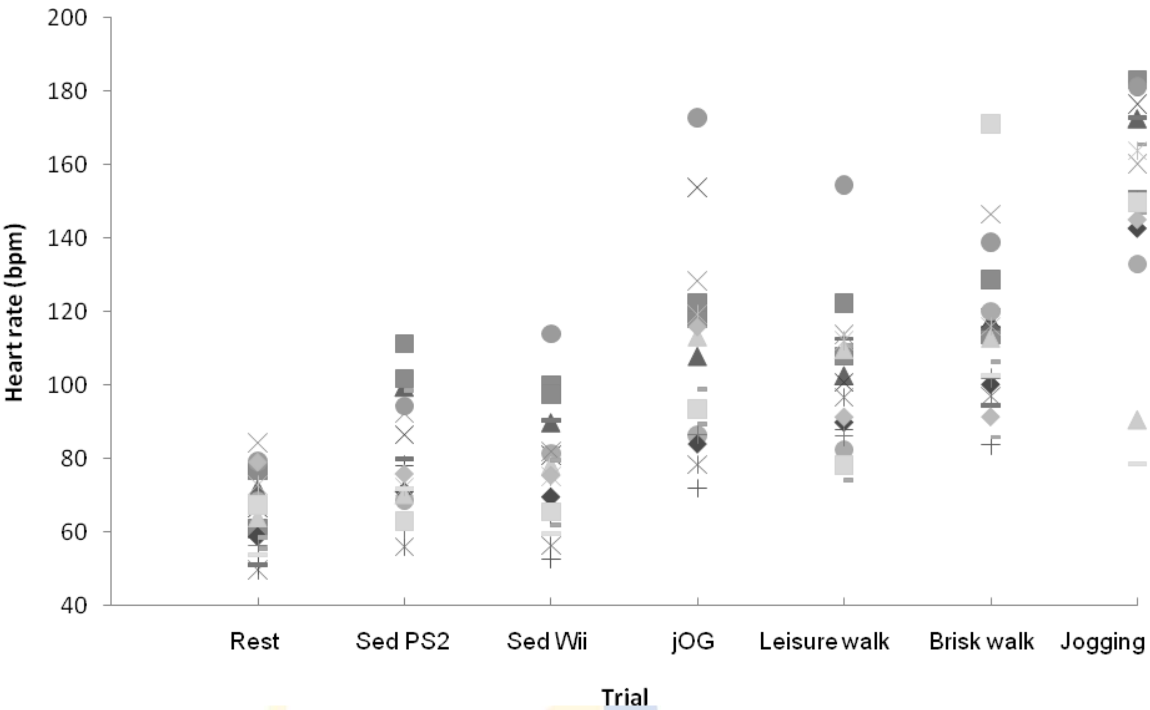

Figure 2: Variability in HR across activities.

Table 3 shows the estimated average time taken to expend 150 kcal. The results indicate that the time taken to expend 150 kcal during step-powered video gaming is significantly less than that of sedentary PlayStation video gaming, sedentary Wii video gaming, and leisurely walking ($p < 0.01$) and significantly greater than jogging ($p < 0.01$). In addition, males would take less time than females to expend 150 kcal during sedentary PlayStation video gaming and all ambulatory activities (Table 3).

Heart Rate (HR)

Figure 2 shows the variability in HR across the different activities. The trial main effect was significant ($p < 0.001$). Post-hoc analyses revealed that compared to step-powered video gaming, the participants' heart rate during rest, sedentary PlayStation video gaming, and sedentary Wii video gaming was significantly lower ($p < 0.01$) and significantly higher during jogging ($p < 0.01$). The trial x gender interaction was also significant. Contrast revealed that, compared to rest, males' HR was greater during sedentary PlayStation video gaming ($p < 0.05$) and when jogging ($p < 0.05$) compared to females'.

DISCUSSION

Active video games significantly increase in energy expenditure as compared to sedentary video games in young people (8, 9, 10, and 14). The physiological cost of active video gaming using the Nintendo Wii Fit has also been reported as significantly greater than sedentary video gaming but lower than that for treadmill exercise in adolescents, young adults, and older adults (10). However, beyond this study, little research examines the physiological responses to active gaming in older populations or compares such responses with those responses to exercise or authentic sports in the same sample population. Moreover, youth focused research has examined a small range of games for use on specific consoles, which may become boring over time due to over-familiarisation and discourage sustained use, thereby negatively impacting any long-term health benefits (16). This study examined the physiological responses to game play using a peripheral device (jOG) that encourages step-powered video gaming that can be used for multiple video games. Additionally, this study focused on university students and compared the findings to sedentary equivalents and more traditional ambulatory activities.

Energy expenditure and HR during step-powered video gaming (i.e., 406.3 $j.kg^{-1}.min^{-1}$ and 108.3 bpm, respectively) were significantly greater than that of

Table 1: Sample characteristics (mean ± SD)

	Males (n = 9)	Females (n = 10)	Group (n = 19)
Age (years)	22.7 ± 2.6	24.3 ± 4.0	23.6 ± 3.4
Stature (m)	1.79 ± 0.04**	1.65 ± 0.06**	1.71 ± 0.09
Body mass (kg)	73.6 ± 6.1**	61.2 ± 4.2**	67.1 ± 8.1
Body mass index (kg.m-2)	23.0 ± 1.6	22.6 ± 1.5	22.8 ± 1.5
Resting heart rate (bpm)	59.3 ± 8.2*	69.2 ± 10.7*	64.5 ± 10.6
Resting energy expenditure (j.kg-1.min-1)	97.7 ± 9.5	99.6 ± 13.9	98.7 ± 11.7
Leisure Walking (km.h-1)	4.8 ± 0.4	4.8 ± 0.7	4.8 ± 0.6
Brisk Walking (km.h-1)	6.2 ± 0.7	6.1 ± 0.7	6.1 ± 0.7
Jogging (km.h-1)	9.5 ± 0.6**	8.5 ± 0.4**	9.0 ± 0.7

Gender differences: * $p \leq 0.05$; ** $p \leq 0.001$

sedentary gaming on the PlayStation (i.e., 149.2 j.kg^{-1}.min^{-1} and 80.2 bpm, respectively), sedentary gaming on the Nintendo Wii (i.e., 128.4 j.kg^{-1}.min^{-1} and 77.7 bpm, respectively) and leisurely walking (i.e., 308.7 j.kg^{-1}.min^{-1} and 100.5 bpm, respectively). However, the energy expenditure and HR during step-powered video gaming is comparable to that of brisk over ground walking (i.e., 388.1 j.kg^{-1}.min^{-1} and 113 bpm) and lower than that of jogging (i.e., 714.5 j.kg^{-1}.min^{-1}; 150.7 bpm) in this sample of university students. The lower energy cost of step-powered gaming as compared to that jogging of is likely because fewer body movements and hence muscle contractions are required for the step-powered gaming as compared to jogging. This highlights the fact that such play is no substitute in terms of energy expenditure for traditional strenuous aerobic exercise, like jogging, and thus supports studies that have derived similar conclusions in child populations (8). Comparable energy costs to moderate intensity activities (Table 2), like brisk walking, suggests that step-powered gaming has the potential to contribute to daily, health benefiting physical activity recommendations for UK adults, i.e., at least 30 minutes of moderate intensity physical activity (7).

The energy expenditure comparisons between activity-based video gaming and jogging in this study are similar to those found by Graves et al. (10), who reported that active video gaming using Nintendo Wii Fit elicited energy expenditures of 178.8 to 345.3 j.kg^{-1}.min^{-1} (i.e., depending on activities in which the participant engaged), and jogging elicited energy expenditures of 764.7 j.kg^{-1}.min^{-1} in their sample of young adults. The present study found that the energy cost of step-powered gaming was similar to brisk walking; however, Graves et al. (10) reported self-paced brisk treadmill walking elicited significantly greater energy expenditure (i.e., 429.7 j.kg^{-1}.min^{-1}) than an aerobic activity session on Wii Fit that included step aerobics, hula hoops, and jogging (i.e., 345.3 j.kg^{-1}.min^{-1}). The difference in these findings is likely due to the fact that step-powered gaming is more continuous in nature than play on the short duration Wii Fit activities. Specifically, the rest periods between the Wii Fit activities lead to declines in VO_2 and hence energy expenditure.

The American College of Sports Medicine (ACSM) and the American Heart Association (AHA) (11) recommend a minimum of 150 kcal per day in physical activity based energy expenditure or approximately 1,000 kcal·wk^{-1} for adults. Based on group energy expenditure data expressed in kilocalories, one hour of step-powered video gaming on the investigated video game would expend

Table 2: Estimated METS for each of the six trials (mean ± SD)

Activity	Males (n = 9)	Females (n = 10)	Group (n = 19)
Sedentary PlayStation 2 gaming	1.9 ± 0.7*	1.2 ± 0.2*	1.5 ± 0.6
Sedentary Wii video gaming	1.4 ± 0.6	1.3 ± 0.3	1.3 ± 0.5
Step-powered Wii video gaming	4.3 ± 1.4	4.1 ± 1.0	4.2 ± 1.2
Leisure walking	3.5 ± 1.0	2.9 ± 0.8	3.2 ± 0.9
Brisk walking	4.2 ± 0.5	3.8 ± 1.1	4.0 ± 0.9
Jogging	8.4 ± 1.7*	6.4 ± 1.2*	7.3 ± 1.8

* Significant gender difference, $p < 0.01$

Table 3: Estimate of expended kcal during one hour of participation (mean ± SD) and average time taken to expend 150 kcal (T=150 min)

Activity	kcal.h-1			T=150 (min)		
	Males (n = 9)	**Females (n = 10)**	**Group (n = 19)**	**Males (n = 9)**	**Females (n = 10)**	**Group (n = 19)**
Sedentary PlayStation 2 gaming	195.9 ± 82.4**	103.8 ± 30.4**	147.4 ± 75.6	53.9 ± 22.3**	92.3 ± 21.5**	74.1 ± 29.9
Sedentary Wii video gaming	142.9 ± 57.1	107.3 ± 21.0	124.1 ± 44.8	69.8 ± 19.3	86.9 ± 17.3	78.8 ± 19.9
Step-powered video gaming	433.8 ± 116.9	349.4 ± 62.3	388.8 ± 99.7	22.0 ± 5.6	26.7 ± 5.4	24.5 ± 5.8
Leisure walking	356.5 ± 101.5	249.3 ± 60.3*	300.1 ± 97.1	27.3 ± 8.6*	38.0 ± 8.8*	32.9 ± 10.0
Brisk walking	425.2 ± 55.3**	327.6 ± 78.8**	373.8 ± 83.5	21.5 ± 2.7*	28.9 ± 7.1**	25.4 ± 6.6
Jogging	858.3 ± 169.3**	547.0 ± 74.0**	694.5 ± 202.4	10.9 ± 2.3**	16.7 ± 2.2**	14.0 ± 3.7

Significant gender difference * $p<0.05$ ** $p<0.01$

Note: T = 150 represents the average time taken to expend 150 kcal during the different activities undertaken.

approximately 430 kcal in males and 350 kcal in females. Therefore, approximately 2 ½ hours of step-powered gaming would be necessary to reach the weekly recommendation. Fifty percent of 16 to 24 year olds in the UK report playing sedentary video games three to seven times per week for approximately 1 ½ hours per session (17). Compared to sedentary gaming, the energy expenditure for step-powered gaming was at least 240 kcal·h^{-1} greater, which is similar to the difference observed between sedentary gaming and game play using the EyeToy baseball game (i.e., 258 kcal·h^{-1}; 14). Therefore, if video game players replaced sedentary gaming with step-powered video gaming, an excess energy expenditure of approximately 1000 to 2500 kcal could accrue each week. This increased energy expenditure could contribute towards weight management and benefit health by converting video gaming from a sedentary to active pastime through such devices. Future studies are needed to assess the sustainability of step-powered video gaming and any associated effects of habitual physical activity and health.

Sell et al. (19) found that when playing a dance simulation game, experienced gamers took 14.5 minutes to expend 150 kcal, while inexperienced gamers required 32.2 minutes, i.e., significantly longer, to achieve the same results. They suggested that experienced gamers had the capability to play at a higher level of difficulty, leading to higher energy demands due to more continuous gaming time (19). In the present study, step-powered video gaming for 24 ½ minutes (Table 3) would result in a 150 kcal expenditure, i.e., approximately halfway between the times required to expend 150 kcal for experienced and inexperienced gamers using the dance simulation game. Since participants in this study only engaged in prior play with the step-powered peripheral device during the familiarisation session, they would be considered inexperienced with the device. Therefore, for inexperienced gamers, step-powered video gaming expends 150 kcal at a faster rate than gaming on the dance simulation game (19). Given its multi-video game compatibility, step-powered video gaming may be a more appealing way to increase regular physical activity and energy expenditure for inexperienced gamers than other active video games with which they are unfamiliar.

Several studies have reported the effects of active video games on children's physical activity levels and energy expenditures (8, 10, 12, 14, 16, and 19). However, fewer studies have reported such effects in adult populations (10 and 19). This study built on previous research by investigating an adult population and using a step-powered interactive gaming system that is compatible with multiple video games. However, some limitations should be noted. Energy expenditure was predicted rather than directly measured, but the Actiheart monitor is considered a reliable predictor of energy expenditure in adults (2). Despite detecting statistically significant differences in energy expenditure and HR, the results are applicable only to university students of ages similar to the study population and to the investigated video games. A larger sample using individuals of different ages may exhibit different responses to the activities investigated. The study was laboratory based and thus may not offer conditions that can be replicated in the home. The results are only indicative of the acute responses of the participants to each activity over a short period of time on one occasion. However, the 10 minutes given for each activity was not a burden to the participants and similar to the time provided in previous studies that examine the energy costs of activities (12 and 14). Longitudinal studies evaluating whether training or learning effects associated with repeated step-powered gaming influences physiological responses are warranted to determine the long-term ability of the device to increase physical activity and energy expenditures.

CONCLUSION

Step-powered video gaming increased energy expenditure and HR as compared to sedentary video gaming. Physiological responses during step-powered gaming were comparable to that of brisk walking. Recommended minimum activity and exercise guidelines (7 and 11) can be met through step-powered video gaming, but the sustainability of this approach has not been established. The greater health benefits associated with traditional jogging as compared to step-powered gaming are highlighted by the significant differences in HR and energy expenditure for the two activities. Step-powered video gaming could be used as an entertaining and appealing tool to increase physical activity, but it should not be used as a complete substitute for traditional aerobic exercise.

ACKNOWLEDGEMENTS

This study was funded by New Concept Gaming Co., Ltd. (Liverpool). The authors have no conflicts of interest that are directly relevant to this research.

REFERENCES

1. Ainsworth BA, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, Paffenberger RS Jr. Compendium of physical activities: Classification of energy costs of human physical activities. *Med Sci Sports Exer* 1993; 25: 71-80.
2. Brage S, Brage N, Franks PW, Ekelund U, Wong M, Andersen LB, Froberg K, Wareham NJ. Branched equation modelling of simultaneous accelerometry and heart rate monitoring improves estimates of directly measured physical activity energy expenditure. *J Appl Physiol* 2004; 96: 343-351.
3. Brage S, Brage N, Franks PW, Ekelund U, Wareham NJ. Reliability and validity of the combined heart rate and movement sensor Actiheart. *Eur J Clin Nutr* 2005; 59: 561-570.
4. Camntech. 2010. The *Actiheart User Manual*. Cambridgeshire: Camntech.
5. Chaudhury M, Esliger E. 2009. Accelerometry in adults. In: Craig R, Mindell J, Hirani V (eds.). *Health Survey for England 2008. Volume 1: Physical Activity and Fitness*. London: NHS Information Centre, 59-88.
6. Daley AJ. Can exergaming contribute to improving physical activity levels and health outcomes in children? *Pediatrics* 2009; 124: 763-771.
7. Department of Health. 2004. *At Least Five a Week: Evidence on the Impact of Physical Activity and its Relationship to Health*. A report from the Chief Medical Office. London: Department of Health.
8. Graves L, Stratton G, Ridgers ND, Cable NT. Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: Cross sectional study. *BMJ* 2007; 335: 1282–1284.
9. Graves LEF, Ridgers ND, Stratton G. The contribution of upper limb and total body movement to adolescents' energy expenditure whilst playing Nintendo Wii. *Eur J Appl Physiol* 2008; 104: 617-623.
10. Graves LEF, Ridgers ND, Williams K, Stratton G, Atkinson G, Cable NT. The physiological cost and enjoyment of Wii Fit in adolescents, young adults and older adults. *J Phys Act Health* 2010; 7: 393-401.
11. Haskell W, Lee I-M, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exer* 2007; 39: 1423-1434.
12. Lanningham-Foster L, Jensen TB, Foster RC, Redmond AB, Walker BA, Heinz D, Levine JA. Energy expenditure of sedentary screen time compared with active screen time for children. *Pediatrics* 2006; 118: 1831–1835.
13. Lohman TG, Roche AF, Martorell R. 1991. *Anthropometric Standardisation Reference Manual*. Champaign, IL: Human Kinetics.
14. Maddison R, Ni Mhurchu C, Jull A, Jiang Y, Prapavessis H, Rodgers A. Energy expended playing video console games: An opportunity to increase children's physical activity? *Pediatr Exerc Sci* 2007; 19: 334–343.
15. McArdle WD, Katch FI, Katch VL. 1991. *Exercise Physiology: Energy, Nutrition, and Human Performance*. Philadelphia: Lea & Febiger.
16. Mellecker RR, McManus AM. Energy expenditure and cardiovascular responses to seated and active gaming in children. *Arch Pediatrics Adolesc Med* 2008; 162: 886-891.
17. Pratchett R. 2005. *Gamers in the UK: Digital Play, Digital Lifestyles*. BBC Audience Research. London: New Media.
18. Robergs RA, Landwehr R. The surprising history of the "HRmax=220-age" equation. *J Exerc Physiol* 2002; 5: 1-10.
19. Sell K, Lillie T, Taylor J. Energy expenditure during physically interactive video game playing in male college students with different playing experience. *J Am Coll Health* 2008; 56: 505-511.
20. Sproston K, Primatesta P. 2004. *Health Survey for England 2003. Volume 2: Risk Factors for Cardiovascular Disease*. London: The Stationary Office.