The Heart Rate Response to Nintendo Wii Boxing in Young Adults

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ABSTRACT

Purpose: To determine if 30 minutes of Nintendo Wii Sports boxing provides cardiorespiratory benefits and contributes to the daily exercise recommendations for healthy young adults. **Methods:** Twenty healthy 23- to 27-year-olds participated in two sessions to measure maximum heart rate (HR_{max}) via a treadmill test and heart rate (HR) response to 30 minutes of Wii Sports boxing. Heart rate in beats per minute (bpm) was measured continuously, and exercise intensity during each minute of play was stratified as a percentage of HR_{max}. Mixed designs analysis of variance (ANOVA) and Pearson product moment correlations were used to analyze the data. **Results:** Mean (SD) HR response to boxing was 143 (15) bpm or 77.5% (10.0%) of HR_{max}. The mean HR response for experienced participants was significantly lower than inexperienced participants, P = .007. The ANOVA revealed a significant interaction between experience and time spent at various intensities, P = .009. Experienced participants spent more time in light to vigorous intensities, inexperienced participants in moderate to very hard intensities. Fitness was not correlated with mean HR response to boxing, P = .49. **Conclusion:** Thirty minutes of Nintendo Wii Sports boxing provides a moderate to vigorous aerobic response in healthy young adults and can contribute to daily recommendations for physical activity.

Key Words: exergaming, cardiorespiratory training, active video games

INTRODUCTION AND PURPOSE

The current American College of Sports Medicine (ACSM) and American Heart Association (AHA) physical activity guidelines for healthy adults recommend 30 minutes of moderate-intensity aerobic activity 5 days per week or 20 minutes of vigorous-intensity aerobic activity 3 days per week.[1] Similarly, the US government[2] recently recommended that adults should participate in 150 minutes of moderate-intensity aerobic exercise or 75 minutes of vigorous-intensity aerobic exercise each week. Activities that recruit large muscles, such as running, cycling, swimming, and racquet sports, tend to elevate heart rate adequately to achieve these guidelines[3] and are activities that have typically been recommended for aerobic or cardiorespiratory fitness.

Younger adults are generally more physically active than older adults, but overall more than half of Americans do not meet the ACSM/AHA guidelines.[1] In the United States, 70% of adults do not participate in any leisure time physical activity or have an adequate amount of physical activity per day.[4] This high percentage of sedentary Americans is alarming given the well-established relationship between exercise capacity and all-cause mortality,[5,6] as well as the association between a sedentary lifestyle and obesity.[7,8]

Playing video games is a common leisure time activity in the United States and may be a contributing factor to the incidence of obesity.[9,10] Seventy to 90% of American youth play video games, but those who play video games encompass a diverse group, including 75% of heads of households.[11] Among adults, 21% report playing video games every day or nearly every day, with younger adults more likely to play video games than older adults.[12]

While video games have traditionally been a sedentary activity, new generation active video games, or *exergames*, make game play a more interactive experience. For example, the Nintendo Wii (Nintendo® Inc., Kyoto, Japan) video game console supports many active games, including Wii Sports boxing. Seventy percent of respondents to an AHA survey reported that they considered active video games to be physical activity,[13] and the AHA and Nintendo of America have formed a partnership to promote physical activity by encouraging individuals to participate in activities that are fun.[13] In spite of greater interactive capabilities, it is unclear whether exergaming can actually take the place of traditional modes of physical activity.

Recent studies have investigated the cardiorespiratory benefits of exergaming in children and adolescents, with an emphasis on the metabolic cost of the activity. Graves et al[14] investigated energy expenditure in 13- to 15-year-old girls and boys when playing Nintendo Wii Sports and a traditional, sedentary video game. The authors concluded that playing new generation active video games required significantly more energy than playing sedentary video games, but that the energy expenditure was not of high enough intensity to contribute to the recommended daily amount of

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exercise for children. Graf et al[15] measured heart rate, ventilatory response, and energy expenditure in 10- to 13-year-old girls and boys using two active video gaming systems and treadmill walking. The responses of the physiological parameters during active video games were similar to those measured while walking on the treadmill at a moderate pace (5.7 km/h), and the responses were deemed appropriate for promoting energy expenditure among children.

While current literature has focused primarily on the adolescent population in reporting physiological responses to active video games,[14,15] a recent investigation[16] quantified the metabolic cost of various Nintendo Wii active games when played by adults. The researchers concluded that over two-thirds of the games are of light intensity, and the remaining one-third are of moderate intensity.[16] Other recent studies assessed the metabolic and heart rate response of young adults playing active video games, using games in an arcade setting,[17] and Wii Fit aerobic activities.[18] These active video games also constituted light- to moderate-intensity aerobic activity.

When considering the physiological responses to active video games, Nintendo Wii Sports boxing has consistently yielded higher energy expenditures in comparison to other active video games.[14-17] Interactive gaming systems are popular among young adults and youths, and because recommendations for aerobic activity and daily energy expenditure are lower in adults than children,[2,3] playing Wii Sports boxing could meet the recommended amount of physical activity for adults. Furthermore, assessing the cardiorespiratory response to one specific game, rather than assessing the response to several games in one session, is more realistic for many young adults. Finally, quantifying the cardiorespiratory response via a focus on the heart rate response to the activity provides a more accessible and useful metric for determining the intensity level of the game and allowing individuals to monitor their response to active video games. Therefore, the purpose of the current study was to determine if 30 minutes of Nintendo Wii Sports boxing provides cardiorespiratory benefits and to determine if it contributes to the recommended daily amount of exercise in young adults. Our specific objective was to describe the heart rate response of healthy young adult males and females who played Wii boxing for 30 minutes and evaluate the influence of experience and fitness on the response. We hypothesized that participants would have a heart rate response to the 30-minute session that would provide cardiorespiratory benefits. In addition, we hypothesized that experience and fitness level would affect the heart rate response.

METHODS

Subjects

Healthy young adults (at least 21 years old) were recruited for the study from a health sciences university and the surrounding community through word of mouth and E-mail. Participants were excluded if they were over 40 years old; smoked; were pregnant; were on medications that would affect their heart rate and/or blood pressure; or had a history of heart attack, coronary revascularization, heart murmur, hypertension, chronic bronchitis, emphysema, asthma, chronic obstructive pulmonary disease, musculoskeletal injuries in the past 3 months, or chronic pain. The A.T. Still University institutional review board approved the study, and written informed consent was obtained from all participants prior to their participation.

Procedures

Participants completed two test sessions within a week of each other, each session lasting about 45 minutes. During session 1, participants completed a questionnaire about their level of experience with Nintendo Wii Sports boxing. The questionnaire was developed for the current study and asked participants if they had previously played Wii Sports boxing and, if so, the number of hours per week they currently spent playing the game. Participants then performed a maximal exercise test on a treadmill using a modified Astrand protocol[19] for measurement of their maximum heart rate (HR_{max}) and oxygen consumption (VO_{2max}). Whole-body oxygen consumption was measured using a Parvo Medics TrueOne 2400 metabolic measurement system (Sandy, UT). A treadmill test was chosen instead of an upper-body ergometer test because the boxing session involved total body movement, engaging both upper and lower extremities during play in a standing position. Wii Sports boxing has previously been shown to significantly involve both total body and upper extremity movements,[20] so we believed this to be the most appropriate test of maximum aerobic capacity.

During session 2, all participants completed a Wii Sports boxing tutorial and participated in 30 consecutive minutes of Wii boxing in a standing position. Both the tutorial and the boxing matches were conducted with the participant playing alone against the computer opponent. After placing a heart rate monitor on the participant (Polar S810, Polar Heart Rate Monitors, Lake Success, NY), the participant rested quietly in a seated position for 15 minutes to achieve a resting heart rate (HR). Then the participant stood up and faced the television screen, and the tutorial was begun. The tutorial demonstrated blocking, punching, and dodging movements used in the game, and participants were prompted visually with written instructions on the screen. Participants were required to practice the blocking, punching, and dodging movements as a part of the tutorial. The participant held the Wii remote in one hand and the Nunchuck remote in the other hand to block and throw punches against the computer opponent. Once participants completed the tutorial and affirmed that they were comfortable with the boxing game, testing was begun. Testing always began with round 1, level 1 for the first match because this was the easiest level of play. Participants progressed to the next level of play and, consequently, to a greater challenge (to a maximum level of 10) if they won the match. If they lost a match, they played the next match at the same level of play. One researcher reset the game promptly at the end of each match, and the participant was encouraged to continue moving in order to promote continuous play throughout the 30 minutes. During testing, HR was measured continuously on a beat-to-beat basis, with 60-second averaging displayed on the receiver. This average value was

recorded upon initiation of the 30-minute session, then at the end of every minute until the 30-minute boxing session was complete. Every 5 minutes, rate of perceived exertion (RPE), using the Borg RPE 6 to 20 scale, was measured to determine perception of exercise intensity. Blood pressure (BP) was measured using a stethoscope and manual blood pressure cuff before and after boxing as a safety measure, but values were not analyzed.

Data Analyses

Mean (SD) was used to describe age (years), body mass index, HR_{max} (beats per minute, bpm), HR response to boxing session (both in bpm and as a percent of HR_{max}), VO_{2max} (mL/kg/min and percentile), and exercise RPE values of the participants. Individual maximum heart rates, measured during the maximal treadmill test, were used to calculate the percentage of HR_{max} achieved during each minute of boxing for each participant. Heart rate responses during boxing were also stratified by the following intensity ranges established by the ACSM: very light (< 50% of HR_{max}), light (50-63% of HR_{max}), moderate (64-76% of HR_{max}), vigorous (77-93% of HR_{max}), and very hard (≥ 94% of HR_{max}).[3] Independent samples *t* tests were performed to determine if heart rate response differed based on experience with the game. A mixed-designs analysis of variance (ANOVA), with one between-groups factor (experience) and one within-groups factor (intensity) was conducted on the stratified heart rate values to determine if there was an interaction between Wii boxing experience and time spent in different levels of intensity. The 5 intensity stratifications were collapsed to 4 levels of intensity for the ANOVA because time spent in level 1 was negligible for both groups, so levels 1 and 2 were combined for this analysis.

Pearson product moment correlations were performed to evaluate the relationship between fitness level and mean HR response to Wii boxing, and the relationship between Wii boxing experience and the number of rounds completed. All data analyses were conducted using SPSS version 19 (IBM, Chicago, IL), and tests were considered statistically significant at $P \leq .05$.

RESULTS

All 20 participants (11 males, 9 females) completed both sessions without incident. Mean (SD) age was 25.4 (1.3) years, BMI was 23.5 (3.4), HR_{max} was 186 (9) bpm, and VO_{2max} was 42.7 (7.7) mL/kg/min. The mean VO_{2max} for males was 45.5 (6.6) mL/kg/min, with the range representing the 20th to the 99th percentile of maximal aerobic power among males in this age range (Table 1).[3] The mean VO_{2max} for the females was 39.7 (7.4) mL/kg/min, with the range representing the 10th to the 95th percentile of maximal aerobic power among women in this age range (Table 1).[3] Independent *t* test revealed no significant difference between males and females for fitness, $t_{18} = 1.87$, $P = .08$, or percentile ranking, $t_{18} = .14$, $P = .90$. Eight participants reported having past experience playing Wii boxing, but no participants reported currently playing any Wii boxing.

Figure 1 shows the mean HR response during each minute of the session for all participants. The overall mean (SD) HR response to 30 minutes of Wii boxing for the group was 143 (15) bpm, representing a mean cardiorespiratory response of 77.5% (10.0%) of HR_{max}. Individual mean HR responses and corresponding mean intensity stratifications are shown in Table 2. Two participants had a mean HR response in the light-intensity range, 8 in the moderate-intensity range, and 10 in the vigorous-intensity range for the 30-minute session. Independent samples *t* test demonstrated a significantly lower mean (SD) HR response for experienced participants (70.5% [7.8%]) than for inexperienced participants (82.2% [8.7%]), $t_{18} = 3.07$, $P = .007$. Mixed-design ANOVA revealed a significant interaction between experience and time spent at various intensities,

Table 1. Fitness Characteristics of Study Participants (N=20)

Characteristic	Mean (SD)	Minimum	Maximum
Age, y	25.4 (1.3)	23	27
BMI	23.5 (3.4)	19.4	29.6
HR_{max}, bpm	186 (9)	164	201
VO_{2max}, mL/kg/min	43.3 (7.6)	29.4	62.1
Males (11)	45.5 (6.6)	38.4	61.8
Females (9)	39.4 (7.9)	28.8	48.9

Abbreviations: BMI, body mass index; HR_{max}, maximum heart rate; bpm, beats per minute; VO_{2max}, maximum oxygen consumption.

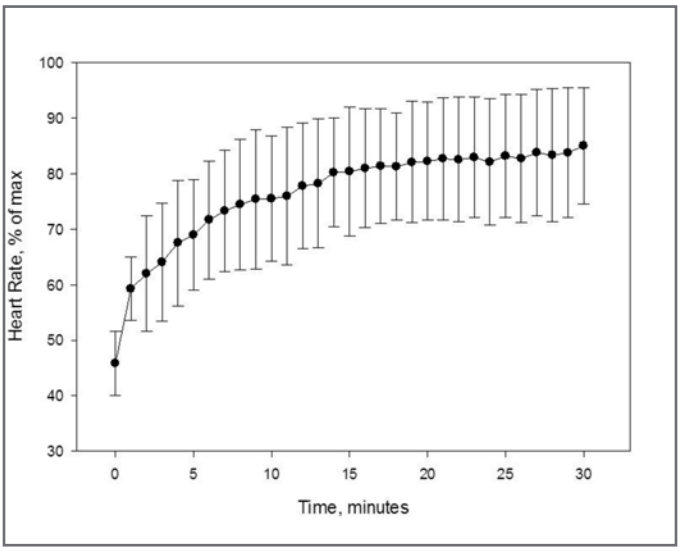

Figure 1. Mean heart rate response of all participants (expressed as a percent of maximum heart rate) to a single Nintendo Wii Boxing session. All values are expressed as mean (SD).

Table 2. Individual Mean Heart Rate Responses to Nintendo Wii Sports Boxing Session

Participant Number	Mean HR (SD)	% of HR_{max}	Intensity
100	114 (9)	56.8	L
101	154 (18)	85.8	V
102	106 (11)	61.4	L
103	147 (12)	76.4	M
104	154 (16)	81.8	V
105	174 (19)	89.1	V
106	153 (15)	87.8	V
107	146 (15)	80.8	V
108	141 (18)	74.3	M
109	163 (13)	86.4	V
110	158 (14)	86.5	V
111	143 (11)	74.9	M
112	175 (16)	88.6	V
113	154 (16)	83.6	V
114	133 (21)	73.1	M
115	107 (11)	65.1	M
116	129 (13)	72.5	M
117	120 (12)	65.3	M
118	164 (15)	89.7	V
119	129 (22)	70.2	M

Abbreviations: HR, heart rate; HR_{max}, maximum heart rate; L, light; M, moderate; V, vigorous. Intensities—light, moderate, or vigorous—are defined by current American College of Sports Medicine guidelines.

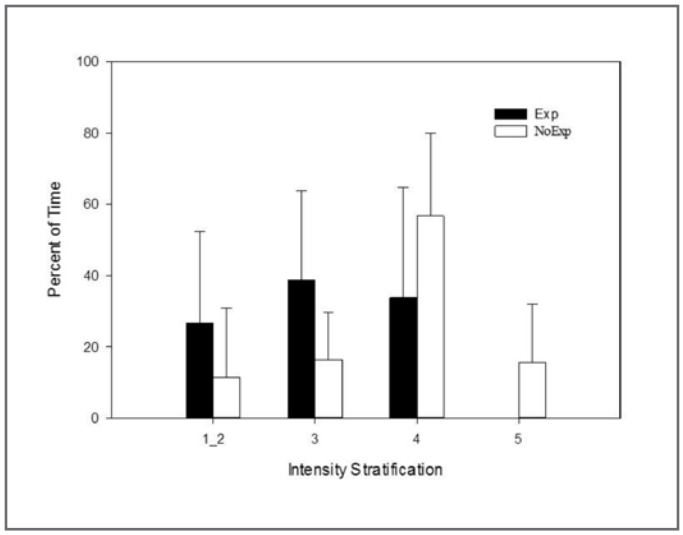

Figure 2. Percent of time spent in each heart rate intensity stratification based on Nintendo Wii Sports Boxing experience. 1_2 ≤ 50% - 63% maximum heart rate (HR_{max}); 3 = 64 - 76% HR_{max}; 4 = 77 - 93% HR_{max}; 5 ≥94% HR_{max}.

$F_{(3, 54)} = 4.22$, $P = .009$. Post hoc analyses revealed significant differences between experienced and inexperienced participants for time spent in intensity level 3 (moderate), $P = .018$, and intensity level 5 (very hard), $P = .016$. The interaction is represented through the intensity stratifications for experienced and inexperienced participants in Figure 2.

The mean (SD) RPE for all participants during Wii boxing was 13.0 (1.6), described as "somewhat hard," with a range of 9.3 ("very light") to 15.8 ("hard"). Mean RPE did not differ by experience (12.3 [2.0] for experienced participants and 13.4 [1.1] for inexperienced participants).

There was no significant correlation between fitness, expressed as percentile of aerobic power for sex and age, and mean HR response to the boxing session, expressed as percent of HR_{max} ($r = 0.165$, $P = .49$). The number of rounds played during the 30 minutes did not correlate significantly with experience ($r = 0.19$, $P = .43$).

DISCUSSION

The purpose of this study was to characterize the heart rate response to 30 minutes of Nintendo Wii Sports boxing to determine if this active video game provides a cardiorespiratory training stimulus and contributes to the daily exercise requirements for healthy young adults. Our hypothesis that participants would achieve a HR response that would provide cardiorespiratory benefits was supported by the finding that 18 of 20 participants had a mean HR response in the moderate-intensity or vigorous-intensity range. Furthermore, this HR response occurred across a range of fitness levels, as evidenced by the wide range of fitness levels among participants and the lack of correlation between fitness level and HR response to the boxing session. Overall, the results of this study indicate that for healthy young adults of varying levels of fitness Wii Sports boxing can serve as a light-intensity to very high-intensity form of aerobic exercise, based on the ACSM guidelines for achieving cardiorespiratory fitness.[3]

The current investigation expands on the findings of other recent investigations that measured HR and metabolic responses in adults when playing several active video games in a 30-minute session.[17,18] Siegel et al[17] studied a similar age group to ours and found that exercise HR was adequate for a training response and energy expenditure was sufficient to meet ACSM recommendations for daily physical activity. These investigators tested a small number of subjects using 3 different active games in an arcade setting, but playing video games at home is a more convenient and likely means of engaging in active video game play. While the mean HR for the 3 arcade games was higher than the mean HR for the current study, 2 of the 3 arcade games primarily involved the lower extremities during play, and participants actively moved from one game to another during the session, making a comparison of HR response in these two settings difficult.[17] Our lower mean HR response, while still considered vigorous,[3] probably engaged the lower extremities to a lesser extent than the arcade games. However, an active video game like Wii boxing that engages both upper and lower extremities may still have the potential to elicit a maximal HR response similar to what one might achieve with a lower-extremity dominant activity such as running.[21]

Graves et al[18] also reported different HR responses to active video games than what we report here, but unlike our findings with Wii Sports boxing, their reported HR response to Wii Fit aerobics was below recommended levels for maintaining cardiorespiratory fitness for adolescents and younger and older adults. The researchers compared the metabolic and HR response in these age groups to inactive video games, Wii Fit games, and treadmill jogging. They found that in spite of the inadequate HR response energy expenditure during Wii Fit aerobics was of moderate intensity, but this intensity was only measured for 10 minutes.[18] We were interested in engaging our participants in a sustained bout of a single active game to assess its effectiveness in producing a cardiorespiratory response similar to a typical bout of conventional aerobic activity. Unfortunately, a direct comparison between HR response and metabolic cost for individuals cannot be made because these two parameters are not linearly related.[22-24] Therefore, we measured HR response because this measure provided a more direct representation of the cardiorespiratory response during Wii Sports boxing, but we did not measure energy expenditure. Miyachi et al[16] also measured the metabolic cost of interactive Wii games (both Wii Sports and Wii Fit games) in adults and, similar to Siegel et al[17] and Graves et al,[18] they concluded that the increased energy expenditure contributes to the 30 minutes of physical activity that adults are recommended to participate in at least 5 days per week. However, based on 8 minutes of metabolic measurements, Miyachi et al[16] concluded that these activities could be considered at most a moderate-intensity activity, depending on the game, but not a vigorous-intensity activity. The relationship between metabolic cost and HR response to an exercise bout is complicated,[24] but this metabolic finding is not consistent with the mean HR intensity, which was in the vigorous or very hard intensity range for our participants for 58% of the 30-minute boxing session. Eight minutes of play may not be sufficient time to interpret whether active video games provide cardiorespiratory benefits and contribute to daily physical activity requirements. There is a benefit in playing these games for a longer period as our participants did, not only because longer play would increase energy expenditure but because it would provide the chance for more challenging levels of play, which could contribute to a greater cardiorespiratory (HR) response.

In contrast to our findings and those of other studies for adults playing active video games, Graves et al[14] compared the caloric expenditure in 13- to 15-year-old adolescents playing active and sedentary video games. As expected, the authors found that playing active video games used significantly more energy than sedentary video games and that the mean energy expenditure during Wii Sports boxing produced the greatest metabolic response of all Wii Sports games, using 730 kJ/h compared to 450 kJ/h for a more sedentary video game. However, the authors concluded that the energy expenditure from playing Wii Sports games was not high enough to contribute to the 60-minute recommended daily amount of exercise for children. Since adults and children have different daily exercise recommendations,[3] the use of active video games to meet daily activity recommendations may be appropriate for adults but not for children.

One consideration in the use of active video games as exercise for both children and adults is that exergaming may not provide the same stimulus as performing the actual activity. Graves et al[14] noted that energy expenditure measured during individual Wii Sports games in their adolescent population was much less than calculated values of energy expenditure during those actual activities. Similarly, Wii Fit aerobics was determined to elicit less energy expenditure than treadmill walking or jogging for adults.[18] Kravitz et al[25] studied the cardiorespiratory response to punching tempo in young adults (mean [SD] age, 22 [2.8] years). During 2-minute shadow boxing trials, participant heart rates were between 167 and 182 bpm, or 85% to 93% of HR_{max}, suggesting that shadow boxing to an upbeat tempo has cardiovascular benefits. The mean HR response of our participants to Wii boxing was lower than the Kravitz et al[25] results, with individual responses ranging from 57% to 90% of HR_{max}, but our exercise session was sustained for a much longer time. Hence, while some forms of exergaming may not produce the same physiological response and benefits as would occur with a real sport, an active video game such as Wii boxing does elicit a physiological response that is consistent with cardiorespiratory benefits. Thus, the current findings suggest that active video games provide an alternative to standard cardiorespiratory training activities, which may be appealing for some people.

An interesting finding in our study was that participants with less experience playing Wii Sports boxing spent more time in vigorous to very hard intensities of activity, while those with previous experience spent more time in light, moderate, and vigorous intensities, but no time in very hard intensity. White et al[26] assessed the influence of experience on energy expenditure during active video game play in boys and concluded that experience did not affect energy expenditure during play. However, Sell et al[27] measured significantly higher energy expenditure and mean HR among college-age males who used the interactive *Dance Dance Revolution* (DDR; Sony Computer Entertainment of America, Foster City, CA). In spite of the trends observed in our study, only one experienced participant had a markedly lower HR response to Wii boxing than the others (mean response 56.7% of HR_{max}) and was the only participant who subjectively reported himself to be an expert in Wii boxing. During the boxing session, this participant was observed using much less upper extremity, trunk, and lower extremity movements than other participants. Such observations were not measured in this study, so they cannot be compared quantitatively among the participants. The lower HR response in this expert player could reflect the participant's playing style, or it might indicate that refined Wii boxing skills reduce the cardiorespiratory response due to greater efficiency of movements. This particular participant was in the 75th percentile for aerobic power and reported engaging in daily exercise that included resistance and aerobic conditioning, but other participants had higher aerobic power and reported similar exercise regimens. Furthermore, one other participant who had a mean HR response in the light intensity range had a similar level of fitness, but

reported no experience with Wii boxing. Considering the stratification trends that occurred in this study, Wii boxing may elicit a higher aerobic response among those with more limited Wii boxing experience. Alternatively, an optimal cardiorespiratory response may be obtained through enthusiastic play and intentional use of the whole body during a session, regardless of experience. This type of play could be encouraged in those who play the game for cardiorespiratory fitness and should be further investigated among individuals of varying levels of expertise with the game. However, the finding of a higher HR response among less experienced players also raises the caution that some individuals, particularly elderly or medically-compromised people, should be monitored carefully during play as Wii boxing could elevate their HR beyond recommended training intensities.

An added benefit of playing active video games is that a player might exercise intensely without perceiving the activity as difficult. In spite of the moderate to vigorous HR response among our participants, the mean RPE rating was "somewhat hard" and did not differ by experience. The perception of exertion could be related to being engaged in an enjoyable exercise. Obese adults have reported walking for pleasure as "light" intensity in terms of perceived exertion, in spite of working at 70% of HR_{max}.[28]

The current study had several limitations that should be acknowledged. First, this study included healthy young adults and only HR response and perceived exertion were measured while they played Wii Sports boxing, an upper extremity dominant active video game. Our results should not be extrapolated to other populations or other active video games. Second, HR responses were measured while subjects played Wii boxing during a single session. The HR response to multiple sessions may differ from the response to a single session, and the potential training effects cannot be determined based on the current study. Finally, delayed-onset muscle soreness or other effects of the session were not monitored during the days following the boxing session, and these effects may need to be taken into consideration if an older or compromised population were to play Wii boxing.

In spite of the acknowledged limitations, the results from the current study support the use of an active video game for cardiorespiratory benefits and provide a useful foundation for future studies. For instance, the longitudinal training effects of Wii Sports boxing should be measured, and the effects of Wii boxing in other populations, particularly those with cardiorespiratory or neurological impairments, should be investigated. Those individuals tend to have much lower aerobic capacity than their healthy counterparts and would benefit from a cardiorespiratory exercise that engages the whole body. Considering the clinical applications of this research, the HR responses from the current study could be compared to HR responses from playing other Nintendo Wii Sports and Wii Fit games, as well as other active video games. Comparing these data could aid clinicians, such as physical therapists and cardiac rehabilitation specialists, in selecting the most appropriate active video games for their patients, and it could be used as the basis for developing and progressing patient treatment plans.

CONCLUSIONS

The current study supports recent literature[14-16] suggesting that playing active video games like Nintendo Wii Sports results in a greater physiological response than sedentary activities and may constitute an aerobic activity. A new finding in this study is that 30 minutes of Wii Sports boxing can provide an adequate aerobic activity for young adults, contributing to their recommended daily physical activity. Wii boxing may be used as a viable alternative to traditional cardiorespiratory training at a light- to high-intensity level.

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