ann. behav. med.
DOI 10.1007/s12160-010-9164-x

ORIGINAL ARTICLE

Motivation and Physiologic Responses of Playing a Physically Interactive Video Game Relative to a Sedentary Alternative in Children

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Abstract

Background While there is emerging research outlining the physiologic cost of the physically interactive Nintendo Wii, there are no evaluations of the relative reinforcing value (RRV) of the Wii versus a sedentary alternative.

Purpose The purpose of this study is to evaluate the physiologic cost, RRV, and liking of playing Wii Sports Boxing (Wii) versus a traditional sedentary video game (SVG) in 11 lean and 13 overweight/obese 8- to 12-year-old children.

Methods Heart rate (HR) and VO_2 were assessed during rest, treadmill walking, and playing an SVG and Wii using a counterbalance design. Liking was assessed during treadmill walking and video game play. RRV was assessed for Wii versus SVG.

Results Average HR, VO_2, and liking were significantly greater for Nintendo Wii ($p \leq 0.001$ for all) than all other conditions. Lean children displayed a greater ($p < 0.001$) peak responding for access to Wii relative to the SVG while overweight/obese children did not ($p \geq 0.16$).

Conclusion Wii was a well-liked activity of greater physiologic intensity than both the SVG and treadmill walking. Lean children were more motivated while overweight/obese children were equally as motivated to play Wii relative to the SVG.

Keywords Exertainment · Nintendo Wii · Reinforcing value · Liking · Hedonics

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Introduction

Eight- to 18-year-old children reportedly spend 1.1 $h\,day^{-1}$ playing video games and up to 6.1 $h\,day^{-1}$ of total screen use (television, computers, video games) [1]. Participation in these sedentary screen activities has been negatively associated with physical activity participation and positively associated with measures of adiposity in children [2–7]. The development of video games such as Dance Dance Revolution (DDR) [8–10], EyeToy [8, 9], and XaviX [11] has created the opportunity for children to play video games while simultaneously expending greater amounts of energy than traditional sedentary screen use. The more recently developed Nintendo Wii is, based upon sales figures (Nintendo, Consolidated financial highlights), arguably the most popular physically interactive video gaming system to date. Like its predecessors, the Nintendo Wii also appears to be more physiologically challenging than a sedentary video game (SVG) in adolescents [12, 13], adults [14], and children [15]. However, while the physiologic cost of playing Wii versus a physical activity has been evaluated in a single study focusing on adults [14], no such comparison exists for children.

While there is mounting evidence that playing Wii is more physiologically challenging than a sedentary alternative, there is a dearth of information focusing on the likelihood individuals would play the Wii versus a traditional sedentary video game. If the Wii is not engaging enough to elicit a desire to play it, then its efficacy as a substitution for sedentary video games is limited. Presently, only a single investigation has attempted to examine the likelihood that individuals would choose the Wii over a sedentary alternative [14]. In this previous investigation, adults indicated a greater liking for Wii play versus a sedentary video game alternative. While liking has been shown to be positively associated with

Published online: 19 February 2010

physical activity participation [16–19], it is a separate construct from and not as strong a predictor of behavior as measurements of relative reinforcing value (RRV) or motivation [19–24].

The purpose of the current study was twofold. First, to evaluate the physiologic cost of playing the popular Nintendo Wii Sports Boxing game in a population of lean and overweight/obese boys and girls relative to a traditional video game and a physical activity (treadmill walking). We hypothesized that Wii play would elicit a greater VO_2 and heart rate than treadmill walking. The second purpose was to examine the RRV and liking (hedonics) of playing Nintendo Wii Sports Boxing versus a traditional sedentary video game. We hypothesized that lean children would be more motivated to play Wii than a traditional video game, and overweight/obese children would be more motivated to play a traditional video game than the Wii.

Methods

Participants

Children between the ages of eight and 12 years and had no contraindications to physical activity including cardiovascular, neuromotor, cognitive, and orthopedic disorders were eligible for participation. Eligibility was determined by a trained exercise physiologist via phone screen with the child's parent or guardian. A total of 24 lean (body mass index (BMI) <85th percentile) and overweight/obese (BMI ≥85th percentile) boys overweight/obese and girls participated in this study (Table 1). Participants were recruited from flyers posted in the local community and from a database of individuals who had previously contacted the Applied Physiology Laboratory at Kent State University to participate in separate unrelated studies. Prior to participation, children read and signed informed assent while their parent or legal guardian read and signed informed consent forms. This study was approved by the Kent State University Institutional Review Board.

In the present study, 8- to 12-year-old children were examined as this age group is among those most likely to play video games, including the Wii [1]. Because of the popularity of video game play among this age group, it is logical that 8- to 12-year-old children would be among those targeted for a physical activity intervention that includes Wii play, should such an intervention be developed. Therefore, a better understanding of the motivation of 8- to 12-year-old children to play Wii is essential for the development of potential physical activity interventions.

Procedures

Children meeting the entry criteria were invited to the Applied Physiology Laboratory at Kent State University. After obtaining informed assent from the child and consent from their parent or legal guardian, children's height and weight were determined. Height was measured with children not wearing footwear and standing erect against a vertical backboard, and measurements were taken to the nearest 0.1 cm using a stadiometer (Health O Meter, Alsip, IL, USA). Weight was measured with children not wearing footwear and wearing minimal clothing; measurements were to the nearest 0.25 kg using a balance beam scale (Health O Meter, Alsip, IL, USA). BMI percentile was calculated for each child using the Center for Disease Control's BMI Percentile Calculator for Child and Teen [25].

Children were then familiarized with the heart rate monitor, metabolic cart, liking, and ratings of perceived exertion (RPE) scales to be utilized during the protocol. After familiarization, all children completed four 10-min activity conditions: resting, treadmill walking, traditional SVG play, and physically interactive video game play (Wii). For the duration of the resting condition, children sat in a recumbent position in a quiet room. Resting was always performed first, and the order of remaining conditions (treadmill walking, SVG, and Wii) was counterbalanced. Three minutes of instruction was provided prior to participation in the treadmill walking, SVG, and Wii conditions. During the instruction period for each video game condition, children were asked (yes, no) if they had previously played either the SVG (Nintendo PunchOut! (Nintendo Co. Ltd., Minami-ku Kyoto, Japan)) or Wii (Nintendo Wii Sports Boxing (Nintendo Co. Ltd., Minami-ku Kyoto, Japan)) games they were about to. After this

Table 1 Participant physical characteristics

Variable	Boys (N=12)		Girls (N=12)	
	Lean (N=4)	Overweight/obese (N=8)	Lean (N=7)	Overweight/obese (N=5)
Age (years)	10.8±1.5	10.3±1.8	10.1±1.8	10.4±1.3
Height (cm)	146.3±14.5	144.6±8.5	143.7±11.4	142.4±13.4
Weight (kg)[a]	41.0±11.5	47.0±8.0	38.3±8.4	51.9±11.0
BMI percentile[a]	71.0±14.0	92.3±4.3	66.1±20.4	95.4±3.6

Data are mean ± SD

[a] Significant difference between lean and overweight/obese children (p<0.02). There were no main or interaction effects of gender (p≥0.35)

instruction period, each child rested in a seated position for a period of 5 min before completing the next condition. Heart rate (beats per minute) was monitored throughout each rest period, and this 5-min period successfully allowed each participant's heart rate to return to resting. Throughout each of the four 10-min conditions, heart rate and oxygen consumption (VO_2 ml $kg^{-1}min^{-1}$) were recorded. Heart rate was recorded via a telemetry monitor (Polar FS1, Kempele, Finland). VO_2 was recorded via indirect calorimetry using a calibrated metabolic cart (Parvo Medics, Truemax 2400 Metabolic System, Sandy, UT, USA), a mouthpiece, and nose clips. Upon completion of the treadmill walking, SVG, and Wii conditions, children were asked to indicate their RPE and liking for each 10-min condition. RPE was assessed using the undifferentiated pediatric OMNI walk/run scale [26]. Liking was assessed using a visual analog scale consisting of a 10-cm line anchored by "do not like it at all" on the left side and "like it very much" on the right side. Liking, or hedonics, is an affective rating of a behavior that directly correlates with physical activity participation [16–19]. This specific scale has previously been shown to successfully predict physical activity behavior in 8–12-year-old children [19].

During the treadmill walking condition, children walked at a speed of 1.5 miles h^{-1} (67.1 $mmin^{-1}$) without holding the rails on the treadmill (Quinton, Medtrack ST 65, Bothell, WA, USA). This speed has previously been identified as a comfortable, self-selected walking pace for children [27] and has been utilized when assessing the relative energy expenditure of sedentary and physically interactive screen time and traditional physical activity in children [9].

During the SVG condition, children played Nintendo PunchOut! which is a boxing simulation game. The game was played with the child in the seated position using a game controller. While children were not instructed against moving their arms during SVG play, none of the children did so. During the Wii condition, children played Nintendo Wii Sports Boxing which is also a boxing simulation game. Wii Sports Boxing was played with the child in a standing position as previously described [13]. Children were given no direction as to the amount of effort they should exert during the SVG or Wii conditions.

Finally, after completing the four activity conditions, children performed a computer task designed to assess the RRV of the SVG condition versus the Wii condition. Determining the RRV of the SVG versus the Wii was accomplished by asking children to perform work, in the form of button presses on a computer mouse, to earn access to either of the two video games. Children had the option to work on two separate computer screens; one screen was associated with earning points towards the SVG and the other with Wii. Children could work to earn points for the SVG or Wii, and they could switch from one screen to the other at any time. Each screen consisted of a series of three different shapes which changed whenever the computer mouse button was pushed. Children received one point for one of the two video games whenever the shapes matched on the screen that corresponded to that particular video game. For each point earned, children were given one minute of access to the corresponding video game. The RRV computer task was performed until a child accumulated a total of seven points from which they earned seven minutes of video game play. The reinforcement schedule for both the SVG and Wii was initially set to a fixed ratio (FR) 4 (children earned one point for every four button presses) for the first point earned. The FR level then doubled with every point earned for each game (complete FR schedule; 4, 8, 16, 32, 64, 128, 256). The schedules for the two video game alternatives were independent in that the FR level for one video game did not increase to the next FR level until the child had completed the necessary number of presses to earn a point for that video game. Once children compiled a total of 7 points, they then played the SVG and Wii in the amount of time they earned for each.

Total participation time was approximately 90 min per child. Each child was given a $10.00 gift certificate to a local store upon completion of the above protocol. While each child meeting the entry criteria successfully completed the entire protocol, if a child had been unable to complete the protocol, they would have still received the $10.00 gift certificate.

Statistical Analysis

The primary outcome measures of this study were RRV, heart rate, and VO_2. The RRV of one behavior versus another can be measured as the amount of motivated responding (work) an individual will engage in to earn access to one of two behaviors [28–30]. The outcome measure for the RRV task in the present investigation was the output maximum (O_{max}) for the SVG and Wii. O_{max} for SVG and Wii is the maximum amount of responding for 1 min of access to each activity [31]. This RRV computer task has previously been shown to be a valid predictor of sedentary versus physical activity participation in children [19, 32].

Differences in participant physical characteristics (age, height, weight, BMI percentile) were assessed using two-way analysis of variance (ANOVA) with gender (boys, girls) and weight category (lean, overweight/obese) both as between-subjects variables. Because the analysis of physical characteristics revealed no significant main ($F(1, 20) < 0.60$, $p > 0.60$ for all) or interaction ($F(1, 20) < 0.90$, $p > 0.40$ for all) effects for gender and because no specific gender effects were

hypothesized, the remaining analyses did not include gender as a between-subjects variable. Chi-squared analysis was performed to determine if there was a difference in the number of lean and overweight/obese children indicating prior Wii experience. Because Chi-squared analysis reviled no differences (χ^2 (3, N=24)=4.33, p=0.23) in the number of lean (six out of 11) and overweight/obese children (ten out of 13) with prior Wii experience, prior Wii experience was not included as an independent variable or covariate in any of the analyses. No children reported previously playing Nintendo PunchOut!; therefore, these data were not analyzed.

Differences in heart rate (beats per minute) and VO_2 (ml $kg^{-1}min^{-1}$) were assessed using separate two weight category by four activity condition (resting, SVG, treadmill walking, Wii) ANOVAs, with weight category as the between-subjects variable and activity condition as the within-subjects variable. Two additional two weight category by three activity condition (SVG, treadmill walking, Wii) ANOVAs were utilized to assess differences in liking and RPE, with weight category as the between-subjects variable and activity condition as the within-subjects variable. Finally, a two weight category by two game option (Wii, SVG) ANOVA, with weight category as the between-subjects variable and game option as the within-subjects variable, was used to examine differences in O_{max} achieved during the RRV computer task. Post hoc analysis for significant main effects of condition and significant interaction effects were performed using T tests with the Benjamini and Hochberg False Discovery Rate correction for multiple comparisons [33].

The primary hypotheses of this investigation were that VO_2 would be significantly greater in children playing Wii than the SVG and that O_{max} for Wii would be greater than SVG for the lean but not the overweight/obese children. Average VO_2 during Wii play and SVG play was 11.9±3.4 ml $kg^{-1}min^{-1}$ and 5.4±1.2 ml $kg^{-1}min^{-1}$, respectively. When analyzed with a paired-samples T test, the difference between the Wii and SVG play yielded an effect size of 2.1 which requires five participants to achieve a statistical power of ≥0.8. Average O_{max} for Wii for lean children was 183.3±105.0 presses and 6.9±12.7 presses for the SVG. This difference yielded an effect size of 1.5 which requires six participants to achieve a statistical power of ≥0.8. Average O_{max} for Wii for overweight/obese children was 83.7±108.2 presses and 121.2±130.0 presses for the SVG. This difference yielded an effect size of 0.17 which requires 282 participants to achieve a statistical power of ≥0.8. Based upon these analysis of power, the current sample size of N=24 was deemed to be sufficient to demonstrate effects where hypothesized.

Results

Physical Characteristics

All participants completed the protocol and tolerated the various conditions well and, therefore, were included in the final analysis. While children were not different for height (F(1, 20) =0.10, p>0.80) or age (F(1, 20) =0.03, p>0.80), overweight/obese children had a significantly greater body weight (F(1, 20) =6.15, p<0.03) and BMI percentile (F(1, 20) =21.32, p<0.001) than lean children (Table 1).

Heart Rate and VO_2

A significant main effect of activity condition (F(3, 66) =67.32, p<0.001) was noted for heart rate (Table 2). Post hoc analysis revealed that the main effect of activity condition was due to a significant incremental increase in heart rate from resting to the SVG condition (t(23) =4.51, p<0.001), from the SVG condition to treadmill walking (t(23) =7.33, p<0.001), and from treadmill walking to the Wii condition

Table 2 Physiologic and perceptual effects of participating in the resting, sedentary video game, treadmill walking, and Wii Sports Boxing conditions

Variable	Resting[a]	Sedentary video game	Treadmill walking (67.1 mmin^{-1})	Wii Sports Boxing
VO_2 (ml $kg^{-1}min^{-1}$)	5.1±1.2	5.4±1.2[b]	10.2±2.4[b,c]	11.7±3.4[b,c,d]
Heart rate (beats min^{-1})	84.4±10.4	91.1±11.0[b]	105.9±12.7[b,c]	121.4±20.3[b,c,d]
Liking (cm)	–	6.9±2.6	6.0±3.1	8.5±1.8[c,d]
RPE	–	1.7±1.5	2.7±2.4	3.4±2.5[c]

p<0.05 for all

[a] Liking and RPE were not assessed during the resting condition

[b] Significantly different from the resting condition

[c] Significantly different from the sedentary video game condition

[d] Significantly different from the treadmill walking condition

($t(23)$ =4.14, $p<0.001$). There were no significant main ($F(1, 22)$ =0.52, $p>0.40$) or interaction ($F(3, 66)$ =1.09, $p>0.30$) effects of weight category on heart rate.

Similarly to heart rate, there was a significant main effect of activity condition ($F(3, 66)$ =92.78, $p<0.001$) for VO_2 (Table 2). Post hoc analysis demonstrated a significant incremental increase in VO_2 from resting to the SVG condition ($t(23)$ = 2.06, $p<0.05$), from the SVG condition to treadmill walking ($t(23)$ = 13.39, $p<0.001$), and from treadmill walking to the Wii condition ($t(23)$ = 2.59, $p<0.03$). There were no significant main ($F(1, 22)$ =0.44, $p>0.80$) or interaction ($F(3, 66)$ =0.43, $p>0.70$) effects of weight category on VO_2.

Liking and RPE

There was a significant main effect of activity condition ($F(2, 44)$ = 7.00, $p<0.002$) for liking (Table 2). Post hoc analysis demonstrated that liking was not different ($t(23)$ = 1.13, $p>0.20$) between the treadmill and SVG conditions. Liking was greater during the Wii condition than the treadmill ($t(23)$ = 4.06, $p<0.001$) and SVG ($t(23)$ = 3.42, $p<0.002$) conditions. There were no significant main ($F(1, 22)$ = 1.19, $p>0.30$) or interaction ($F(2, 44)$ = 0.33, $p>0.70$) effects of weight category on liking.

There was also a significant main effect of activity condition ($F(2, 44)$ = 6.14, $p<0.004$) for RPE (Table 2). Post hoc analysis demonstrated that RPE from the treadmill condition was not different from either the Wii ($t(23)$ = 1.61, $p>0.12$) or SVG ($t(23)$ = 1.84, $p>0.08$) conditions. RPE during Wii play was greater than the SVG ($t(23)$ = 3.78, $p<0.002$) condition. There were no significant main ($F(1, 22)$ = 0.03, $p>0.90$) or interaction ($F(2, 44)$ = 1.59, $p>0.20$) effects of weight category on RPE.

RRV

Response patterns from the RRV computer task for access to Wii versus the SVG alternative are presented in Fig. 1. There was a significant weight category by game option interaction ($F(1, 22)$ = 8.12, $p<0.009$) for differences in O_{max}. Post hoc analysis demonstrated that lean children exhibited a significantly greater ($t(10)$ = 5.02, $p<0.001$) O_{max} for Wii (183.3±105.0 presses), relative to the SVG option (6.9±12.7 presses) while overweight/obese children's O_{max} (Wii 83.7±108.2 presses, SVG 121.2±130.0 presses) was not different ($t(10)$ = 0.60, $p>0.50$) from one video game option to the other. Further analysis demonstrated that lean children achieved a significantly greater ($t(22)$ = 2.28, $p<0.04$) O_{max} for Wii than overweight/obese children, while the overweight/obese children achieved a significantly greater ($t(22)$ =2.90, $p<0.01$) O_{max} for SVG than lean children. There were no significant main effects of game option ($F(1, 22)$ = 3.42, $p>0.07$) or weight category ($F(1, 22)$ = 0.17, $p>0.60$) for differences in O_{max}.

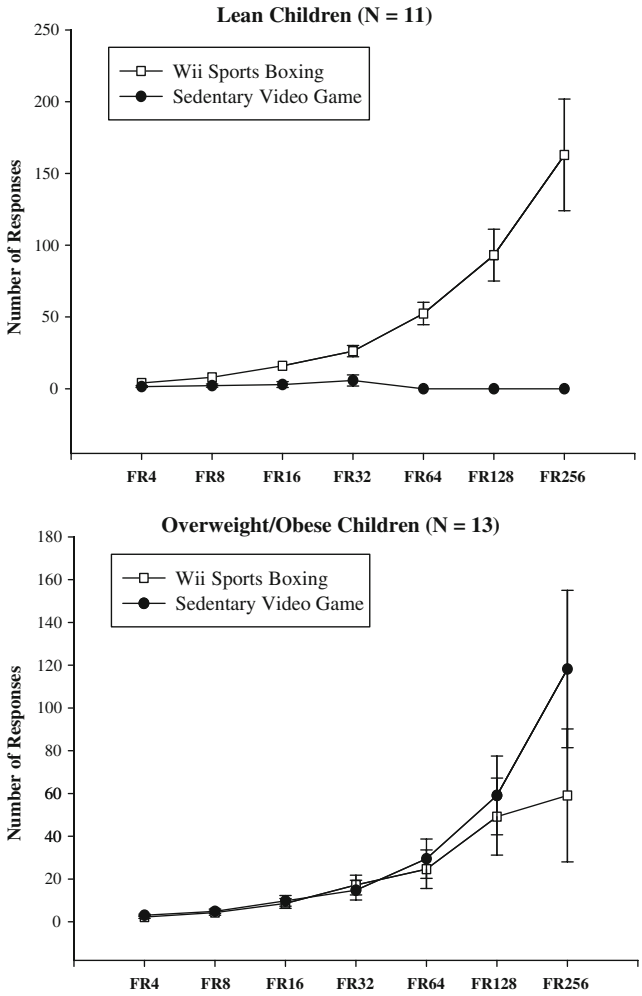


Fig. 1 Average response patterns across the seven fixed ratio (*FR*) levels to gain access to Wii Sports Boxing and sedentary video game play for lean children (*top panel*) and overweight/obese (*bottom panel*). Data presented are means±SE

Discussion

Previous studies have demonstrated that playing Wii Sports Boxing significantly increases heart rate and VO_2 relative to an SVG in adolescents (11–17 years old) [12, 13], children [15], and adults [14]. The present study was the second to demonstrate this effect in a group of children (8–12 years old). This was also the first study to demonstrate that playing Wii Sports Boxing elicited a significantly greater heart rate and VO_2 relative to treadmill walking in children. The metabolic equivalent (MET) levels (VO_2 ml kg^{-1} min^{-1}/3.5= 1 MET) achieved by children during Wii Sports Boxing play in the present study (3.3±1.0) were very similar to those

previously achieved in adolescents (3.2±1.4) [12, 13] and somewhat less than what was achieved in adults (4.4±1.3) [15]. This suggests that the average MET level associated with playing Wii Sports Boxing is great enough to be considered moderate physical activity [34] in adolescents, children, and adults. Therefore, time spent playing Wii Sports Boxing would count towards the 60 min day^{-1} of physical activity that is recommended for children [35, 36]. Because the majority of American children allocate substantial amounts of time to daily video game play [1], substituting Wii Sports Boxing for a traditional sedentary video game could increase the amount of daily physical activity children accumulate.

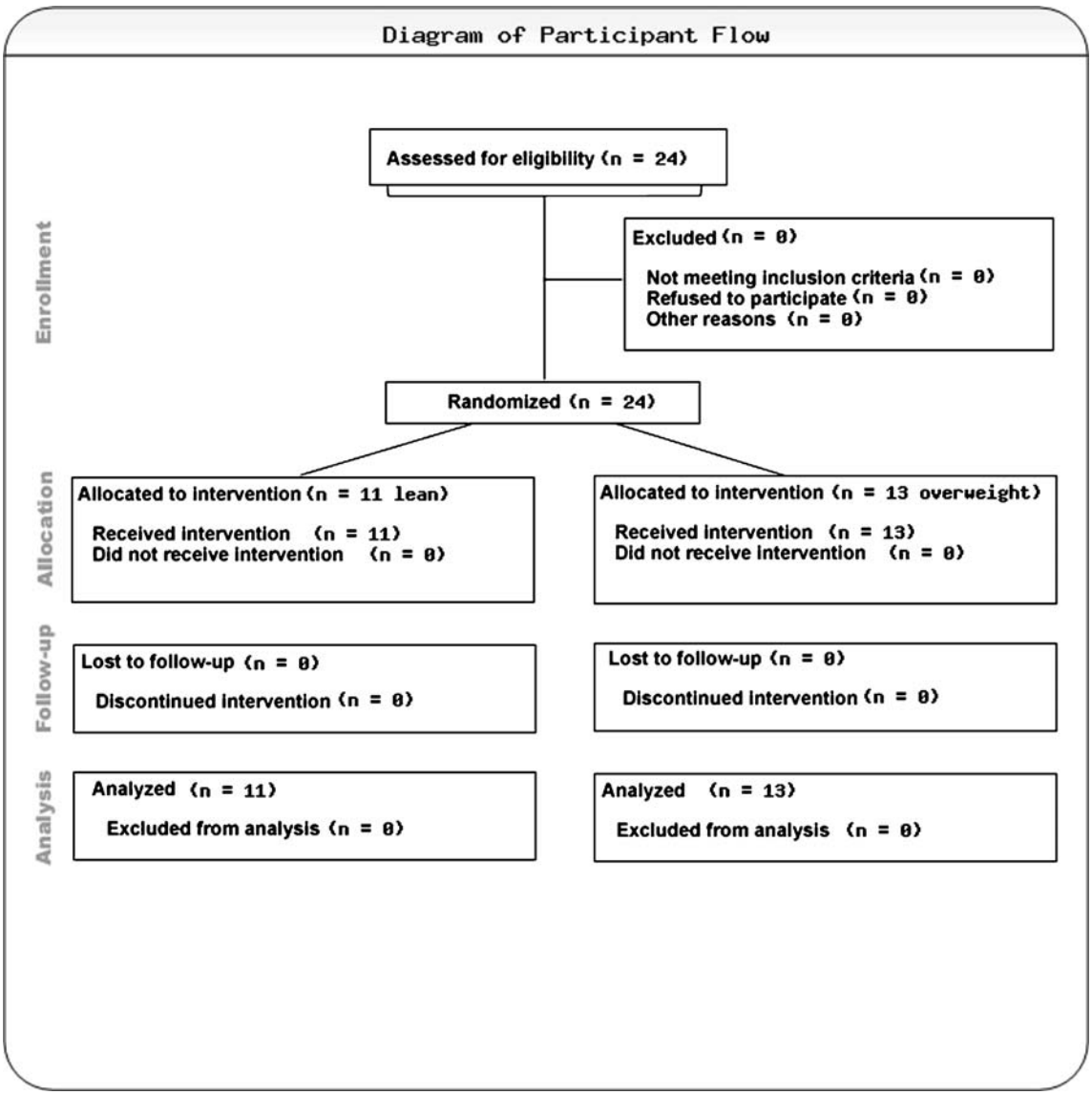
While a single study [37] did evaluate the RRV of the physically interactive DDR video game versus a sedentary alternative, the present investigation was the first to assess RRV of playing Wii Sports Boxing versus a traditional SVG. The results demonstrated that Wii was significantly more reinforcing than the SVG condition in lean children but not overweight/obese children. Furthermore, lean children performed more work to gain access to Wii than overweight/obese children, while the opposite is true for the SVG condition. The previous evaluation of the RRV of the physically interactive DDR did not demonstrate differences between lean and overweight children. However, the present finding that lean children exhibit a greater RRV for a physical activity than overweight/obese children is similar to research examining the RRV of cycle ergometer exercise versus sedentary alternatives (watching a video) [21]. These findings are important when considering the use of Wii as a potential substitute for an SVG. The greater RRV of Wii in the lean children suggests that if lean children had access to both an SVG and Wii they would be more motivated to play the Wii. Thus, the addition of Wii to a lean child's present SVG system may significantly increase physical activity as lean children would likely allocate more time for Wii play. Conversely, overweight/obese children appear equally motivated to allocate time towards SVG and Wii. Therefore, in overweight/obese children, the removal of an SVG and subsequent substitution with Wii may be necessary to significantly increase physical activity via game play.

As is the case with RRV, liking [16–19] has also been demonstrated to be a predictor of physical activity behavior in children. RRV, which is controlled by the dopamine neurotransmitter system, is different from liking which is controlled by the opioid neurotransmitter system [20]. Because of this difference, it is possible to find a behavior reinforcing while simultaneously not liking the behavior or vice versa [22–24]. In the present investigation, both lean and overweight/obese children reported a greater liking for Wii play relative to the SVG. The greater liking for Wii without a greater RRV versus an SVG in the overweight/obese children is further evidence of the discrepancy between liking and RRV. Because RRV is considered a better predictor of behavior [22], the overweight/obese children's indifferent RRV for Wii and the SVG could be considered a better indicator of the likelihood that they would choose to play Wii over an SVG in a free-living setting. However, because both lean and overweight/obese children reported greater liking and a greater or similar RRV for Wii versus the SVG, it is reasonable to suggest that both groups of children appear to be at least as motivated to play the physically interactive Wii as they are to play a sedentary alternative.

While these results indicate Wii as a potentially motivating and physiologically challenging alternative to an SVG, there are limitations to this study. Adequate statistical power was present to test the current hypotheses; however, the sample size was small and limited only to 8–12-year-old children. Future research examining older children/adolescents may be advisable as teenagers also regularly play video games and may benefit from more physically active game play [1]. The present investigation also only evaluated a single Wii game and a single SVG. Wii Sports Boxing was chosen as it is included with the standard Wii system, likely making it one of the most widely circulated Wii games. Additionally, Wii Sports Boxing has been previously demonstrated to elicit the greatest VO_2 of the Wii games that have been evaluated [12, 13]. Future research should examine physiologic measures of effort, RPE, liking, and RRV in additional games from the rapidly expanding Wii library. Nintendo PunchOut! was chosen as the SVG as it, like Wii Sports Boxing, is a boxing simulation. While it is unlikely that alternate SVGs would differentially affect VO_2, heart rate, or RPE, it is possible that different SVGs may be more or less liked or reinforcing. Finally, while the present results indicate that children reported the greatest liking for the Wii and were either more motivated or as motivated to play the Wii versus the SVG, there is presently no research evaluating the actual free-living patterns of Wii play in children. Future research should seek to evaluate the effect that the substitution of a Wii "gamming" system for a traditional sedentary "gamming" system has on the time children allocate for video game play in lean and overweight/obese children.

In conclusion, Wii significantly increased physiologic measures of intensity (VO_2, heart rate) over an SVG, treadmill walking, and resting. Wii was also significantly more reinforcing than the SVG in lean children and equally as reinforcing as the SVG in overweight/obese children. Finally, Wii was the most liked activity condition for both groups of children despite being perceived as requiring greater effort to play than the SVG. Taken together, these results suggest that Wii was a well-liked activity of greater

physiologic intensity than an SVG and treadmill walking, and lean children appear more motivated while overweight/obese children appear as motivated to play Wii relative to the SVG. While additional research is warranted, Wii appears to be a viable candidate to substitute for a sedentary "gamming" system in interventions designed to increase physical activity in children who regularly play SVG. However, while the Wii may be capable of increasing daily, moderate-intensity physical activity, which has multiple health benefits [38], the intensity of Wii play does not appear great enough to substantially alter cardiorespiratory fitness in healthy children. While it may be superior to sedentary video games, it is likely not advisable to recommend Wii play in place of traditional physical activity for children.



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