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Original Research

Energy Cost of Active and Sedentary Music Video Games: Drum and Handheld Gaming vs. Walking and Sitting

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ABSTRACT

International Journal of Exercise Science 10(7): 1038-1050, 2017. To compare energy expenditure during and after active and handheld video game drumming compared to walking and sitting. Ten experienced, college-aged men performed four protocols (one per week): no-exercise seated control (CTRL), virtual drumming on a handheld gaming device (HANDHELD), active drumming on drum pads (DRUM), and walking on a treadmill at ~30% of VO_{2max} (WALK). Protocols were performed after an overnight fast, and expired air was collected continuously during (30min) and after (30min) exercise. DRUM and HANDHELD song lists, day of the week, and time of day were identical for each participant. Significant differences ($p < 0.05$) among the average rates of energy expenditure ($kcal \cdot min^{-1}$) during activity included WALK > DRUM > HANDHELD. No significant differences in the rates of energy expenditure among groups during recovery were observed. Total energy expenditure was significantly greater ($p < 0.05$) during WALK (149.5 ± 30.6 kcal) compared to DRUM (118.7 ± 18.8 kcal) and HANDHELD (44.9±11.6 kcal), and greater during DRUM compared to HANDHELD. Total energy expenditure was not significantly different between HANDHELD (44.9 ± 11.6 kcal) and CTRL (38.2 ± 6.0 kcal). Active video game drumming at expert-level significantly increased energy expenditure compared to handheld, but it hardly met moderate-intensity activity standards, and energy expenditure was greatest during walking. Energy expenditure with handheld video game drumming was not different from no-exercise control. Thus, traditional aerobic exercise remains at the forefront for achieving the minimum amount and intensity of physical activity for health, individuals desiring to use video games for achieving weekly physical activity recommendations should choose games that require significant involvement of lower-body musculature, and time spent playing sedentary games should be a limited part of an active lifestyle.

KEY WORDS: Calorie expenditure, moderate-intensity exercise, cognitive task, metabolic rate, interactive screen time, exergaming

INTRODUCTION

American adults (> 18 y) are participating in more sedentary screen-based activities including television viewing and video game playing than at any previous point in history (5, 10, 19). Furthermore, handheld gaming devices (e.g. PSP® and Nintendo® DS) and cell phones have made screen time activities more accessible and common among young adults. Increased time spent in sedentary behavior such as playing video games can translate into decreased time spent being physically active. Because less than adequate physical activity levels and screen-time (independent of regular exercise) have been causally linked to obesity, cardiovascular disease (CVD) and type II diabetes (10, 24), standards have been established to help guide activity choices as it relates to personal health. Specifically, the American College of Sports Medicine (ACSM) recommends adults to accumulate 150 minutes of moderate-intensity exercise (3.0-5.9 metabolic equivalents (METs)), 75 minutes of vigorous-intensity exercise, or an equal combination of the two, every week, in order to maintain health benefits (7). Considering that only about 21% of adults meet these criteria (27), and because video games have come under scrutiny as potential contributing factors for increasingly sedentary lifestyles in young adults (16), the video game industry has taken a more active approach to game development.

Specifically, video game companies including Sony®, Nintendo®, and Xbox® have developed gaming consoles that promote active play that require the user to move in order to complete objectives within the game. According to studies that have reported energy costs similar to common exercise activities (2, 8, 13, 14, 17, 18, 22, 25, 29), video games like Dance Dance Revolution® and many of the Nintendo Wii® games appear to have the potential to help individuals decrease time in sedentary behaviors, increase physical activity engagement, and potentially meet ACSM physical activity recommendations. Specifically, Wii® Boxing and Jogging have shown comparable energy expenditure levels to low- (< 3 METS) and moderate-intensity activities (3.0 to 5.9 METS), respectively (18). Wii® Boxing games have even been shown to exceed the energy costs of treadmill walking (2), and 22 out of 68 different active Wii® games have been classified as moderate-intensity activities (17). Playing Wii® games has elicited from ~165 to 180 kcals per hour (8), while Dance Dance Revolution® has been shown to elicit energy expenditure as high as 190 kcals per hour in adolescents (26). Even classic, non-active video arcade games such as Mrs. Pac Man® have shown an increase in energy expenditure similar to walking at 2.0 mph (20). When comparing these energy expenditure rates to those from sitting (~80.9 $kcals \cdot hr^{-1}$) (11), it seems possible that active video-game play can represent a non-traditional, and perhaps more entertaining, moderate-intensity physical activity.

Music-based gaming, such as Rock Band® drumming, represents yet another possible form of active gaming, despite the fact that it does not require the physical movements of running, jumping or dancing. To date, only one study has empirically quantified energy expenditure with active drumming on the video game Rock Band®, however, metabolic rates did not exceed 1.45 METS because 67% of the participants played the game at the most basic-level (15). Conversely, more intense drumming, such as during concert performances and a laboratory drum test increased metabolic rates to values ranging from 8 to 10 METs (6). Thus, it remains unclear whether video game drumming is a sufficiently intense physical activity that could contribute to weekly exercise recommendations. Therefore, the purpose of this investigation was to compare energy expenditure from expert-level drumming on the video game Rock Band® to moderate-intensity walking at 30% of VO_{2max}. Furthermore, because slight increases in energy expenditure during sedentary game-play have also been observed (2, 14), a secondary objective of this study was to compare virtual drumming on a handheld gaming device versus a no-exercise resting trial. Comparing nearly identical handheld and active drumming trials (versus a resting trial) enabled us to consider the potential energy cost of the cognitive task of video game drumming, since seated cognitive tasks have previously been shown to increase energy expenditure (1). Because drumming has been shown to elicit 8-10 METs, we hypothesized that 30 minutes of expert-level drumming on the video game Rock Band® would result in significantly greater energy expenditure compared to 30 minutes of walking at 30% of VO_{2Max}. Similarly, considering the previous data in the literature, we hypothesized that the increased cognitive demand of the handheld video game would result in greater energy expenditure compared to the 30 minutes of quiet sitting.

METHODS

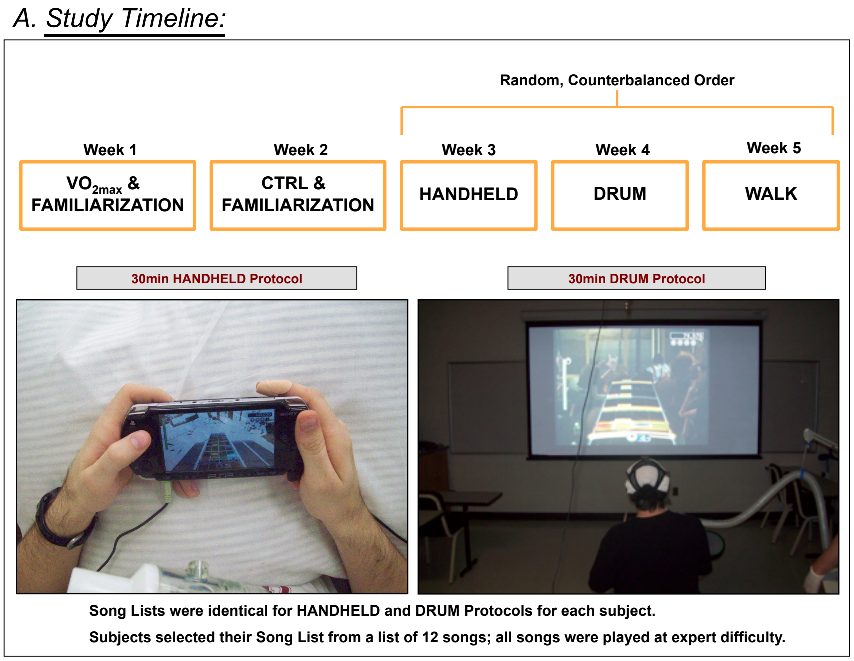
Participants

Ten men (20±1.4 years of age) volunteered to participate in this investigation. Participants had average body mass 79±13 kg, height 178±7.6 cm, body-fat 13±1.1 %, and VO_{2max} 47±7.9 $ml \cdot kg \cdot min^{-1}$. All participants were non-smoking, free of any chronic diseases, and free from medications, ergogenic supplements, glandular disorders, and any conditions that could affect metabolism. All participants refrained from structured exercise outside of the requirements for this study and were able to proficiently play the video game Rock Band® on the "expert" difficulty setting. This study was approved by the Committee on Human Research at Salisbury University, and each participant provided informed consent prior to any testing.

Protocol

Study Design: Participants performed four experimental protocols using different modes including no-exercise control resting (CTRL), virtual drumming on a handheld gaming device (HANDHELD), active drumming on drum pads (DRUM), and walking on a treadmill at 30% of VO_{2max} (WALK) (see Figure 1). We tested the hypotheses that different protocols would significantly affect energy expenditure so that DRUM > WALK > HANDHELD > CTRL.

Baseline Testing and Familiarization: To avoid lingering effects of previous exercise on metabolism, participants visited the laboratory once each week over a five-week period. Each session was held on the same day of the week and at the same time in the morning following an overnight fast (10-12 hours). During the first visit (Week 1), body mass and height were measured to the nearest 0.10 kg and 0.10 cm, respectively, using a Cardinal Detecto 750 scale (Detecto Scale Company, Webb City, MO) and a Seca Model 213 Stadiometer (Seca, Chino,



B. *Study Design:*

	CTRL	HANDHELD	DRUM	WALK
Duration	30 min	30 min	30 min	30 min
% of VO_{2max}	7.8 ± 1.8 %	8.8 ± 2.7 %	23 ± 5.4 %	29 ± 1.8 %

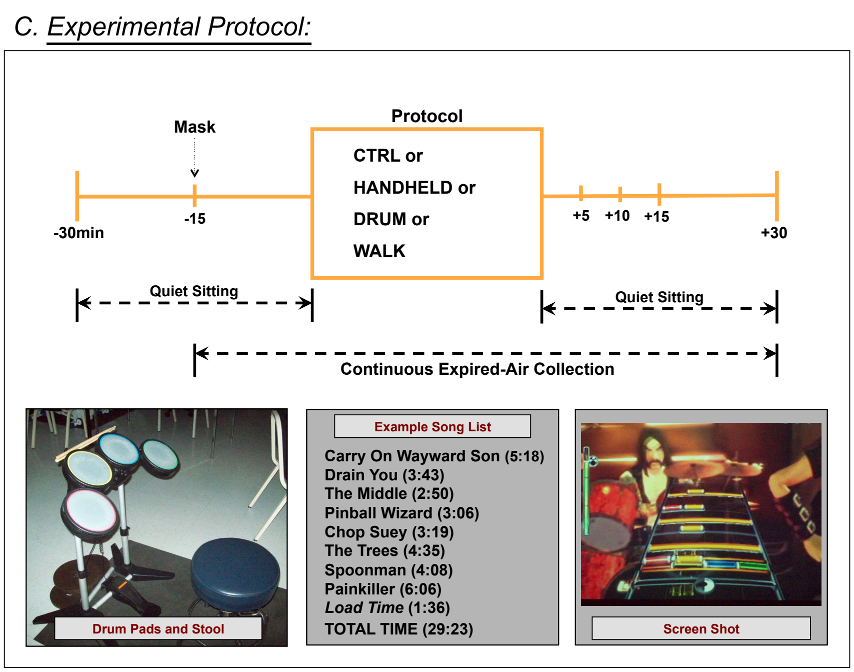


Figure 1. Study timeline (A), study design (B), and experimental protocol (C) used to compare the energy costs of no-exercise (CTRL), handheld drumming (HANDHELD), active drumming (DRUM), and walking (WALK)

CA). Skinfold measurements were obtained from seven sites (triceps, sub-scapular, mid-axillary, chest, supra-iliac, abdomen, and thigh), and the equation described by Jackson and Pollock (1978) was used to estimate body density (12). All skinfolds were taken on the right side of the body in duplicate. If the duplicate values were more than 2mm different, a third skinfold was taken for that sight. Subsequent skinfolds were then averaged and used for calculation of percent body fat. Percent body fat was subsequently estimated using the value obtained for body density and the Siri equation (23). Participants also performed a maximal graded exercise test on a motorized treadmill (VO_{2max}) at ambient temperature. Testing was performed using a two-way non-rebreathing mouth piece and nose clip supported by head gear (Hans Rudolph, Inc., Kansas City, MO), and expired air was sampled continuously using a metabolic cart (ParvoMedics, Sandy, UT). Oxygen and CO_2 gas analyzers were calibrated before each test with standard gases of known concentrations. Briefly, after a three-minute warm-up (light jog at a self-selected speed), participants ran on a treadmill to volitional exhaustion at a constant self-selected speed, while the treadmill incline was incrementally increased 2% every two minutes. VO_{2max} was confirmed if subjects accomplished three of the four following criteria: an increase in workload and no change in VO_2 > 200 ml O_2, a rating of perceived exertion (RPE) ≥ 17, RER > 1.1 and a heart rate maximum within +/- 10 beats per minute of age predicted heart rate max (3). VO_{2max} for each participant was determined from the highest rate of O_2 consumption measured over a 30 second average. Following VO_{2max} testing, participants were familiarized with video game drumming by completing one song using the DRUM pads (Harmonix Music Systems, Inc., Cambridge, MA) interfaced to a video game system (Sony PlayStation 2, Tokyo, Japan), and one song using the HANDHELD device (Sony Computer Entertainment, Inc., Tokyo, Japan).

Two days later, participants performed a 20-min submaximal exercise session on the treadmill at ambient temperature to become familiarized with the exercise intensity used during the subsequent treadmill testing session (WALK). To ensure that subjects were exercising on the treadmill at ~30% of VO_{2max}, participants wore a two-way non-rebreathing nose and mouth face mask, and their expired air was continuously sampled using the metabolic cart. During this familiarization trial, treadmill speed was adjusted if necessary until the desired exercise intensity was established and recorded for use during the subsequent WALK experimental testing session.

Control Protocol: Exactly one week later (Week 2), participants performed a no-exercise resting CTRL energy expenditure trial that required the participant to lay in a reclined position for 90 total minutes. The first 15 minutes, the participants stayed in the reclined position quietly without the face mask, and then for 75 minutes while wearing the two-way non-rebreathing nose and mouth face mask, with expired air being continuously sampled by the metabolic cart to mimic the 15-min resting, 30 min protocol, and 30 min recovery phases also used in the other three experimental protocols. After the CTRL trial was completed, the subject was familiarized with drumming while wearing the metabolic face mask by playing one song with DRUM and one with HANDHELD. Exactly one week later, participants completed one of three experimental protocols in a randomized, counterbalanced order.

Experimental Protocols: All protocols consisted of laying in a reclined position for 15 min (without the mask), followed by continuous expired air collection for a 15 min pre-exercise resting period (laying in a reclined position), during (30 min), and for 30 min after each protocol using the metabolic face mask and metabolic cart described above. Participants were instructed to remain still, silent and awake during the pre- and post-activity periods.

HANDHELD: During the 30-min HANDHELD protocol, participants sat semi-reclined and played along with songs cued by the video game Rock Band® using only the thumbs and fingers (to a lesser extent) with a handheld PlayStation Portable (PSP)® device (Sony Computer Entertainment, Inc., Tokyo, Japan), with arms and hands supported by pillows in order to reduce energy expenditure not related to game play.

DRUM: During the 30-min active DRUM protocol, participants sat upright on a stool, and played along with songs cued by the video game Rock Band® using drum sticks, four drum pads, and one foot pedal.

WALK: During the 30-min WALK protocol, participants walked at 30% of VO_{2max} on a motorized treadmill at 0% incline.

Indirect Calorimetry: Oxygen consumption ($L \cdot min^{-1}$) data (30 sec averages) were used to calculate average rates of energy expenditure ($kcal \cdot min^{-1}$) at baseline (REST); during activity (averaged across each of the three ten-minute periods (0-10, 11-20, and 21-30), and for +5, +10, +15, and +30, min post-activity. All data were corrected for dead-space associated with the time necessary for expired air to travel from the mouth to the analyzers. Energy expenditure ($kcal \cdot min^{-1}$) was calculated using O_2 consumption data and the equation $L\ O_2 \cdot min^{-1}$ multiplied by 4.9 (28). Because there were no differences in energy expenditure rates before nor after each trial, total energy expenditure values (kcals) were calculated for the 30-min duration of each protocol using the trapezoidal area under the curve method (AUC) for each participant and for each trial separately.

Statistical Analysis
Results were considered significant at $p < 0.05$. Data are presented as means ± standard deviations (MEANS ± SD). A four-factors repeated measures analysis of variance (ANOVA) was used to test for significant group x time interactions, and Fisher's Least Significant Difference (LSD) post hoc analyses were used when appropriate to determine specific pair-wise differences (Statistica V4.1, StatSoft, Inc.). Separate one-way ANOVA's were used to test for group differences at REST for each variable, and for group differences in total energy expenditure.

RESULTS

Rates of energy expenditure ($kcal \cdot min^{-1}$) increased significantly ($p < 0.05$) with DRUM and WALK during activity and after +5 min of recovery compared to the Rest time point (see Figure 2). There was a significant group x time interaction (p=0.00) for the rates of energy expenditure, with WALK (4.9±1.1, 5.0±0.9, 5.1±1.0 $kcal \cdot min^{-1}$) > DRUM (3.5±0.5, 3.6±0.6, 4.7±1.0 $kcal \cdot min^{-1}$), HANDHELD (1.5±0.4, 1.5±0.4, 1.5±0.4 $kcal \cdot min^{-1}$), and CTRL (1.3±0.2, 1.3±0.2, 1.3±0.2 $kcal \cdot min^{-1}$); and DRUM > HANDHELD and CTRL from 0-10, 11-20, and 21-30min of activity, respectively. There were no differences among protocols in rates of energy expenditure at Rest, nor during recovery. Total energy expenditure (kcal) was significantly greater during WALK (149.5±30.6 kcal) compared to DRUM (118.7±18.8 kcal) and HANDHELD, and greater during DRUM compared to HANDHELD (44.9±11.6 kcal) and CTRL (38.2±6.0 kcal) (see Figure 3). Total energy expenditure was not different between HANDHELD and CTRL.

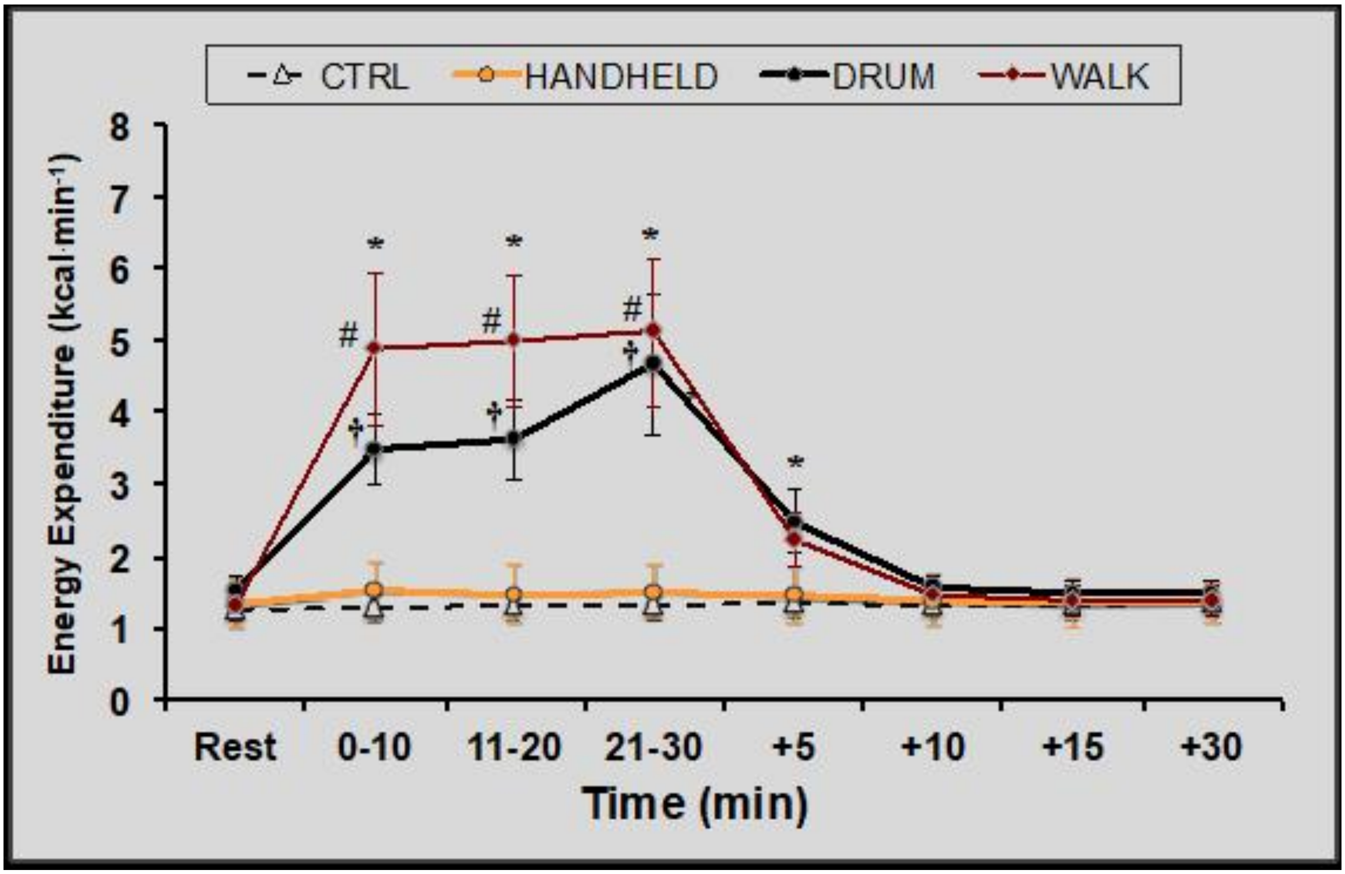


Figure 2. Rates of energy expenditure (kcal·min^{-1}) before (Rest) during the first 10 (0-10), middle ten (11-20), last ten (21-30), and for 30 minutes after a no-activity control trial (CTRL), virtual drumming at expert-level using a handheld game device (HANDHELD), active drumming at expert-level using drum pads and sticks (DRUM), and treadmill walking at 30% of VO_{2max} (WALK). Data are Means ± SD. * denotes P < 0.05 vs. corresponding Rest value for WALK and DRUM only. # denotes P < 0.05 vs. corresponding DRUM, HANDHELD, AND CTRL values. † denotes P < 0.05 vs. corresponding HANDHELD and CTRL values.

DISCUSSION

To our knowledge, this was the first study to quantify the energy costs of active video game drumming at expert-level in comparison with moderate-intensity walking. Contrary to our hypothesis, energy expenditure was greater during walking compared to drumming, suggesting a potential limitation as it relates to the intensity of video game drumming for meeting physical activity guidelines. The nearly identical handheld drumming protocol used in the current study is also unique to the literature, providing a standardized opportunity to estimate the energy cost of the cognitive task of video game drumming. Ultimately, handheld video game play provided essentially no stimulus for increased metabolism compared to resting.

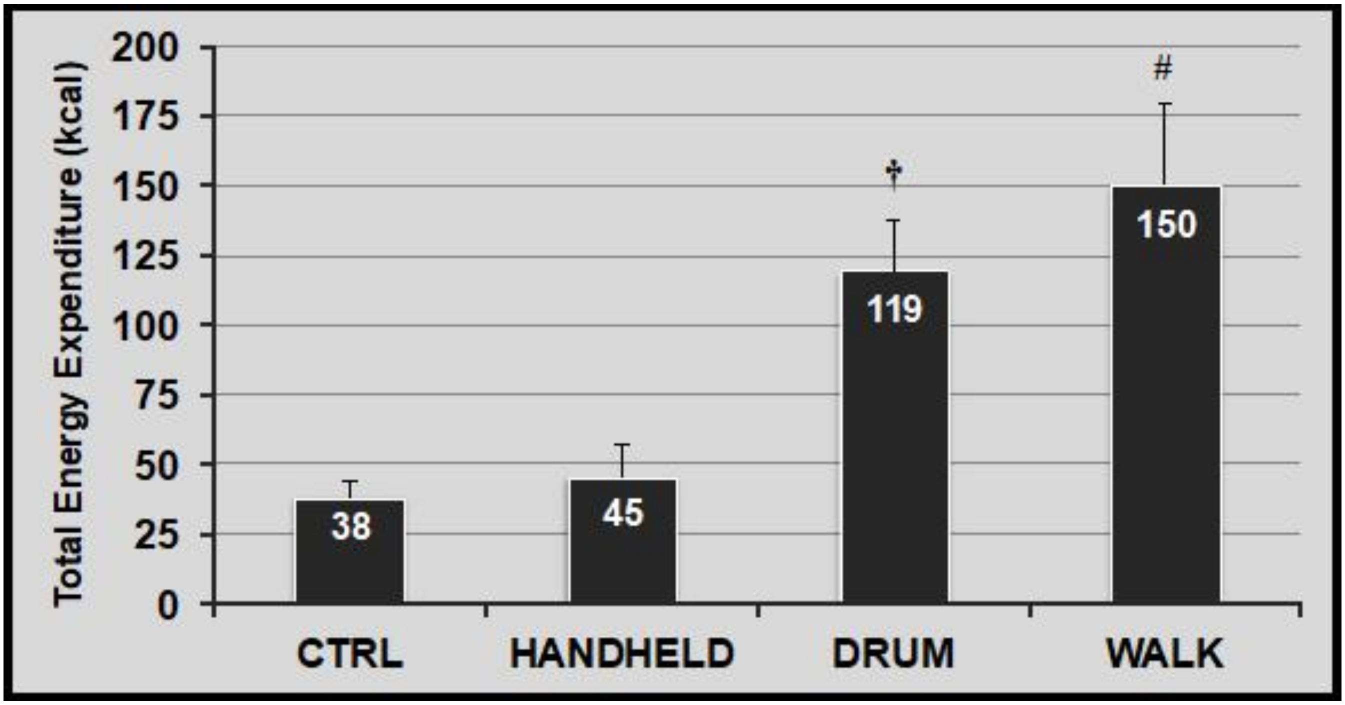


Figure 3. Total energy expenditure (kcal) from 30 minutes of a no-activity control trial (CTRL), virtual drumming at expert level using a handheld game device (HANDHELD), active drumming at expert level using drum pads and sticks (DRUM), and treadmill walking at 30% of VO_{2max} (WALK). Data are Means ± SD. † denotes $P < 0.05$ vs. corresponding HANDHELD and CTRL values. # denotes $P < 0.05$ vs. corresponding DRUM, HANDHELD, AND CTRL values.

Our initial hypothesis was that active drumming would exceed walking because previous findings from traditional vigorous drumming exceeded 10 METS in professional drummers (6). However, we found that energy expenditure during walking was greater than video game drumming. For our subjects, the drumming protocol was performed at an average of 3 METS, just reaching the minimum for moderate-intensity activity as defined by ACSM (3.0 to 5.9 METS) (7). Furthermore, drumming in our study was not as demanding as walking, with our participants averaging 3.9 METS during WALK. These findings were surprising since all subjects reported that the drumming protocol was more difficult than walking, and these reports were supported by the fact that each subjects' peak VO_2 was highest during their drumming compared to their respective walking protocol. The reason for this was because the participants selected the most challenging songs that they could perform at an expert-level, requiring significant physical effort. Furthermore, subjects had to perform their most difficult songs at the end of the session due to the fact that they could not sustain that intensity beyond a few songs. Thus, video game drumming caused our participants to reach a level of exhaustion while barely meeting the minimum for moderate-intensity exercise, leading us to conclude that it may not be a sufficiently intense activity for helping to meet daily exercise recommendations.

A potential explanation for why active drumming resulted in lower than expected metabolic rates is related to the muscle mass required, and the limited number of drum pads in the video game Rock Band®. Drumming requires less contribution from the lower body, and instead requires significant involvement of the smaller shoulder and arm muscles. Similar to traditional lower- versus upper-body exercise, energy expenditure with video game play is higher as more and more lower-body musculature is required. Data reported in 2008 by Sell et al. supports this notion, with Dance Dance Revolution® (DDR) requiring significant sustained contributions from lower-body musculature, and accordingly, the highest amount of calories expended in comparison with other video game results (22) (see Figure 4). In addition to DDR®, video game boxing elicits large energy expenditure responses. The reason for this is because boxing requires stepping, lunging and changing directions with the lower body, in conjunction with significant upper-body movements (2, 14). Thus the differences in energy expenditure between DRUM and WALK may likely be explained by the fact that more, sustained lower-body muscle contractions were required for walking. Indeed, Figure 4 shows that our WALK protocol (shown with a red bar) was a moderate-intensity activity, exceeding 3 METS, and was ranked near the top of the graph with boxing (2, 14) and DDR® video games (22). Conversely, kcals for DRUM were lower than for inexperienced DDR® video game play (22). A second potential explanation for the lower than expected metabolic rates with DRUM was that the participants in our study used only four drum pads and one foot pedal with the video game Rock Band®, compared to full drum sets used by professional Pop/Rock drummers, such as those tested during concert performances by De La Rue et al. (6). Lastly, the professional drummers in the De La Rue et al. (2013) study were also much more experienced than the video game drummers tested here (6).

To our knowledge, this was also the first study to compare nearly identical virtual handheld and active video games where the only difference between protocols was that handheld was played using only the thumbs and hands (with arms supported), while active was played with sticks and drum pads requiring significant muscular activity from the arms and shoulders. Participants played identical song lists, using the same video game, at the same time of the day, and on the same day of the week. Furthermore, scores (%) for the completion of each required note for each song were similar between the handheld and active drumming trials for all participants (< 3% difference). The only other study to our knowledge that compared similar virtual and active video games was a study by Barkley and Penko (2). In that study, adults performed active Wii Sports® Boxing during one trial, and a similar PunchOut!!® boxing game as a handheld virtual simulation. Different from our study, however, the boxing games did not allow the researchers to standardize the responses and activities of the opponent in the game, making the two video game activities inconsistent. Furthermore, participants in the Barkley and Penko study were playing essentially two completely different video games (2). Therefore, the data from the current study represent the first comparison of energy costs between standardized active versus virtual handheld video game play, with active drumming resulting in approximately 75 more total calories expended.

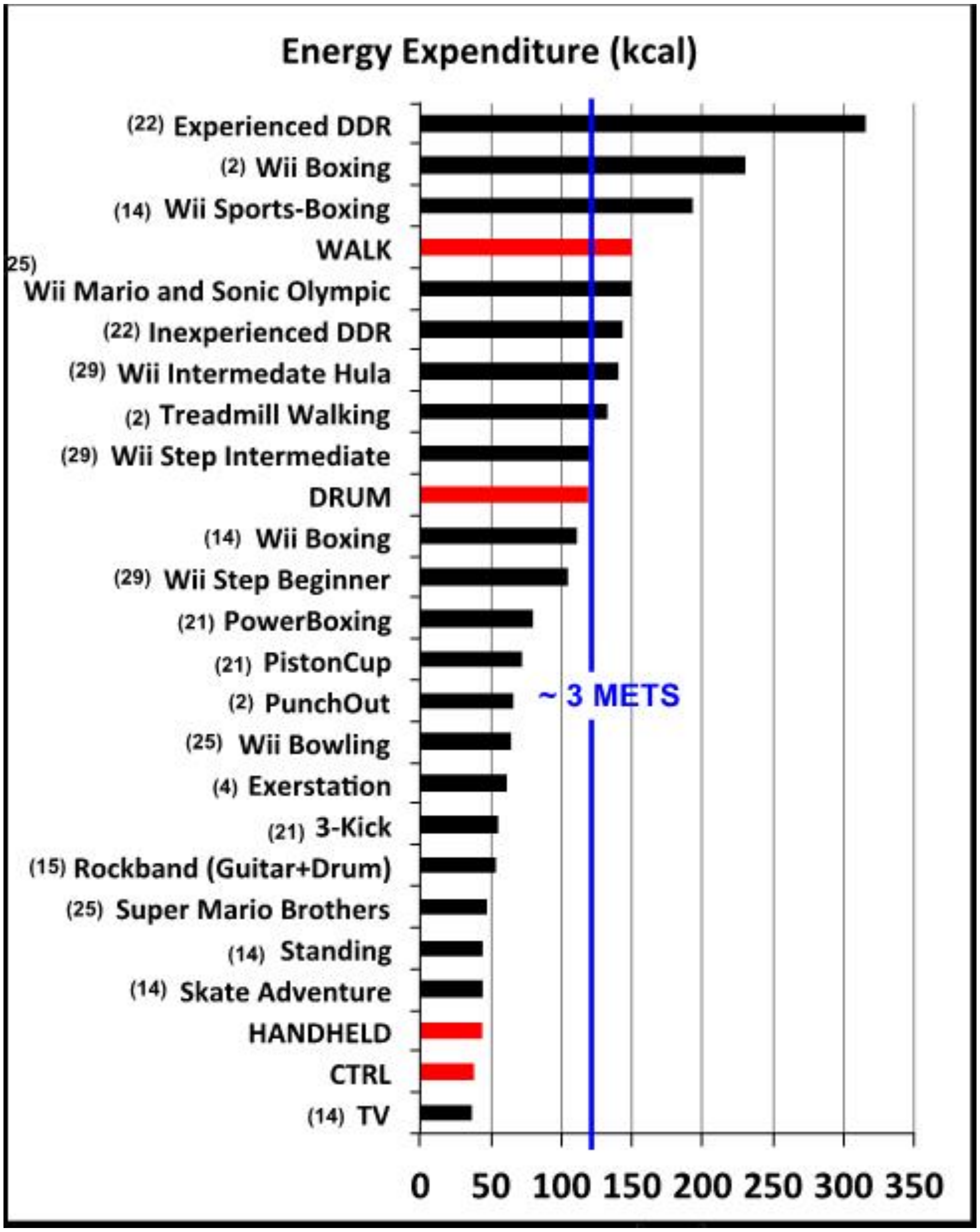


Figure 4. Approximate energy expenditure values (kcal) from 30 minutes of video gaming and other activities (e.g., sitting, television, standing, and walking) from various research studies. Also included with red bars is our no-activity control resting (CTRL), virtual drumming at expert-level using a handheld gaming device (HANDHELD), active drumming at expert-level using drum pads and sticks (DRUM), and treadmill walking at 30% of VO_{2max} (WALK). Data in black bars are approximate values from previous research studies with references provided. Studies exceeding 3 METS represent moderate-intensity activities.

We also compared handheld drumming with a control resting trial to determine if the cognitive task associated with playing resulted in any additional energy cost above resting, and it did not. These current findings are different from previously reported (2, 14), but a potential explanation may be related to differences in dependent variables analyzed. For example, Al-Naher et al. (2016) reported significant metabolic increases above resting (1.05 versus 1.21 METS) while performing a simple cognitive task (math) requiring only minimal button pushing (1). However, when we converted their data from $kcals{\cdot}kg{\cdot}day^{-1}$ to kcals (using a 70 kg man), the estimated increase from 30 minutes of cognitive testing (compared to resting) was only 5.9 kcals (1). This estimated difference was very similar to our findings, where 30 minutes of handheld drumming was approximately 6.7 kcals greater on average than resting. Therefore, there was a negligible energy cost associated with the cognitive task of handheld video game drumming, despite the fact that our participants played at an expert-level. In fact, the majority of the 6.7 kcal increase can likely be explained by contractile activity from the thumbs and fingers, with very little energy cost actually coming from performing the cognitive task, however further research is evidently needed. Indeed, other studies that reported increased metabolism with sedentary video games did not make efforts to minimize extraneous movements, but instead were attempting to quantify the energy costs of playing those games authentically by allowing standing, upright sitting, rocking, or moving that naturally occurred (2, 14, 20). However, our study is not without limitations. For instance, the present study only investigated males and therefore these results may not be generalizable for females. In addition, although our sample size was relatively small we were still able to detect differences in energy expenditure between protocols.

To help us better understand the potential value of active video game drumming as an option for weekly physical activity requirements, the current study tested whether energy expenditure during drumming at an expert-level would be greater than moderate-intensity walking. While energy expenditure during active drumming did not exceed walking, it seems likely that it may provide health benefits that outweigh sedentary gaming. A nearly identical handheld protocol was also tested to determine if sedentary video game play (and the cognitive task of drumming) would elicit a significant increase in energy expenditure above resting. Supporting national recommendations that sedentary screen-time should be limited, the handheld drumming protocol elicited essentially no change in resting metabolism. In conclusion, traditional aerobic exercise remains the more effective mode for promoting health benefits because active video game drumming hardly met moderate-intensity criteria. Individuals should select video games that require more involvement from lower-body musculature in order to maximize energy expenditure and help work towards meeting national physical activity recommendations. Lastly, the songs that were chosen for the DRUM protocol (although all played on the expert difficulty setting) varied in their speed, intrinsic difficulty, and the volume of kick pedal use. Future research is warranted to determine if a set-list consisting of more difficult songs or songs that utilize the kick pedal could elicit higher rates of energy expenditure than walking.

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