Energy Expenditure During Physically Interactive Video Game Playing in Male College Students With Different Playing Experience

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Abstract. **Objective**: Researchers have yet to explore the effect of physically interactive video game playing on energy expenditure, despite its potential for meeting current minimal daily activity and energy expenditure recommendations. **Participants** and **Methods**: Nineteen male college students—12 experienced *Dance Dance Revolution* (DDR) players and 7 inexperienced players—completed maximal oxygen uptake assessments and a 30-minute DDR gaming session. The authors recorded heart rate (HR), rating of perceived exertion (RPE), respiratory exchange rate (RER), oxygen consumption (VO_2), and total steps (TS_{30}). **Results**: Experienced participants showed higher exercise HR, RPE, RER, VO_2, total and relative energy expenditure, exercise intensity, TS_{30}, and average steps per minute, and less time and steps to expend 150 kilocalories ($p < .05$). **Conclusions**: Participants with greater playing experience can work at higher intensities, promoting greater energy expenditure.

Keywords: ACSM recommendations, college students, *Dance Dance Revolution*, physical activity, video games

Physical inactivity is associated with increased risk for numerous chronic disease conditions, such as cardiovascular disease, type 2 diabetes, hypertension, and cancer.[1,2] A lack of physical activity has also been linked with the increasing prevalence of overweight and obesity in children and adults in the United States and many developed countries worldwide.[1,3,4] Results from the 2003 National College Health Assessment (ACHA–NCHA) show that 32% to 47% of college students are inactive.[4]

To reduce health risks, adults should accumulate at least 30 minutes of moderate-intensity physical activity on most, if not all, days of the week.[5,6] The American College of Sports Medicine (ACSM) recommends a minimum physical activity-derived energy expenditure of 150 kilocalories (kcal) per day or about 1,000 kcal/wk.[7] The Institute of Medicine, the International Association for the Study of Obesity, and the Dietary Guidelines Committee support these recommendations as a baseline public health recommendation but emphasize the need for a greater volume of physical activity to elicit notable increases in caloric expenditure.[8–10] Although activities such as walking or cycling can be used to achieve physical activity recommendations, many college students do not enjoy these traditional types of physical activity.[11,12] Identifying more enjoyable and nontraditional ways of acquiring recommended levels of physical activity may be a means by which young adults can overcome their reluctance to participate in traditional modes of physical activity.

Research suggests a strong negative correlation between physical activity and obesity with television watching among children.[13–15] A similar relationship has not been observed for physical activity and video gaming among children,[16] although minimal research is available in this area. For college students, the relationship between television watching, video gaming, and computer use is even less well established. Buckworth and Nigg[17] suggested that computer use, not television watching, was negatively correlated with the amount and frequency of moderate and vigorous physical activity among college students. The relationship between physical activity behaviors and video gaming was unclear, given that they grouped video gaming and television watching together as 1 media variable and, again, that few researchers have explored this relationship in college students.

A growing body of research supports using physically interactive video games (PIVGs) that require substantial

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body movement and exertion for energy expenditure.[18] The growing popularity of PIVGs has been well documented,[19] but little research exists on the prevalence of PIVG use in college students. For many, video games that require physical interaction present a viable, practical, and attractive alternative to walking or cycling. In 1996 alone, video game sales in the United States reached $7 billion,[20] and recently, gaming programs such as *Dance Dance Revolution* (DDR; Sony Computer Entertainment of America, Foster City, CA)[19] have been promoted for commercial and home use. DDR is a PIVG that emphasizes lower-body movements. The DDR home version requires players to face a television screen while standing on a 3-foot-square plastic pad (or platform) that has arrows pointing forward, back, left, and right. Once the game is started, arrows scroll up the video screen to the beat of a chosen song. The purpose of the game is to step on the arrow on the pad corresponding to the onscreen arrow as it reaches the top of the screen. Different arrow combinations are displayed depending on the difficulty level chosen. Studies exploring the utility of DDR to meet current minimal physical activity and energy expenditure recommendations—30 minutes of moderate-intensity physical activity or an energy expenditure of 150 kcal—have generated mixed results. Lillie and colleagues[21] found that inexperienced DDR players expended only 122.3 ± 27.4 kcal during a 30-minute bout of DDR game play. Luke et al[22] found that energy expenditure and exercise intensity (78% age-predicted heart rate) elicited while playing DDR was consistent with ACSM recommendations. Participants in both studies expressed high levels of enjoyment while playing DDR, suggesting that DDR might provide a viable alternative exercise modality.[21,22]

Although few researchers have investigated the influence of experience with PIVG on the relative energy expenditure of players, investigators have examined the influence of experience among cyclists. Cycling experience and competitive experience influence overall aerobic demand (and consequently energy cost and expenditure) and reliance on anaerobic energy production.[23,24] However, the influence of playing experience on current recommendations for energy expenditure has not been examined relative to PIVG in healthy, nonclinical populations such as college students. Investigation is warranted, given current research suggesting that PIVGs are a viable method by which college students can meet current minimal daily recommendations for physical activity and energy expenditure.[21,25]

Therefore, our purpose in this study was twofold. First, we wanted to determine whether playing experience influences energy expenditure during a single DDR exercise bout. Second, we wanted to determine whether experienced and inexperienced DDR players are able to meet the minimal recommendations for daily physical activity and energy expenditure through playing DDR. We hypothesized that experienced DDR players would expend more kilocalories but that both inexperienced and experienced participants would achieve the minimal daily recommendations for physical activity and energy expenditure during a 30-minute bout of DDR play.

METHODS

Participants

Nineteen male college students volunteered for the study (*M* age = 21.8 ± 3.5 years; *M* height = 178.3 ± 6.7 cm; *M* weight = 80.0 ± 21.5 kg): 12 experienced DDR players and 7 inexperienced players. We recruited participants in summer 2004 via flyers and a snowball sampling approach. We defined *experienced players* as individuals who regularly and consistently played DDR in the heavy mode option (level 4), whereas *inexperienced players* were able to consistently maintain play in the beginner or light modes (levels 1 or 2). Participants were healthy nonsmokers, free from any condition that would prevent a maximal effort in a graded exercise test or limit moderate-intensity upper-body movements. (In regard to the all-male sample, we recruited participants via a snowball approach, so male students simply may have recruited other men with similar interests.)

The institutional review board at the University of Utah granted approval prior to study initiation. After providing a risk evaluation and informed consent, each participant completed 2 laboratory sessions: a maximal graded exercise treadmill test to assess maximal oxygen uptake (VO_{2max}) and a session of DDR. We collected pre-exercise baseline metabolism prior to the DDR session. Participants sat and rested quietly for 15 minutes after arriving at the laboratory. We recorded resting oxygen consumption (VO_2), respiratory exchange rate (RER), and heart rate (HR) during each minute of this time using open-circuit spirometry (Parvo Medics Metabolic Measurement System MMS 2400, Salt Lake City, UT) and a Polar heart rate monitor (Polar CIC Inc, NY, NY).

We asked participants to refrain from eating at least 2 hours (not more than 8 hours) prior to all testing sessions and to avoid strenuous physical activity for 24 hours prior to each laboratory visit. We allowed a minimum of 24 hours between laboratory visits. In addition, participants abstained from alcohol ingestion 48 hours prior to participation and drank water liberally (2 L/d) 1 day prior to each testing session. During all test sessions, participants wore shorts, t-shirts and athletic shoes to avoid differences in metabolic and thermoregulatory responses caused by clothing. Ambient temperature was maintained at 22–24°C.

Testing Protocols

Graded Exercise Test

We used a graded treadmill exercise test to determine participants' VO_{2max} as a gauge of their maximal exercise capacity. Participants warmed up by walking or jogging for 5 minutes at a self-selected pace. After the warm-up, participants put on a heart rate monitor and were fitted with a mouthpiece and noseclip for use with the open-circuit spirometry system. The treadmill remained at the self-selected speed, but we increased the treadmill grade by 2% every 2 minutes for the duration of the exercise test. We continuously monitored VO_2, RER, and HR and recorded the data at the end of each minute. We recorded a rating of perceived

exertion (RPE; a subjective indication of effort at that instant) every 2 minutes during the test. Participants had achieved VO_{2max} when at least 3 of the following criteria were met: (1) an RER of ≥ 1.15, (2) no further increase in HR with increasing intensity, (3) a plateau of oxygen uptake with increasing workload, (4) an RPE of > 17 (6–20 scale), and (5) volitional fatigue. During this laboratory visit, we also gave participants at least 10 minutes to familiarize themselves with the DDR game, during which time we provided instruction on game use.

DDR Video Game Testing

During the second laboratory visit, participants completed 30 minutes of continuous DDR game play. Prior to DDR gaming, we collected baseline pre-exercise data as previously described. During game play, each participant faced a television screen while standing barefoot on a 3-foot-square plastic pad that had an arrow pointing forward, back, left, and right. Participants self-selected a difficulty level they were able to maintain during game play from a choice of beginner (1; easiest), light, standard, and heavy (4; hardest) modes. We instructed participants to step on the arrow on the pad corresponding to the arrow displayed on the video screen in accordance with the rhythm of the accompanying song. Once one song and the associated arrows were finished, the participant immediately selected another song and continued game play to minimize any nonplaying time. To avoid interference during game play, we secured the hose attached to the mouthpiece used for open-circuit spirometry to the participant's body. A heart rate monitor (Polar CIC Inc., Port Washington, NY) measured HR. We assessed participants' RPE at 5-minute intervals during this submaximal exercise bout. Participants also wore a pedometer (Digiwalker SW-701, Optimal Health Products, San Antonio, TX) attached at the hip to monitor the number of steps taken during the submaximal exercise bout. In addition, we recorded total energy expenditure (TEE_{30}), total steps taken (TS_{30}), and a subjective rating of overall enjoyment (ranging from 1 [*not enjoyable*] to 5 [*highly enjoyable*]) during the 30-minute exercise bout. After the exercise bout, we calculated the time participants took to expend 150 kcal (T_{150}), energy expenditure relative to body weight ($Rel\text{-}EE_{1.0}$), steps taken per minute ($S_{1.0}$), and steps required to expend 150 kcals (TS_{150}) using the raw data.

Statistical Analyses

The exercise variables we investigated were HR, RER, RPE, relative VO_2, TEE_{30}, T_{150}, TS_{30}, $S_{1.0}$, TS_{150}, $Rel\text{-}EE_{1.0}$, and enjoyment level. We generated group averages for experienced and inexperienced players for each variable. We calculated TEE_{30} and $Rel\text{-}EE_{1.0}$ during physical activity using RER and absolute VO_2 on the basis of nonprotein respiratory quotient thermal equivalents.[26] We determined activity intensity on the basis of self-reported RPE, percentage of oxygen consumption reserve (VO_2R) achieved, and average energy expenditure per minute (Avg. $EE_{1.0}$). Given that a component of VO_2R is resting oxygen consumption, we considered it a measure of intensity relative to a given individual. Therefore, we were able to determine an overall estimate of the relative exercise intensity for experienced and inexperienced participants. We evaluated variable differences between groups using a repeated measures analysis of variance, and we re-evaluated these after controlling for body weight, with statistical significance set at $p < .05$.

RESULTS

Nineteen participants completed the VO_{2max} test and the DDR session. Table 1 shows participant descriptive data. Experienced participants were significantly younger than were inexperienced players ($p < .05$), but no significant differences existed between groups concerning height, weight, body mass index (BMI), or relative VO_{2max} ($p > .05$). Baseline pre-exercise data (resting heart and metabolic rates) collected prior to the DDR exercise bouts showed that, similar to the VO_{2max} values, no significant differences existed between experienced and inexperienced participants for baseline resting VO_2 (3.9 ± 0.9 mL/kg × min^{-1} and 3.9 ± 0.6 mL/kg × min^{-1}, respectively; $p > .05$), although we observed significant differences in baseline HR (73.2 ± 8.4 bpm and 64.5 ± 5.3 bpm, respectively; $p < .05$).

Table 2 presents exercise data. Compared with inexperienced participants, experienced participants exhibited significantly higher average exercise values on all cardiovascular variables including HR, RPE, RER, VO_2, and VO_2R, and

TABLE 1. Participant Characteristics

	Experienced participants (n = 12)		Inexperienced participants (n = 7)	
Characteristic	*M*	*SD*	*M*	*SD*
Age (y)	19.7	2.1	25.6	1.6*
Height (cm)	180.2	6.4	174.9	6.3
Weight (kg)	86.3	20.8	69.2	19.3
Body mass index (kgm^2)	26.5	6.1	22.8	6.7
VO_{2max} (mL × kg^{-1} × min^{-1})	49.2	9.8	56.8	10.7

*$p < .05$.

TABLE 2. Interactive Video-Game Exercise Bout Data

	Experienced participants (n = 12)		Inexperienced participants (n = 7)	
Exercise variable	*M*	*SD*	*M*	*SD*
Heart rate (bpm)	161.2	13.8	95.5	10.5*
RER	0.94	0.05	0.84	0.04*
Avg. VO_2 ($mLkg^{-1} \times min^{-1}$)	25.2	5.1	13.1	2.2*
VO_2R (%)	47.7	8.4	18.0	4.2*
RPE (6–20 scale)	13.4	1.5	10.7	1.7*
TEE_{30} (kcal × 30 min^{-1})	315.5	61.2	144.0	28.7*
Avg. $EE_{1.0}$ (kcal × min^{-1})	10.5	2.0	4.8	1.0*
Relative $EE_{1.0}$ (kcal × kg^{-1} × min^{-1})	0.13	0.03	0.08	0.04*
T_{150} (min × 150 $kcal^{-1}$)	14.5	2.8	32.2	7.4*
TS_{30} (step × 30 min^{-1})	3,305.0	271.1	2,207.4	514.7*
$S_{1.0}$ (step × min^{-1})	110.2	9.0	73.6	17.2*
TS_{150} (steps × 150 $kcal^{-1}$)	1,590.9	263.6	2,273.2	187.1*
Enjoyment (1–5 scale)	4.7	0.5	3.9	1.1*

Note. RER = respiratory exchange rate; VO_2 = oxygen consumption; VO_2R = percentage of oxygen consumption reserve; RPE = rate of perceived exertion; TEE_{30} = total energy expenditure; $EE_{1.0}$ = energy expenditure per minute; T_{150} = time to expend 150 kcal; TS_{30} = total steps taken in 30 minutes; $S_{1.0}$ = steps taken per minute; TS_{150} = steps required to expend 150 kcal.
*$p < .05$.

reported higher levels of enjoyment (4.6 ± 0.5 and 3.9 ± 1.1, respectively) when playing DDR ($p < .05$). Experienced participants also generated significantly greater $S_{1.0}$, and TS_{30} ($p < .05$). Experienced participants generated greater TEE_{30}, Avg. $EE_{1.0}$, and Rel-$EE_{1.0}$, after controlling for body weight, and significantly lower T_{150} and TS_{150} ($p < .05$). According to ACSM guidelines,[7] experienced players achieved a VO_2R equivalent to moderate intensity (47.7 ± 8.4 %VO_2R) and inexperienced players achieved a VO_2R equivalent to very light intensity (18.0 ± 4.2 %VO_2R). During the 30-minute bout, experienced participants expended more than 150 kcal (315.5 ± 61.2 kcal/30 min), whereas inexperienced participants generated marginally less than 150 kcal (144.0 ± 28.7 kcal/30 min).

COMMENT

Despite past findings[7] demonstrating the utility of PIVGs in helping college students meet current physical activity recommendations, little was known about the influence of playing experience on energy expenditure through PIVG playing in this population. To our knowledge, we are the first to investigate the relationship between energy expenditure and DDR playing experience in college students—or any population.

Few researchers[22,27] have examined PIVGs' utility in eliciting significant energy expenditure in healthy populations, especially relative to established physical activity recommendations. Segal and Dietz[27] demonstrated that PIVG could elicit an Avg. $EE_{1.0}$ of 10.9 ± 0.5 kcal/min among 16- to 25-year-old participants. Sell and colleagues[28] showed that energy expenditure during a 30-minute bout of an upper-body PIVG was less than that generated by treadmill walking for the same duration. However, participants expressed a greater level of enjoyment while playing the PIVG, suggesting that they might be more willing to engage in this form of physical activity. Ridley and Olds[18] found a wider range of energy expenditure for children playing 4 types of video games (7.6–26.5 mL/kg × min^{-1} and 0.09–0.57 kJ/kg × min^{-1}, respectively). This difference was largely attributed to the type of video game played; twitch games involving small rapid hand movements generated lower energy expenditure than did games with large-muscle lower-body movements. The researchers did not explore other explanations, such as the influence of playing experience.

In addressing the first purpose of this study, greater DDR playing experience was associated with greater relative energy expenditure. Playing at higher levels of difficulty produced higher average HR, RER, RPE, VO_2, TS_{30}, and Rel-$EE_{1.0}$, which, in turn, led to greater %VO_2R, TEE_{30}, Avg. $EE_{1.0}$, and $S_{1.0}$, and lower T_{150} and TS_{150}. The 2 primary findings support the argument that the observed differences in energy expenditure during 30 minutes of game play were a function of experience level. First, we found no statistically significant differences in cardiorespiratory fitness levels (VO_{2max}) or baseline metabolic rates between experienced and inexperienced participants ($p > .05$). Second, any differences in body weight were statistically controlled—we examined energy expenditure relative to body weight (Rel-$EE_{1.0}$). Although no significant differences in body weight or BMI were present ($p > .05$), we did observe significant differences in Rel-$EE_{1.0}$ ($p < .05$). In addition, the significant difference in TEE_{30}, Avg. VO_2,

$Rel\text{-}EE_{1.0}$, and T_{150} between experienced and inexperienced participants suggests that greater experience, as opposed to simple familiarization with the DDR game, facilitated a higher work-rate and greater energy expenditure.

Mechanisms through which greater playing experience facilitated higher energy expenditure are likely related to the capacity of experienced participants to play at a higher level of difficulty (eg, level 4 vs level 1). On the basis of researcher observation during the DDR exercise bouts, experienced participants had greater on-task and continuous playing time. Physiologically, being able to play at a higher level of difficulty was associated with a higher HR, RER, and VO_2—a trend observed in other sports.[25,28] On the basis of observations, game play at a higher level of difficulty also may be associated with greater use of the arms and lower body, and thus more vigorous overall bodily movement. The addition of upper-body movements or weights to physical activity (eg, bench and step aerobics, walking) can potentially increase HR[29,30] and energy expenditure,[18,28,31,32] which may help explain the observed increase in energy expenditure for experienced participants.

Another possibility is that experienced players' greater degree of familiarity promoted greater relaxation, less playing anxiety, and an improved ability to concentrate and successfully complete the task. Overall, increased concentration and focus may increase playing time at a relatively higher level of difficulty that would potentially help increase energy expenditure. Junge and colleagues[33] explored this trend in football players. Experienced players demonstrated better reaction times, less competitive anxiety, and better levels of concentration.

Participants with greater playing experience also accumulated more steps over the 30-minute DDR exercise bout. A faster rate of stepping associated with the difficulty level selected, greater continuous playing time, and more efficient transitioning between songs also could be factors. Any pauses in play during the 30-minute testing session, although minimal for all participants, may have been relatively shorter for experienced players. An exact measure of transition times between songs might have helped clarify this trend, but we did not record it in this study because we considered those transitions reflective of the real-life playing environment. We thus permitted discontinuous playing time in an effort to replicate real-world play, as researchers[18,23,33] have done in previous studies with children and adolescents. Further research is needed to examine the influence of each of these possible mechanisms during PIVGs. Overall, DDR game play at a higher level appears to elicit greater energy expenditure, suggesting that increasing an individual's proficiency through practice will promote increases in energy expenditure and potentially generate greater long-term health benefits.

We addressed the second purpose of this study by examining measures of energy expenditure and physical activity intensity. On average, experienced participants achieved the ACSM recommendations for moderate-intensity physical activity (40% to 59% VO_2R), whereas inexperienced players achieved a percentage equivalent to very light intensity (< 20% VO_2R). Experienced and inexperienced participants exceeded or came close to achieving the recommended energy expenditure of 150 kcal per 30-minute physical activity bout. The moderately strong relationship ($r = .61$, $p < .05$) between self-reported RPE and percentage VO_2R during DDR activity suggests that participants were able to evaluate the intensity of the activity, regardless of experience level. The ability to evaluate intensity as indicated in this study would facilitate activity prescription in the future. Intermittent physical activity, such as that performed in this study, is certainly beneficial, and ACSM and other researchers[18,34,34] encourage accumulating moderate-to-vigorous intensity physical activity throughout the day for those reluctant to engage in 30 minutes of continuous aerobic activity.

Previous research has suggested that college students find playing PIVGs more enjoyable than treadmill walking (a commonly prescribed mode of physical activity) for generating energy expenditure.[22,27] Experienced players in our study expressed a significantly greater level of enjoyment (on the basis of a 1 [*not enjoyable*] to 5 [*highly enjoyable*] scale) than did inexperienced players (4.7 ± 0.5 vs 3.9 ± 1.1, respectively; $p < .05$), but all players preferred game play over treadmill walking. Thus, in addition to the energy expended, the level of enjoyment experienced by all participants suggests that PIVG play could be a means to promote regular exercise in young adults for which a traditional physical activity program might not be possible or desirable.[27,35,36]

Limitations

This exploratory investigation is limited by the small convenience sample and its relatively homogeneous male composition, and thus these results apply only to male college students in this study. A larger sample or other populations may respond differently. The college students included in this study were from one university; further research is needed to verify these results in college students nationwide. We also used a cross-sectional approach to determine the influence of playing experience on energy expenditure during PIVG play, and we assessed only 1 PIVG that primarily emphasized lower-body movements. A longitudinal study is warranted to evaluate a training effect on energy expenditure.

Future Research

Researchers should target larger, more diverse populations, such as young women and children, to evaluate the efficacy and prevalence of DDR and other PIVG as alternatives to traditional modes of physical activity. Investigators in follow-up studies could examine the use of an intervention (eg, training program) to promote greater DDR playing experience to increase the potential for energy expenditure using DDR or other PIVGs, such as those stimulating large muscles of the upper body. In future studies, researchers should incorporate a measure of body composition as opposed to BMI to gauge whether PIVG play can elicit decreases in body fat.

Conclusions

Participants with greater DDR playing experience had greater energy expenditure and playing intensity relative to inexperienced participants. Experienced players met or exceeded the current recommendations for moderate-intensity physical activity. On the basis of the data in this study, a 68-kg, experienced DDR player would expend, on average, an additional 102 kcal/30-min session than would an inexperienced player of the same weight. DDR could be a useful device for individuals exploring innovative approaches to promote energy expenditure. If maintained, DDR play may lead to increases in daily physical activity and fitness, and reduce the risk of hypokinetic disease. The relevance of these findings are further highlighted by the utility of DDR to elicit high levels of enjoyment in all participants, experienced or inexperienced. Enjoyment is highly correlated with continued participation in the given activity[37,38] and thus may motivate college students to become more physically active on a regular basis. For individuals interested in using DDR to contribute to current physical activity and energy expenditure recommendations, gaining game-playing experience will facilitate these goals.

NOTE

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