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Vigorous Energy Expenditure with a Dance Exer-game

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ABSTRACT

Noah JA, Spierer DK, Tachibana A, Bronner S. Vigorous Energy Expenditure with a Dance Exer-game. **JEPonline** 2011;14(4):13-28. Physical inactivity is a risk factor for heart disease, diabetes, and obesity. Efforts to increase physical activity can include active video games. While many active video games demonstrate exertion levels commensurate with light to moderate exercise, it is unclear whether these games can meet requirements for vigorous activity. The purpose of this study was to determine whether the active video game, *Dance Dance Revolution* (DDR), can provide vigorous exercise in a wide range of adults. Twelve adults (18 to 53 yrs, BMI 18 to 37) were studied while playing DDR at an advanced level. Metabolic measures were collected during a 30 min game-play protocol at the advanced "Heavy" level of difficulty. Mean values achieved were the following: 8 METs, heart rate 157 beats·min^{-1}, and energy expenditure 9 kcal·min^{-1}. DDR is played similarly to that of interval type exercise where each game-song is followed by a brief rest period. Subjects reported that DDR is fun, and that the competitive nature of playing with others is enjoyable. This study found that DDR is effective in meeting vigorous physical activity requirements for improving or maintaining physical fitness.

Key Words: Exercise, Active Video Game, Heart Rate, Metabolism

INTRODUCTION

Physical inactivity is the fourth leading risk factor of global mortality (39). Studies indicate a direct relationship between physical activity and cardiorespiratory health, metabolic health, weight maintenance; and some studies indicate a possible link between physical activity and prevention of breast and colon cancer (26).

Activity guidelines recommend that adults between 18 to 65 years should perform moderate intensity aerobic physical activity (40 to 60% VO_2 max or 3 to 6 METs; walking at ~3.3 $miles \cdot hr^{-1}$) for a minimum of 150 $min \cdot wk^{-1}$ (26,33,39). Alternatively, vigorous activity can be performed for 75 $min \cdot wk^{-1}$ (>60% VO_2 max or >6 METs; similar to jogging). A combination of moderate and vigorous activity can also be performed to meet these requirements and higher volumes of activity (greater than 150 $min \cdot wk^{-1}$) are shown to be associated with additional health benefits (39). Since the majority of the population is sedentary, prior physical activity recommendations have focused more on moderate exertion (32).

Recent clinical trials demonstrate a greater reduction in cardiovascular risk factors with vigorous intensity exercise and suggest that moderate physical activity may be insufficient (28,37). Interval training, characterized by brief bursts of high intensity work alternated with periods of rest or light activity, can be used to meet vigorous activity requirements. Interval training historically has been reserved for those interested in peak performance, but new data demonstrate cardioprotective and musculoskeletal benefits for a range of populations (10). Furthermore, interval training has been demonstrated to be safe and effective in a variety of populations including adults with coronary heart disease (28). Interval training can be performed using exercise modes that are commonly found in a fitness facility (e.g., stationary cycle ergometers, treadmills, and rowing ergometers) or at home.

An alternative to more traditional exercise practices includes active video games in which the participant interacts with screen avatars during activity. For example, active video games include exer-games such as *Dance Dance Revolution*, *Wii Sports*, and *Wii Fit*, multiple games designed for the Sony *EyeToy* and *PlayStation Move* and, most recently, a number of games for the Microsoft *Kinect* including *Dance Central* and *Kinect Adventures.* There is a growing body of evidence suggesting that exer-games may represent a viable alternative to traditional exercise to meet suggested physical activity requirements.

Current statistics report that 67% of households in the US play video games (8). According to a recent survey from the American Heart Association, 29% of adults between the ages of 25 to 55 are active video game players (30). People who play active video games are more active than non-gamers. Specifically, 34% of active-play gamers engage in 30 min of exercise five or more $d \cdot wk^{-1}$ compared to 23% of non-gamers. Furthermore, 9% of people who play active video games say that exercise is more fun. In respondents who play active video games, 68% have become more physically active overall. Of those, 58% started a new fitness activity like walking, playing tennis or jogging.

Clearly, playing active video games is a trend that is rising in popularity. Studies on the effects and efficacy of active games like *Wii Fit* and *Wii Sports*, mini games for the *Sony EyeToy*, and *Dance Dance Revolution* demonstrate that light to moderate intensity levels of 1.7 to 4.2 METs in children, 1.9 to 5.0 in young adults, and 1.9 to 3.2 in older adults can be achieved (4,5,9,11-13,17,19,22,27,31,34). One study also reported on less common games (Cybex Trazer, LightSpace, Sportwall, and XaviX) and found that energy expenditure in children reached 6 to 7 METs in a 10 min test (4). Only one *Dance Dance Revolution* study reported adolescents achieved 7 METs in a 10 min test (31).

Vigorous exercise is a time efficient means for improving or maintaining physical fitness. Active video games that elicit exertion levels exceeding 6 METs are considered vigorous games that may help achieve the recommended levels of energy expenditure to increase fitness. One exer-game that provides players with the potential for a workout progression from basic to advanced physical challenges is *Dance Dance Revolution* (DDR). Experience of the DDR player has been found to have a great influence on whether higher levels of energy are expended (27). Study participants also report high levels of enjoyment and motivation in playing the game. Thus, the motivating factor of DDR, that the participant perceives that he or she is "dancing" or "playing" not "exercising," may influence the intensity and energy expended during game-play. This is known as game-flow, the notion that the player experiences a full immersion in the game.

The purpose of this study was to determine whether experienced subjects playing DDR meet minimum requirements for vigorous activity and whether DDR elicits similar physiological responses to that of interval training. A secondary purpose was to determine how participants felt about the game-play experience. First, it was hypothesized that the experienced players would be able to meet requirements for vigorous activity (>6 METs), and that the energy expenditure would be dependent upon each song's beats$\cdot$min^{-1} and step/song value. The structure of DDR game-play is such that active periods alternate with rest periods. Participants play a game-song and then take time to select the next game-song. Second, based on the work-rest ratio, it was hypothesized that DDR could act as a surrogate method for interval training. Third, it was hypothesized that experienced players of DDR would respond positively to the *Video Game Training Effect Questionnaire* after a minimum of 20 hrs of play.

METHODS

Subjects

Twelve players were tested (mean age 27.2 ±11.3 yrs, range 18 to 53 yrs, 4 males, 8 females). This was a sample of convenience of subjects who met the training and DDR level of game-play requirements. No power analysis was performed, as this was a descriptive study. Subjects had a mean height of 1.67 m ± 0.08 (range 1.50 to 1.85), mass of 69.2 kg ± 11.7 (range 50 to 109), and BMI of 24.7 ± 6.1 (range 17.9 to 37.3) (Table 1). Participants were healthy non-smokers, free from any cardiovascular, musculoskeletal or neurological condition that precluded them from performing a maximal exercise test or training session.

All participants had a minimum of 20 hrs of experience playing an open source dance simulation game similar to DDR, *Stepmania*, and were able to play in the advanced "Heavy" mode (level 4). This open source software was selected to allow for saving and analyzing games scores and level of game difficulty progression over time as participants trained. To understand how subjects responded cognitively, physiologically, and/or socially to the exer-game training experience, participants answered a multi-part "*Video Game Training Effect Questionnaire*" following their testing. The *Video Game Training Effect Questionnaire* contains questions based on a validated survey on DDR developed by Höysniemi (14) as well as questions directly related to the eight components of flow (6,7,23,25,29). It uses a 5-point Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree). All participants signed an informed consent approved by the university Institutional Review Board.

Table 1. Demographics.

Subject	Gender	Age (yrs)	Height (m)	Mass (kg)	BMI ($kg \cdot m^{-2}$)	Baseline HR ($beats \cdot min^{-1}$)	HR max * ($beats \cdot min^{-1}$)
Subject 1	M	36	1.74	84	27.8	53.44	182.78
Subject 2	F	23	1.63	68	25.6	78.55	191.49
Subject 3	F	21	1.75	72	23.5	73.28	192.83
Subject 4	F	21	1.50	84	37.3	- -	192.82
Subject 5	F	53	1.60	58	22.6	75.71	171.39
Subject 6	F	24	1.63	50	18.8	85.38	190.82
Subject 7	F	29	1.62	50	19.0	81.47	187.47
Subject 8	F	20	1.74	57	18.8	- -	193.50
Subject 9	M	36	1.67	60	21.5	82.55	182.78
Subject 10	M	22	1.85	109	31.8	72.45	192.16
Subject 11	F	24	1.52	48	20.8	- -	190.82
Subject 12	M	18	1.72	69	17.9	71.02	194.84
Mean		**27.2**	**1.67**	**69.2**	**24.7**	**75.22**	**187.80**
±SD		**11.3**	**0.08**	**11.7**	**6.1**	**4.26**	**7.56**

*HR_{max} calculated using Karvonen formula (2,16). Abbreviations: baseline HR, baseline resting heart rate; HR max, predicted maximal heart rate.

Instrumentation

Participants were outfitted with a telemetric gas analysis system ($K4b^2$ Cosmed Inc., Rome, Italy) comprised of a small metabolic analyzer, battery pack, and facemask and a chest strap heart rate (HR) monitor (Polar Inc., Lake Success, NY). The facemask was attached to a turbine flowmeter that allowed for real-time collection of VO_2 values. The $K4b^2$ unit (~925 g) was strapped to the participant's shoulders and torso using the manufacturer's harness throughout the exercise bout. The $K4b^2$ has been validated previously (15,21). The $K4b^2$ was calibrated according to the manufacturer's instructions prior to each testing session. During testing, VO_2 ($mL \cdot min^{-1}$), VCO_2 ($mL \cdot min^{-1}$), and HR ($beats \cdot min^{-1}$) were monitored continuously and recorded using the $K4b^2$ breath-by-breath analysis.

Testing Protocol

Participants were tested between 9:00 am and 5:00 pm and were asked to refrain from eating at least 2 hrs prior to testing. During the test session, participants wore comfortable workout attire and played in socks or bare foot, as they preferred. Ambient lab temperature was maintained at 22 to 24°C. After donning the telemetric gas analysis system, participants were asked to sit and rest quietly for 10 min prior to collecting 5 min of baseline resting metabolic data. Each participant then completed the DDR testing protocol (DDR max) to assess metabolic data during varied song intensities. Following completion of the DDR max protocol, the subjects were again asked to sit and rest quietly for 5 min to collect recovery metabolic data. After testing, the data were transferred and saved onto a computer hard drive for analyses.

During DDR max the participants played on a commercial metal platform, connected to a computer running Microsoft Windows 7 Ultimate and a large 50 in video monitor. The testing protocol was structured to reflect the equivalent of an interval training session. The goal was to provide a vigorous workout that allowed for recovery time in between roughly 90-sec bouts of intense activity (20). The recovery time was varied as is customarily done in other interval training programs including sprints and hill climbs. The songs were chosen based on beats·min^{-1} of the music to create increasing intensity of game-play during each sequence. Three levels of song intensity (beats·min^{-1}) were used: low, medium, and high. The first level used two songs at 138 beats·min^{-1}, while the second level was played at 150 beats·min^{-1}, and third level was 170 and 190 beats·min^{-1} (Table 2).

Table 2. Game songs used for DDR_{max} testing protocol.

Game song	DDR Game	Artist	Duration (sec)	Beats·min^{-1}	Steps/song
Boys	DDR, 2nd mix	SMILE.dk	85	138	208
Mr. Wonderful	DDR MAX2	SMILE.dk	89	138	243
Freckles-Sobakasu	DDR 6th mix	Tiggy	92	150	314
Midnite Blaze	DDR MAX	U1 Jewel Style	92	150	333
Butterfly	DDR Extreme2	SMILE.dk	87	170	322
Breakdown	DDR MAX2	BeForU	106	190	403

Testing protocol entailed playing three sequences of the six game-songs. In the first round of 6 songs, players received a 45-sec break between each song (Sequence 1). In the second round, players received a 30-sec break (Sequence 2). There was a 15-sec break between songs in the third round (Sequence 3). The break times between game-songs served as recovery periods. The slower beats·min^{-1} in the initial game-songs served as a warm-up since the more intense game-songs were capable of initiating maximum predicted HR in some players.

Statistical Analyses

Data recorded from the K4b^2 were exported as a .txt file into Microsoft Excel for subject and group analysis. Mean ± SD for the following exercise variables were calculated: baseline pre-exercise and post-exercise recovery data (resting HR and metabolic rates), METs, respiratory exchange ratio (RER), HR (beats·min^{-1}), volume of expired oxygen (V_E L·min^{-1}), volume of oxygen consumption (VO_2 mL·kg^{-1}·min^{-1}, and energy expenditure (EE kcal·min^{-1}) per game-song, per sequence, and for the entire test. The overall metabolic expenditure of the workout was determined as the average of a game-song play trial minus the rest intervals. Between-song rest intervals for each sequence were also determined. Predicted maximal heart rate (HR max) was calculated for each subject using the Karvonen formula (2,16).

To mark the beginning and end of each game-song, the K4b^2 marker feature was used, which placed an indicator in the text file. Across subjects there was a small amount of variability in the duration as this was done manually. To accommodate for these differences, individual song durations were time normalized using an interpolation function to fit the data to the overall percent of song. Data for individual song metabolic expenditures were then averaged across subjects. Comparisons between sequences were conducted using one-way ANOVA (P= 0.05).

Data from the *Video Game Training Effect Questionnaire* were entered into Microsoft Excel and means were calculated for each question separately.

RESULTS

At the initial 5 min baseline period, normalized mean ± SD resting METs were 1.72 ± 0.24 (range 1.22 to 2.31) and normalized resting HR were 76.81 ± 2.96 (range 69.06 to 81.89) beats·min^{-1} (Table 3). During the recovery period, subject METs averaged 3.29 ± 1.84 (range 1.49 to 7.67) and HR were 126.49 ± 16.08 (range 106.09 to 162.55) beats·min^{-1}. Calculated HR max ranged from 171.39 to 193.50 beats·min^{-1} (Table 1). Mean EE was 1.88 ± 0.27 kcal·min^{-1} at baseline and 3.92 ± 2.27 at recovery.

Table 3. Mean (±SD) baseline and recovery data.

Variable	Baseline	Recovery
METs	1.72 ± 0.24	3.29 ± 1.84
RER	0.91 ± 0.08	1.03 ± 0.08
HR (beats·min^{-1})	76.81 ± 2.96	126.49 ± 16.08
V_E (L·min^{-1})	11.61 ± 1.44	24.76 ± 11.11
VO_2 (mL·kg^{-1}·min^{-1})	8.00 ± 1.18	13.61 ± 5.98
EE (kcal·min^{-1})	1.88 ± 0.27	3.92 ± 2.27

Abbreviations: RER, respiratory exchange ratio; HR, heart rate; V_E, volume of expired oxygen; VO_2, volume of oxygen consumption; EE, energy expenditure.

Total time to complete DDR testing (including rest intervals) was 35.05 min. Total game-play time was 27.55 min. Normalized average exertion for the entire test in METs was 8.02 ± 1.45 with average peaks ranging from 11.47 to 14.24. Normalized average HR across subjects for the entire test was 156.75 ± 16.36 beats·min^{-1} with average peaks ranging from 186.23 to 195.25 beats·min^{-1}. Normalized mean EE was 9.41 ± 1.63 kcal·min^{-1} with average peaks ranging from 13.02 to 17.06 kcal·min^{-1}. Comparisons of the three sequences found no differences in any of the variables with the exception of RER (P=0.002) and HR (P=0.01) (Table 4), despite decreasing rest intervals between songs depending on the sequence. RER values in Sequence 2 exceeded those of Sequence 3. The HR values increased from Sequence 1 through 2, and 3.

Table 4. Mean (±SD) and range of values of combined DDR_{max} test and sequence data.

Variable	Combined	SEQ 1: 45 sec	SEQ 2: 30 sec	SEQ 3: 15 sec
METs	8.02 ± 1.45	7.94 ± 1.89	7.99 ± 1.23	8.16 ± 1.09
Range	2.41 – 14.24			
RER	1.07 ± 0.10	1.09 ± 0.12	1.09 ± 0.10	1.05 ± 0.08
Range	0.64 – 1.99			
HR (beats·min^{-1})	156.75 ± 16.36	148.10 ± 19.30	157.41 ± 13.22	164.46 ± 11.26
Range	82.56 – 195.25			
V_E (L·min^{-1})	62.78 ± 11.93	59.71 ± 14.95	64.30 ± 10.01	64.31 ± 9.57
Range	17.94 – 118.00			
VO_2 (mL·kg^{-1}·min^{-1})	28.45 ± 5.06	28.25 ± 6.60	28.24 ± 4.27	28.85 ± 3.84
Range	7.15 – 51.97			
EE (kcal·min^{-1})	9.41 ± 1.63	9.45 ± 2.15	9.36 ± 1.36	9.42 ± 1.23
Range	2.26 – 17.06			

Abbreviations: SEQ, sequence; RER, respiratory exchange ratio; HR, heart rate; V_E, volume of expired oxygen; VO_2, volume of oxygen consumption; EE, energy expenditure.

Mean values during song rest intervals for each sequence (e.g., 45 sec, 30 sec, and 15 sec) were quite similar (Table 5). Mean metabolic values tended to remain stable or increase minimally by Sequence 3, with the exception of RER and EE values.

Table 5. Descriptive data of the subjects.

Variable	SEQ 1: 45 sec	SEQ 2: 30 sec	SEQ 3: 15 sec
METs	7.93 ± 2.01	7.95 ± 2.05	7.87 ± 1.99
RER	1.08 ± 0.13	0.99 ± 0.09	0.96 ± 0.10
HR (beats·min^{-1})	145.87 ± 17.11	155.12 ± 15.27	159.41 ± 13.91
V_E (L·min^{-1})	55.16 ± 15.50	55.32 ± 13.78	54.98 ± 13.18
VO_2 (mL·kg^{-1}·min^{-1})	26.55 ± 7.13	26.92 ± 7.00	26.97 ± 6.73
EE (kcal·min^{-1})	9.04 ± 3.74	9.15 ± 2.30	8.82 ± 2.16

Abbreviations: METs, metabolic equivalents; RER, respiratory exchange ratio; HR, heart rate; V_E, volume of expired oxygen; VO_2, volume of oxygen consumption; EE, energy expenditure.

Comparisons of game-songs found distinct changes across songs for both METs and HR (Figures 1 and 2). In Sequence 1, MET values increased from '*Boys*' to '*Breakdown*'. In Sequences 2 and 3, '*Boys*' immediately followed the hardest song, '*Breakdown*', with corresponding elevated METs. There was a drop in MET values during '*Mr. Wonderful*' in Sequences 2 and 3. Mean HR also showed increasing values with each song, with the exception of the second song, '*Mr. Wonderful*'. Energy expenditure changes paralleled those of METs. Throughout the three sequences, subjects worked at 75 to 92% of their estimated HR max (mean 82%).

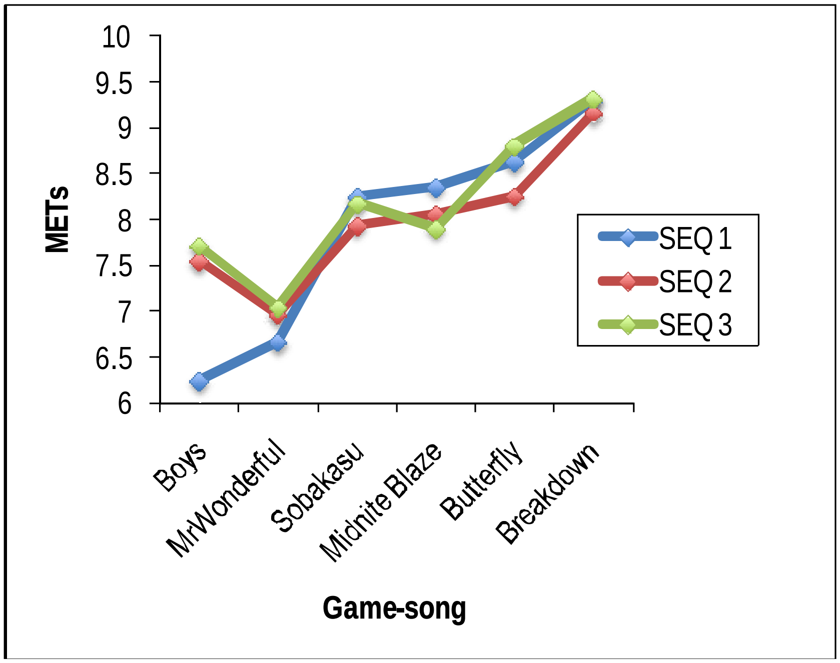

Figure 1. Mean METs per song for each sequence.

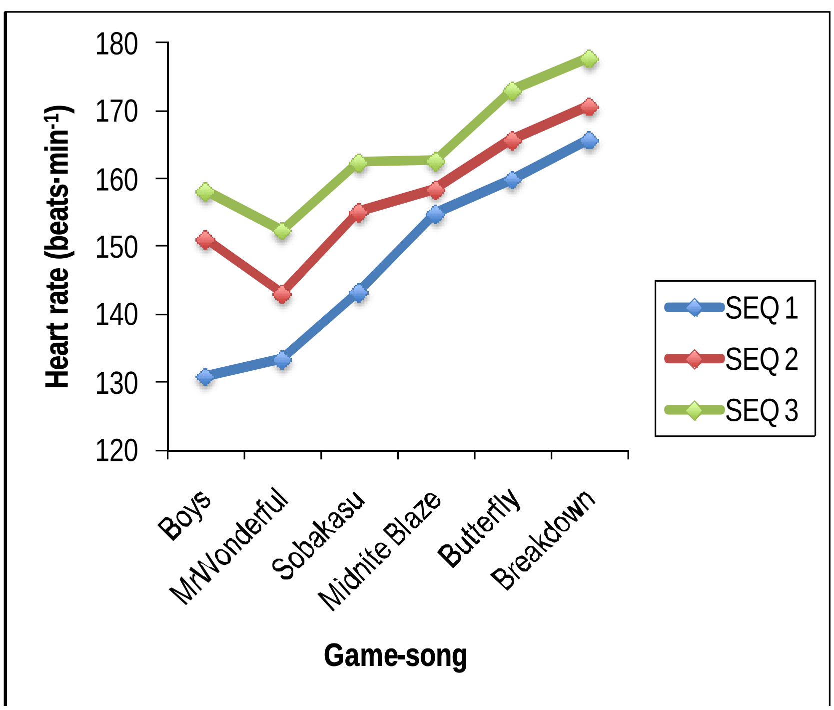

Figure 2. Mean heart rate per song for each sequence.

Subjects represented a wide age range and BMI. Therefore, the pattern of METs and HR per song was examined for each subject. Subject 4, with the highest BMI of 37.3, worked at the lowest range of METs (mean 5.04 METs), while Subject 5, age 53, averaged 9.44 METs. Subject 6, with one of the lowest BMI values (18.82), worked at the highest MET level (mean 9.56 METs). Subject 10, with the greatest height and weight (BMI = 31.8), had the highest energy expenditure (mean 15.95 kcal·min^{-1}).

Results from the *Video Game Training Effect Questionnaire* were positive (Figure 3). All subjects agreed that DDR was a useful workout (4.8), was good for their health (4.9), training was fun (4.9), and they would be willing to continue to play DDR as a workout (4.7). Subjects also agreed that group play encouraged them to improve their skills (4.8), and they enjoyed the competitive nature of playing with others (4.6) as well as against themselves (4.8). They also agreed the game had clear goals (4.6), gave direct and immediate feedback (4.7), and required concentration (4.8). Finally, subjects agreed that when playing with others their sense of time duration was altered (4.4), and they felt immersed in the game-song (4.5).

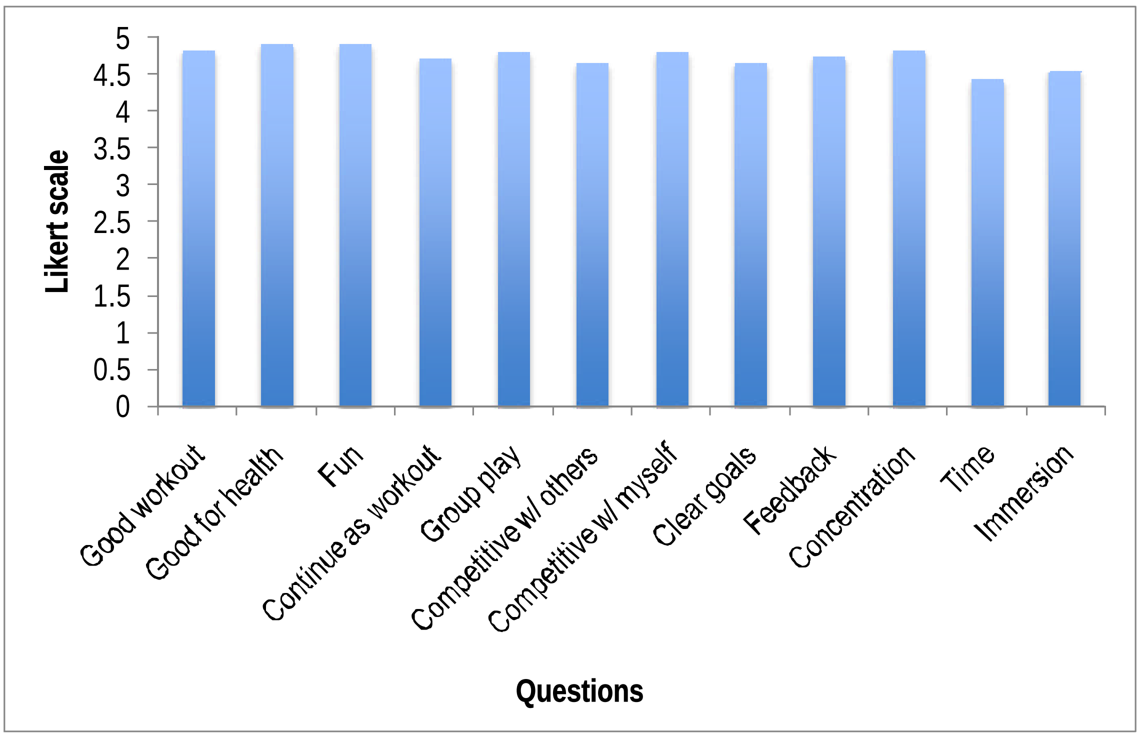

Figure 3. Mean responses to the *Video Game Training Effect Questionnaire*.

DISCUSSION

The primary purpose of this study was to determine whether experienced players could achieve a level of intensity commensurate with vigorous activity and to explore whether DDR can be used as an alternative method to standard interval training. Secondarily we wanted to explore players' perception or experience of game-play. The data demonstrate that DDR elicited a level of physical activity in experienced players high enough to meet vigorous activity guidelines. Current guidelines suggest a minimum of 75 min·wk^{-1} at greater than 6 METs. These players tended to play for 60 min and 4 to 5 d·wk^{-1}, equivalent to 240 to 300 min·wk^{-1}. Furthermore, work–rest periods similar to that used in high intensity interval work-bouts can be simulated while playing DDR. Players responded positively to the questionnaire, indicating an experience of game immersion or flow.

In response to the game-play testing session, participants produced HRs that averaged 82% of age predicted maximum and exertion levels that averaged 8 METs and frequently exceeded 14 METs. A MET level of 8 is comparable to running 5 miles·hr^{-1}, jumping rope, playing basketball or playing singles tennis. A MET level of 14 is commensurate with running at 8.6 miles·hr^{-1}, speed skating, and track and field events such as hurdles or the steeplechase (1).

Caloric expenditures during the sequences in this study were a mean of 9.41 kcal·min^{-1}, ranging from 2.26 to 17.06 kcal·min^{-1} across songs and participants. The fact that DDR resulted in these findings is not surprising. It is well-established that regular physical activity using large muscle groups can significantly increase HR, exertion, and exercise capacity. DDR is a full body exercise with constant involvement of lower and upper extremity musculature. The nature of the game forces the participant to jump and move quickly, facilitating neuromuscular drive that requires coordination, balance, dexterity, and cardiovascular fitness. With greater experience, players must jump more and move faster with increasing steps/song.

Games such as DDR are often studied in children, but data are rare in adults. While the majority of data suggest that DDR can be used to meet minimum requirements for moderate physical activity, it was unknown whether DDR game-play can reach vigorous levels for sustained periods (18,27,31,34). While Sell et al. (27) reported on experienced college students who played on “Heavy,” similar to players in this study, levels and game-songs were not standardized but self-selected in 30 min of game-play. They reported a VO_2 reserve equivalent to moderate intensity, although mean HR reached 161 beats·min^{-1}. This underscores the difference in physical activity depending on game-song beats·min^{-1} and number of “feet” (difficulty within each level). To add to the work done by Sell et al. (27), the current study imposed a 30 min standardized protocol based on recovery duration and song selection. The data suggest that experienced DDR players can sustain vigorous activity for an extended period of time. This is in contrast to previous work that only examined a 10 min playing duration (31).

Previous data did not provide explicit information about the game-song beats·min^{-1} at which the players performed. Data from Tan et al. (31) suggest that inexperienced players played at light intensity (low beats·min^{-1}) while experienced players played at moderate intensity. This would explain the correlation between experience and energy expenditure. In order to properly address this point, specific details of the game must be transparent. Not knowing the beats·min^{-1} of each song while exercising is roughly the equivalent of not knowing the belt speed during a treadmill exercise bout.

Data from the current study suggest that DDR does elicit high levels of physical activity in its players. The difference in our findings compared to previous work (27) may belie the experience of the players being tested. In the current study, participants had trained at playing DDR for at least 20 hrs. They were also capable of playing at the “Heavy” level where song cadence and difficulty is at its highest. Previous studies may not have matched the ability of the player to the song cadence. As long as the player is not being challenged by the beats·min^{-1}, there will not be a significant cardiovascular response. Thus, the findings in the present study support the hypothesis that DDR game-play at the “Heavy” level in experienced players meets requirements for vigorous activity.

Interval training, defined by fixed activity and recovery periods, elicits high HRs and, therefore, includes appropriately timed recovery bouts after each interval is completed. In this study, participants underwent a varied work to rest ratio (e.g., 90:45 sec, 90:30 sec, and 90:15 sec) while maintaining HR exceeding 80% of age predicted maximum. Prior work illustrates that anywhere from 25 to 40% of VO_2 max or 50 to 70% of peak HR is considered an appropriate recovery effort after short intervals of high intensity exercise (35,37). In this study, HR interval recovery ranged from 62 to 99% (mean 81%)

of HR max. suggesting that these intervals pushed the subjects beyond what is standard. However, the nature of game-play must be considered when developing fixed periods of activity and rest.

Interval training has been shown to be effective in both athletic and clinical populations. A recent study reported that interval training can reverse cardiac remodeling, reduce left ventricular end diastolic volumes, and improve endothelial function in stable post-infarction subjects who maintained intensities of 90 to 95% of HR max as compared to those who exercised a moderate levels of exertion (70% HR max) (35,37). Although this study was not designed to measure the effect of DDR as an intervention, the MET levels attained over the 20 hr period suggest that DDR may act as a surrogate method to conventional interval training exercise from which cardiovascular adaptations are well-established (3,24).

Although we did not measure lactate in the blood, minute ventilation (V_E) levels, a reflection of anaerobic glycolysis, averaged 63% of maximum suggesting participants may have exceeded their anaerobic threshold while playing. This is in agreement with data that show anaerobic threshold is generally achieved between 50 to 60% of maximal capacity in non-athletic populations (36). Surprisingly, anaerobic metabolism during game-play was not reflected in RER values. Although the average RER value across subjects exceeded 1.0 (1.07), the changes in RER values from Sequence 1 to 3 did not show an expected progression as recovery time was reduced. The reduction in RER value from Sequence 1 to 3 may indicate a training adaptation owing to a greater reliance on free fatty mobilization and aerobic metabolism. These data suggest that DDR may be used as an alternative method to provide similar adaptations including improved glycolic efficiency and the eventual influence on oxidative metabolism (38). Another explanation for the reduction in RER value from Sequence 1 to 3 is that Sequence 1 served somewhat as a warm up. It takes time to begin efficiently processing the arrows on the screen. By Sequence 2 and 3, the subjects were playing at their characteristic skill levels.

The levels of activity demonstrated by the subjects in this study were in part attributable to their experience level in playing the game. However, the DDR game can be played at progressively difficult levels depending upon a player's ability. This is not to say that everyone must play at the "Heavy" level, but ascending through the progression of songs will bring about adaptations in a relatively short time. Furthermore, the ongoing challenge of harder game-songs may provide ongoing motivation to play.

The results from the exit questionnaire provided indicators of an immersive game-flow experience when participants played (6,7,23,25,29). Flow theory relates to the optimal experience of enjoyment regardless of the activity, context, or culture (6). Game-flow components include clear goals, concentration, merging of action and awareness, transformation of time, direct and immediate feedback, balance between ability level and challenge, sense of personal control over the situation or activity, and intrinsically rewarding activity so there is an effortlessness of action (29). Flow is less well studied in movement-based interfaces. The exit questionnaire included statements related to each of these elements. All players agreed that these were part of their DDR game-play experience. At the advanced level of playing, DDR appears to provide all the elements of game-flow. It remains unknown what level of skill is necessary before players feel the presence of flow.

One limitation of this study is that it was conducted on a small sample of the participants. However, regardless of age, gender, or BMI, each participant demonstrated an ability to exercise at vigorous intensity levels. Only the player with the highest BMI did not exceed a mean of 6 METs, although she did display peaks up to 12 METs. It may be necessary for her to train for a longer period of time as she was the least active of the players when she began DDR training. In addition, the current study is descriptive in nature and was not conducted to demonstrate a long-term training response. However, it is worth noting that each participant was able to exercise at higher MET levels with concomitant lower RER values after 20 hrs of play. This short-term training effect needs to be examined more closely to elucidate the exact adaptations to which DDR exercise may be linked. The primary intention of this study was to determine whether playing the DDR game could bring about levels of intensity considered to be vigorous. Future projects should focus on the training effects of DDR on cardiovascular fitness and indices of health such as BMI.

Interestingly, modifications of the interval rest periods for this DDR study was such that the amount of rest was proportional to the decrease in HR between game-songs. The menu system of DDR did not allow us to provide a true “no rest” period between songs. Instead, there was always a delay of approximately 15 sec before actual game-play began. While the menu system was short in DDR, it did allow some recovery of HR and other metabolic measures between songs. As games are being targeted as alternative workout programs, it is important for developers and exercise physiologists to keep the menu systems in mind with respect to the level of the workout. Many games have an extensive menu system that can take upwards of 30 sec or more to navigate in order to progress from level to level or game to game. This may play a substantial role on the overall impact of a workout in terms of energy expended per time period because the user is spending too much time navigating the menu as opposed to playing the game and exercising.

Clearly, DDR represents one mode of activity that could be used to achieve vigorous activity levels through gaming. Even though DDR is an older exer-game compared to other games of similar design, its resurgence is owed to the use of technology, variation in song selection, and social networking aspects that allow for group participation and national and international competition. The government and large health organizations are starting to realize that active gaming may be the way to entice currently sedentary individuals to increase their daily physical activity (30).

As this activity initiative moves forward, many of the current commercially available games are focused on improving health through active play. But games that enhance balance or specific movements such as push ups and sit ups fall into the same category as standard exercise protocols upon which physical activity guidelines are based. The unique aspect of DDR is that it does not involve standard exercise modes, but rather dancing, of which many people, especially those who have been studied, find fun. Much of the reason why people, in general, don’t participate in physical activity is because they find it boring. However, when presented with a “game,” people may be more apt to be engaged.

The information provided by this study may be useful to the general public seeking alternative methods of physical activity and to those looking for a way to meet current physical activity requirements. Given the current data, it is appropriate to discuss the use of active video games in a more prescriptive sphere. *Dance Dance Revolution* provides an excellent example of an active video game that can be manipulated in terms of duration and intensity. These modifications speak directly to DDR as a prescriptive exercise, where players begin at the lowest duration and intensity in their song selection and work toward more difficult songs. Although it is true that many individuals terminate their exercise regimen because of time constraints whether at home or in a facility, DDR possesses the essential components of fitness that can be manipulated to serve any person interested in meeting physical activity requirements.

CONCLUSIONS

This is the first research study to demonstrate that an active video game, DDR, is effective in meeting vigorous physical activity requirements through testing for a prolonged period of game-play. The current study supports DDR as a surrogate to an interval type exercise session, which can result in greater caloric expenditure and may confer health benefits related to cardiovascular fitness. Moreover, the immersive experience of DDR game-play suggests why players may continue to play over time. By using games to promote activity, we may be broaching an untapped market. Epidemics such as obesity, diabetes, and heart disease are in large part thought to be attributable to inactivity. Thus, this type of alternative movement or exercise may be what is needed to engage participants while they are playing a "game" and at the same time meeting requirements for physical activity.

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