Objective: To examine the metabolic, physiologic, and hemostatic responses to action video game play in a group of young boys.

Design: Comparison study.

Setting: Laboratory of Clinical and Applied Physiology, University of Miami.

Participants: Twenty-one boys aged 7 to 10 years.

Main Outcome Measures: Blood pressure monitored before and during game play and blood glucose and lactate levels measured before and immediately after game play. Measurements were continuously recorded throughout game play. Dependent t tests were used to compare measurements recorded at baseline and during or after game play. Effect sizes using the Cohen d were examined for comparisons.

Results: Significant increases from baseline were found for heart rate (18.8%; P < .001), systolic (22.3%; P < .001) and diastolic (5.8%; P = .006) blood pressure, ventilation (51.9%; P < .001), respiratory rate (34.8%; P < .001), oxygen consumption (49.0%; P < .001), and energy expenditure (52.9%; P < .001). Effect sizes for these comparisons were medium or large. No significant changes were found from baseline to after video game play for lactate (18.2% increase; P = .07) and glucose (0.9% decrease; P = .59) levels.

Conclusions: Video game play results in significant increases in various metabolic and physiologic variables in young children. Thus, it should not be combined with television viewing for the evaluation of sedentary activities. The magnitude of change, however, was lower than that observed during standard physical exercise and below national health recommendations. As such, video game play should not be considered a substitute for regular physical activities that significantly stress the metabolic pathways required for the promotion of cardiovascular conditioning.

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The prevalence of obesity and overweight is increasing in adults and children throughout the world. For example, in children aged 6 to 11 years, the prevalence of obesity has increased from 6.5% (NHANES II [second National Health and Nutrition Examination Survey]) to 11.3% (NHANES III) to 15.3% (NHANES 1999-2000). Although the rising prevalence of obesity is multifactorial, insufficient physical activity is suspected to play a primary role. Television viewing is considered a sedentary behavior that has gained much attention recently. Children and adolescents have been reported to watch television for 2.77 to 3.54+ hours per day, averaging 19.39 to 24.78 hours of television viewing per week. Dietz and Gortmaker reported that each additional hour of television viewing per week increased the risk of obesity by 2%. The experimental study by Robinson found strong evidence of a causal link between television viewing and children’s overweight.

Television viewing and video game play may be combined for the purpose of evaluating sedentary behaviors. Playing video games, however, may not be a passive activity and may not have the same impact on the prevalence of overweight as watching television. Watching television expend the same energy as sitting quietly. Unlike television viewing, however, studies have shown increases in oxygen consumption (VO2), blood pressure (BP), heart rate (HR), and energy cost in response to video game play. For example, Segal and Dietz found that video game play significantly increased HR, systolic BP (SBP), diastolic BP (DBP), and VO2 in 16- to 25-year-old young adults. Ridley and Olds found that the magnitude of energy expenditure (EE) is related to the amount of body movement associated with video game play in 11- to 12-year-old children. However, there is a lack of research
in young children, who constitute a large video game consumer population.

Given the rising rates of childhood obesity and the implications of sedentary behaviors contributing to this problem, it is important to determine the calorie expenditure of video game play in young children. It is also important to examine additional metabolic responses to video game play, including glucose and lactate levels, to determine their comparability with values typically observed during exercise. Thus, the purpose of this study is to examine the metabolic and physiologic responses to action video game play in a group of 7- to 10-year-old boys.

**METHODS**

**PARTICIPANTS**

Volunteers were recruited through direct communication with local public school officials in after-school programs, parks and recreation departments, and youth centers. Volunteers enjoyed playing video games and considered themselves very experienced at playing all video games. All the participants were boys aged 7 to 10 years (10 were white, 9 were Hispanic, and 2 were African American). Testing was conducted at the Laboratory of Clinical and Applied Physiology, University of Miami. An informed consent form was signed by the participants and their parents in accordance with the guidelines of the institutional review board for the use of human subjects at the University of Miami. Before testing began, an orientation was given to all the parents and children to discuss the procedures and protocol requirements during testing.

**PROCEDURES**

Height was measured in shoeless boys using a stadiometer (Detecto Scale Inc, Brooklyn, NY) and was recorded to the nearest 0.1 cm. Weight was measured to the nearest 0.1 kg using a balance scale (Detecto Scale Inc), with calibration procedures performed before data collection. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

After the participants maintained a seated position for 5 minutes, BP was measured twice by a trained investigator (A.C.P.) using standard procedures, with 5 minutes of rest between the 2 measurements. The mean of the 2 measurements was recorded to the nearest 2.0 mm Hg. If the 2 measurements were more than 4 mm Hg apart, a third measurement was taken after 5 minutes, and the mean of the 3 measurements was recorded. Blood pressure was measured by the same investigator halfway through game play.

Before video game play, all the participants underwent a familiarization period using the mask and electrodes required for testing. A simulated testing session without blood analysis and video game play was provided at this time so that participants felt more comfortable during actual testing.

A metabolic cart (model 2900; SensorMedics, Yorba Linda, Calif) was used to measure physiologic responses (including ventilation [VE], tidal volume, and respiratory rate) and metabolic responses (including VO2 per kilogram, EE, and respiratory quotient) during video game play. Data were continuously monitored and recorded throughout the testing session. A small-sized 3-valve mask (Hans-Rudolph Inc, Kansas City, Mo) was fitted to the participant’s face. The mask covered the boy’s nose and mouth and was customized for each individual to ensure a tight seal around the edges. This was achieved by adding gauze to the nasal bridge area and petroleum jelly to the area on the perimeter of the mask. Both HR and 12-lead electrocardiography were continuously monitored using an electrocardiograph (MAX-1; SensorMedics) (Figure 1).

**HEMOSTATIC VARIABLES**

Approximately 200 µL of blood was obtained from the tip of the middle finger of the nondominant hand as part of baseline data collection and before video game play. Blood samples were also obtained again from the top of the middle finger of the dominant hand immediately after completion of game play. Samples were immediately analyzed for lactate and glucose concentrations according to the user instructions of the VITROS DT60 II Analyzer (Johnson & Johnson Clinical Diagnostics Inc, Rochester, NY). Calibration was conducted in accordance with methods described by the manufacturer.

**VIDEO GAME**

The video game Tekken 3 (Namco Hometek Inc, San Jose, Calif), an action video game played on a Sony Playstation (Sony Computer Entertainment America, Foster City, Calif), was selected. Players controlled their character against the computer-controlled character in a mock martial arts contest. Buttons on the video game controller included “move left,” “move right,” “jump,” “duck,” “high punch,” “low punch,” “high kick,” and “low kick.” The participants started from the “Arcade Mode” and had identical game variables, including game time, opponent level, and game rules, throughout the study. Instructions regarding how to operate the video game were given to participants during the familiarization period and again immediately before video game play. The participants were allowed to pick their own character and to change this character at any time during the game. They were encouraged to do their best and were told that they were competing against other players in the study. The Playstation and video game console were turned on after 5 minutes of baseline data collection of metabolic and physiologic measurements. The Playstation and video game were turned off after 15 minutes of game play, and blood samples were obtained again. The mask was subsequently removed for the comfort of the child.

**ANALYTIC METHODS**

All the statistical analyses were completed using a software program (SPSS version 10.1; SPSS Inc, Chicago, Ill). Mean ±SD are reported for all the variables. For each participant, mean values of measurements obtained by continuous monitoring us-

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**Figure 1.** Video game data collection using a metabolic cart and an electrocardiograph.
ing a metabolic cart and an electrocardiograph were calculated for the 5-minute baseline period, the 15 minutes of game play, and the most active 3 minutes of game play. Dependent $t$ tests were used to compare measurements at baseline with those during video game play, including all the physiologic and metabolic variables. Mean values of measurements for the most active 3 minutes were also compared with their corresponding baseline values using dependent $t$ tests. The most active minutes were simply those with the highest metabolic values. We chose to use the average of the most active 3 minutes rather than 1 minute to avoid any single aberrant or unusual value produced during a single minute of video game play. Thus, we used the most active 3 minutes rather than 1 minute against which to compare baseline values. Hemostatic measurements before game play were compared with those immediately after game play. $P<0.05$ was considered statistically significant.

Effect sizes for the dependent $t$ tests were examined using the Cohen $d$. A $d$ value of 0.8 or greater refers to a large effect size, and a value of 0.5 to 0.8 refers to a medium effect size. Both large and medium effect sizes have been used to indicate a substantial difference between means. A Cohen $d$ value less than 0.5 refers to a small effect size, which indicates a trivial difference between mean values.

### RESULTS

Twenty-one boys volunteered for the study (age, $8.8 \pm 1.1$ years; height, $139.5 \pm 7.4$ cm; weight, $31.8 \pm 7.6$ kg; and BMI, $16.2 \pm 3.0$). The height, weight, and BMI of the participants were at the 90th, 75th, and 25th percentile, respectively, for their age and sex.13,14

Table 1 includes comparisons of metabolic and physiologic measurements at baseline and during game play and comparison of hemostatic variables at baseline and immediately after game play. Values during game play were significantly higher than their respective baseline values for HR, SBP, DBP, VE, respiratory rate, $\text{VO}_2$, and EE. Specifically, $\text{VO}_2$ showed a 49.0% increase, from 4.90 to 7.30 mL·min$^{-1}$·kg$^{-1}$, and EE showed a 52.9% increase, from 1.36 to 2.08 kcal·hr$^{-1}$·kg$^{-1}$. Of the aforementioned variables, HR, SBP, VE, respiratory rate, $\text{VO}_2$, and EE had Cohen $d$ values much greater than 0.8, thereby reflecting large effect sizes. Diastolic BP showed an increase in medium effect size. In contrast, tidal volume, respiratory quotient, and glucose concentration showed numerical decreases; however, their $t$ test values were not significant, and their effect sizes were small. Lactate level showed a nonsignificant increase and a small effect size.

### COMMENT

The present study evaluated the metabolic and physiologic effects of video game play in young children. Participants included white, Hispanic, and African American boys averaging 8.8 years of age with above-average height and weight and a low BMI. Their mean resting SBP and DBP were 106.0 and 67.0 mm Hg, respectively, which are considered average for their age and sex. To our knowl-

### Table 1. Comparison of Physiologic and Metabolic Measurements at Baseline vs During Video Game Play and of Hemostatic Measurements at Baseline vs After Game Play Using Dependent $t$ Tests in 21 Boys

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Baseline, Mean ± SD</th>
<th>During or After Game Play, Mean ± SD</th>
<th>Change, % (95% CI)</th>
<th>$P$ Value</th>
<th>Cohen $d$</th>
</tr>
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<tbody>
<tr>
<td>Physiologic variables</td>
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<tr>
<td>HR, beats·min$^{-1}$</td>
<td>86.9 ± 10.9</td>
<td>103.2 ± 7.0</td>
<td>18.8 (−21.52 to −10.99)</td>
<td>&lt;.001</td>
<td>1.41*</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>106.0 ± 16.8</td>
<td>129.6 ± 13.3</td>
<td>22.3 (−34.42 to −12.95)</td>
<td>&lt;.001</td>
<td>1.00*</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>67.0 ± 7.1</td>
<td>70.9 ± 6.2</td>
<td>5.8 (−6.57 to −1.24)</td>
<td>.006</td>
<td>0.67†</td>
</tr>
<tr>
<td>VE, L·min$^{-1}$</td>
<td>5.2 ± 1.6</td>
<td>7.9 ± 2.1</td>
<td>51.9 (−3.56 to −1.97)</td>
<td>&lt;.001</td>
<td>1.59*</td>
</tr>
<tr>
<td>Tidal volume, L</td>
<td>0.32 ± 0.08</td>
<td>0.31 ± 0.07</td>
<td>−3.1 (−0.03 to 0.05)</td>
<td>.69</td>
<td>0.15</td>
</tr>
<tr>
<td>Respiration rate, per minute</td>
<td>16.6 ± 4.6</td>
<td>25.7 ± 5.1</td>
<td>54.8 (−11.00 to −7.16)</td>
<td>&lt;.001</td>
<td>2.16*</td>
</tr>
<tr>
<td>Metabolic variables</td>
<td></td>
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</tr>
<tr>
<td>$\text{VO}_2$, mL·min$^{-1}$·kg$^{-1}$</td>
<td>4.90 ± 1.3</td>
<td>7.30 ± 1.6</td>
<td>49.0 (−3.06 to −1.64)</td>
<td>&lt;.001</td>
<td>1.52*</td>
</tr>
<tr>
<td>RQ</td>
<td>0.85 ± 0.04</td>
<td>0.84 ± 0.04</td>
<td>−1.2 (−0.017 to 0.022)</td>
<td>.79</td>
<td>0.17</td>
</tr>
<tr>
<td>Energy expenditure, kcal·hr$^{-1}$·kg$^{-1}$</td>
<td>1.36 ± 0.44</td>
<td>2.08 ± 0.47</td>
<td>52.9 (−31.11 to −15.16)</td>
<td>&lt;.001</td>
<td>1.49*</td>
</tr>
<tr>
<td>Hemostatic variables</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Glucose, mg·dL$^{-1}$</td>
<td>109.95 ± 7.93</td>
<td>108.95 ± 9.39</td>
<td>−0.9 (−2.82 to 4.82)</td>
<td>.59</td>
<td>0.13</td>
</tr>
<tr>
<td>Lactate, mmol·L$^{-1}$</td>
<td>1.92 ± 0.52</td>
<td>2.27 ± 0.68</td>
<td>18.2 (−0.73 to 0.036)</td>
<td>.07</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; DBP, diastolic blood pressure; HR, heart rate; RQ, respiratory quotient (calculated as carbon dioxide production/$\text{VO}_2$); SBP, systolic blood pressure; VE, ventilation; $\text{VO}_2$, oxygen consumption.

*A Cohen $d$ value of 0.8 or greater indicates a large effect size.

†A Cohen $d$ value of 0.50 to 0.8 indicates a medium effect size.
edge, this is the first study to examine the metabolic and physiologic responses to video game play in children younger than 10 years. It is also the first study to measure serum glucose and lactate levels before and after video game play.

These findings show that during action video game play there was a significant increase in EE. The values rose to levels similar to those reported by Ridley and Olds,11 whose participants played driving simulation games and were older (mean age, 12.5 years). Because our average EE during game play was 2.08 kcal·h⁻¹·kg⁻¹, body weight and the reported average time children spend playing video games is 20 to 39 minutes a day,6,5,15 a 9-year-old child at 28.5 kg (50th percentile for body weight13) may expend an average 19.76 to 38.53 kcal daily by playing video games. Although this value seems small, after many years, it translates into weight loss of approximately 1.8 kg per year and 9.0 kg in 5 years.

In addition, physiologic changes elicited by video game play included a 22.3% increase in SBP and a 5.8% increase in DBP, which are in accordance with changes seen for adults during video game play.10,16,17 Our results show that the mean BP was 129.6/70.9 mm Hg and that the mean HR was 103.2 beats·min⁻¹ during game play. Although the highest SBP during game play was 150 mm Hg for 1 participant, the increases in BP or HR generally did not represent a clinically significant or unsafe situation for participants during video game play (Table 1).

We found that respiratory rate and VE increased statistically significantly during game play. Ledunois and colleagues18 concluded that video game play may increase arousal and elicit a strong emotional response, both of which would lead to the observed increase in breathing frequency and VE in our study. On the other hand, the act of focusing attention on game play may actually prompt children to inhibit any movement and, in particular, breathing. According to the previous investigators,18 the increases in breathing rate and VE found in our study were most likely due to a stronger arousal and emotional component during game play than to attention load.

We also measured serum glucose and lactate levels before and after video game play. The purpose of examining these measures was to compare metabolic responses with those typically observed during regular exercise. Lactate levels, which typically increase during exercise, increased 18.2% from baseline to after game play; however, the change was not statistically significant. Because many video games involve hand movements, which constitute activation of a small amount of body mass, one would expect video games that invoke larger body mass movements to result in greater accumulation of lactate. Glucose levels barely changed during video game play, which is in contrast to what has been observed in response to physical exercise.19 Therefore, video game play did not elicit the same metabolic responses as exercise, which may be because of the smaller amount of muscle mass involved.

Investigators often use metabolic equivalents (METs) to quantify the intensity of exercise, thereby enabling comparison of intensity across different exercises. One MET is equivalent to 3.5 mL·O₂·kg⁻¹·min⁻¹, which represents the energy expended at rest. In the present study, the mean VO₂ at baseline was 4.9 mL·kg⁻¹·min⁻¹, corresponding to 1.4 METs. It was somewhat higher than expected, indicating that our children may have some level of excitement or arousal in anticipation of game play. The mean VO₂ during video game play was 7.30 mL·kg⁻¹·min⁻¹ and during the most active 3 minutes was 8.60 mL·kg⁻¹·min⁻¹, corresponding to 2.1 and 2.5 METs, respectively. The calculated energy cost during video game play was approximately equivalent to walking 2.0 mph, which is similar to that reported by Segal and Dietz10 for adults. In addition, SBP, DBP, and HR in the present study increased to approximately the same level shown for cycling at a work rate of 60 W or walking at 3 mph in boys of similar age and body composition.20 In contrast, the VO₂ values observed in this study were much lower than those for cycling at 60 W or walking at 3 mph. Based on VO₂ and MET levels, the intensity of video game play is less than moderate. Public health officials have suggested that 20 to 30 minutes of moderate to vigorous activity per day is recommended for children. In fact, up to 60 or more minutes of moderate-intensity activity daily has been recommended by several health organizations.21 Therefore, video game play is insufficient for children to meet these guidelines, although metabolic variables were significantly higher than those observed at baseline.

Recent studies22,23 have also shown a significant association between electronic game use and obesity, with nearly a 2-fold increased risk of obesity for every hour

### Table 2. Significant Results From Dependent t Tests Comparing Physiologic and Metabolic Measurements at Baseline and During the Most Active 3 Minutes of Video Game Play in 21 Boys

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Baseline, Mean ± SD</th>
<th>Most Active 3 Minutes, Mean ± SD</th>
<th>Change, % (95% CI)</th>
<th>Cohen d**</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR, beats·min⁻¹</td>
<td>86.9 ± 10.9</td>
<td>116.0 ± 12.2</td>
<td>33.5 (−36.35 to −11.43)</td>
<td>1.63</td>
</tr>
<tr>
<td>VE, L·min⁻¹</td>
<td>5.2 ± 1.6</td>
<td>9.5 ± 2.3</td>
<td>82.7 (−5.50 to −3.26)</td>
<td>1.78</td>
</tr>
<tr>
<td>Respiratory rate, per minute</td>
<td>16.6 ± 4.6</td>
<td>30.3 ± 6.1</td>
<td>82.5 (−16.77 to −10.64)</td>
<td>2.04</td>
</tr>
<tr>
<td>Metabolic variables</td>
<td></td>
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</tr>
<tr>
<td>VO₂, mL·min⁻¹·kg⁻¹</td>
<td>4.90 ± 1.3</td>
<td>8.60 ± 2.0</td>
<td>75.5 (−151.29 to −82.27)</td>
<td>1.60</td>
</tr>
<tr>
<td>Energy expenditure, kcal·hr⁻¹·kg⁻¹</td>
<td>1.36 ± 0.44</td>
<td>2.53 ± 0.58</td>
<td>86.0 (−45.94 to −26.74)</td>
<td>1.79</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; HR, heart rate; VE, ventilation; VO₂, oxygen consumption.

*A Cohen d value of 0.8 or greater indicates a large effect size. P < .001 for all.
spent playing electronic games daily.22 An inverse relationship between time spent using video games and daily physical activity has also been observed.24 Thus, if video game play is used as a substitute for regular physical activity, the positive association between game play and obesity is certainly plausible; however, if it is used to replace time spent watching television or simply resting, video game play can serve to move positively affect EE. The volunteers in our study considered themselves to be very experienced at video game play, yet they were very slender for their age.

There are several limitations that should be noted regarding this study. First, the sample size was small, and the participants were all relatively lean. Children with large BMIs may manifest different EE levels during video game play than lean children. Therefore, we could not generalize our results to larger samples in practice. Second, no girls were included in this study. Because in adults there are reported sex differences in free fatty acid, glycogen, and glucose use during exercise,23 we believed that combining boys and girls might confound the results of metabolic variables during video game play. Third, the data were collected in a laboratory. Although the children were familiarized with the equipment and testing procedures before actual data collection, it still was not a natural setting in which children typically play video games. This was observed because the baseline MET level was higher than 1 and thereby might have resulted in a smaller increase during game play.

In summary, the present study demonstrates that video game play is not a passive activity in young children because it results in significant increases in various physiologic and metabolic responses. As such, we recommend not combining it with television viewing for the purpose of evaluating sedentary activities. In contrast, the intensity of video game play is insufficient for the enhancement of cardiovascular conditioning. Despite similarities between video game play and cycling or walking with respect to physiologic variables, such as HR and BP, metabolic variables, such as VO₂, glucose, and lactate levels, were lower than those associated with physical exercise. These differences may have been due to the smaller amount of muscle mass actually used during video game play. Thus, although video game play should not be considered a sedentary activity, it should in no way be considered a substitute for regular physical activities that significantly stress the metabolic pathways required for the enhancement of cardiovascular conditioning.

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Correspondence: Arlette C. Perry, PhD, Exercise and Sport Sciences Department, School of Education, University of Miami, PO Box 248065, Coral Gables, FL 33124 (aperry@miami.edu).

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