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The Energy Expenditure of an Activity-Promoting Video Game compared to Sedentary Video Games and TV Watching

Naim Mitre, MD^{1,2,3}, Randal C Foster, MS⁴, Lorraine Lanningham-Foster, Ph.D.^{2,4}, and James A. Levine, MD., Ph.D.²

¹Division of Pediatric Endocrinology and Metabolism, Mayo Clinic College of Medicine, Rochester, MN

²Endocrine Research Unit, Division of Endocrinology, Department of Internal Medicine, Mayo Clinic College of Medicine, Rochester, MN

³Department of Endocrinology, Children's Mercy Hospitals and Clinics, Kansas City, MO

⁴Food Science and Human Nutrition, Iowa State University, Ames, IA

Abstract

Background—Screen time continues to be a major contributing factor to sedentariness in children. There have been more creative approaches to increase physical over the last few years. One approach has been through the use of video games. In the present study we investigated the effect of television watching and the use of activity-promoting video games on energy expenditure and movement in lean and obese children. Our primary hypothesis was that energy expenditure and movement decreases while watching television, in lean and obese children. Our secondary hypothesis was that energy expenditure and movement increases when playing the *same game* with an activity-promoting video game console compared to a sedentary video game console, in lean and obese children.

Methods—Eleven boys (10 ± 1 year) and eight girls (9 ± 1 year) ranging in BMI from 14–29 kg/m² (eleven lean and eight overweight or obese) were recruited. Energy expenditure and physical activity were measured while participants were watching television, playing a video game on a traditional sedentary video game console, and while playing the same video game on an activity-promoting video game (Nintendo Wii) console.

Results—Energy expenditure was significantly greater than television watching and playing video games on a sedentary video game console when children played the video game on the activity-promoting console (125.3 ± 38.2 Kcal/hr vs. 79.7 ± 20.1 and 79.4 ± 15.7 , $P < 0.0001$, respectively). When examining movement with accelerometry, children moved significantly more when playing the video game on the Nintendo Wii console ($p < 0.0001$).

Conclusion—The amount of movement and energy expenditure of television watching and playing video games on a sedentary video game console is not different. Activity-promoting video games have shown to increase movement, and be an important tool to raise energy expenditure by 50% when compared to sedentary activities of daily living.

Keywords

video-games; television; obesity; energy expenditure; children; physical activity

Correspondence James A. Levine, MD., Ph.D. Endocrine Research Unit, 5-194 Joseph Mayo Clinic 200 First Street, SW Rochester, MN 55905 Phone: (507) 255-8076; Fax (507) 255-4828 Levine.james@mayo.edu.

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Background

Efforts to improve physical activity in children have increased dramatically over the last few years, since the obesity epidemic became a mayor health concern. (1) Almost 50% of the US children spend more than the recommended 2 hrs per day in sedentary behaviors such as television watching, playing video games and computer screen time. (2, 3)

The question about how television affects energy expenditure (EE) in children has not been completely answered since results have been contradictory. The assumption has been that watching television lowers energy expenditure secondary to decreased physical activity. However some small studies have shown that energy expenditure does not decrease, and hypothesized that weight gain could be related to higher food consumption while watching TV. (4,5,6) On the other hand, the use of video games as a means to increase physical activity has been recently studied with promising results so far. The use of video games to convert sedentary screen time into active screen time is likely a fun and engaging way for children to burn more calories in the comfort of their homes. (7, 8)

One caveat to these studies is that, even though they demonstrated increased in energy expenditure with the activity-promoting video games consoles, participants played *different games*. Potentially some of the games selected for these studies were more exothermic than others making the comparison among activity-promoting and sedentary consoles less accurate.

In the present study we investigated the effect of television watching and the use of activity-promoting video games on energy expenditure and movement in lean and obese children. Our primary hypothesis was that EE and movement decreases while watching television with the sound and screen ON compared to OFF, in lean and obese children. Our secondary hypothesis was that EE and movement increases when playing the *same game* with an activity-promoting video game console compared to a sedentary video game console, in lean and obese children.

Materials and Methods

Subjects

Nineteen healthy children of varying age (8–12 years), eleven male (10 ± 1 year) and eight girls (9 ± 1 year) ranging in BMI from 14–29 Kg/m² were recruited through local advertisement (Table 1). Eleven subjects (6 males and 5 females) were considered lean according to their BMI (5th percentile < BMI < 85th percentile for age and sex) and eight (5 male and 3 female) were considered overweight or obese (BMI ≥ 85th percentile for age and sex).

Television Watching

The content of the video was standardized as all the participants watched the same movie called Cars (Disney/Pixar, Burbank, California) during the TV portion of the protocol.

Video Game Consoles and Games

Four video game systems were used. The sedentary video game consoles were Playstation 2 (Sony Computer Entertainment, San Mateo, California), Xbox 360 (Microsoft, Redmond, WA), Nintendo DS lite (Nintendo Company Ltd., Kyoto, Japan). The activity-promoting video game was Nintendo Wii (Nintendo Company Ltd., Kyoto, Japan). The Playstation 2 used a hand-held controller connected by a wire to the system, the Xbox 360 used a wireless hand-held controller and the Nintendo DS was a dual-screen device with the bottom one

being a touch screen used to control the game while using a stylus. The Nintendo Wii used a wireless remote controller. The video game used was standardized and the same video game called Sega SuperStar Tennis (Sega, Tokyo, Japan) was played in all the consoles. The game was rated “E” (for everyone) by the Entertainment Software Rating Board (ESRB). During the study protocol, all the participants played the same video game with the same game settings.

Physical Activity Measurement System (PAMS)

Physical Activity was measured using the PAMS which was developed and validated in our laboratory in children (9). We combined inclinometers (Model CXTA02, Crossbow Technology, San Jose, California) and triaxial accelerometers (Model CXL02LF3-R, Crossbow Technology) and data loggers (Ready DAQ2000, Valitec, Dayton, Ohio) to continuously detected body posture and motion. PAMS included 6 sensors, 4 inclinometers and 2 accelerometers. The sensors were fixed onto Lycra short and shirts with Velcro straps. Two of the 4 inclinometers were positioned over the lower-thigh (right and left), and the other 2 inclinometers were positioned on the trunk, approximately 10 centimeters below the underarm (right and left). Two triaxial accelerometers were attached to the shorts at the participant's lower back. The output from these accelerometers allowed body motion to be quantified for any given body position. All participants wore the same PAMS throughout the protocol.

Energy Expenditure

Measurements of energy expenditure were performed using an indirect calorimeter (Columbus Instruments, Columbus, OH). Expired air was collected using a dilution face mask that covered the entire face. A primary gas standard (0.5% CO₂, 20.5% O₂, balanced N₂) was used for gas calibrations. Data were collected every thirty seconds and stored on a personal computer. Weekly alcohol burn experiments showed CO₂ and O₂ recoveries of 99%.

Body Mass Index (BMI)

Height and weight were measured without shoes and wearing light clothing using a calibrated stadiometer-scale (Seca 644 hand-rail scale, Seca 245 measuring rod, Seca, Hanover, MD). BMI percentiles were calculated by using the BMI calculator for Child and Teen from the Centers for Disease Control and Prevention (CDC) (10). The measured height to the nearest 0.1 cm and weight to the nearest 0.1 Kg, together with the sex, date of birth and date of measurement were entered.

Anthropometrics

Fat-free mass was estimated by using height, age and sex from previous published equation (11).

Protocol

The testing protocol was approved by the Mayo Clinic's Pediatric and Adolescent Medicine Research Committee and the Institutional Review Board. Informed written assent was obtained from the child and informed written consent was obtained from the parent. The child was instructed to fast (water allowed) for at least 6 hrs before arriving at the Clinical Research Unit, Mayo Clinic, Rochester, MN. All participants wore light clothing and comfortable shoes. The child's height and weight was measured. After arriving to the laboratory the study personnel helped the participant to put on the PAMS, which was worn underneath clothing. The child rested in a dimly-lit, quiet room for 30 minutes. Resting energy expenditure (REE) was then measured for 20 minutes using indirect calorimetry as

described above. During the REE measurement, the child was awake, semi-recumbent (10° head bed tilt), lightly clothed and in thermal comfort (68 to 74 °F). The child was asked not to talk or move during the REE measurement. All children watched the same movie called Toy Story (Disney/Pixar, Burbank, California) movie during the resting and REE period. After measuring REE, the child was given a standardized 400 calorie light breakfast. Immediately after breakfast the indirect calorimetry mask was replaced, the participant sat on a chair in front of the television and energy expenditure (EE) was measured while they performed the following activities in a randomized order for 10 minutes each: watch the movie with TV screen ON and sound ON; watch the movie with TV screen ON and sound OFF; listen to the movie with TV screen OFF and sound ON and look at the TV screen which had the picture turned OFF and sound OFF.

After a 15 minute resting period was completed, the indirect calorimeter mask was replaced and EE was measured while the participants proceeded with the video game portion of the study. Before each video game console was played, each participant was allowed to play for approximately 3 minutes in order to become familiar with the game. The order of the video game part was the same for every participant. Participants were asked to play for 10 minutes, while seated, in the following order with the sedentary consoles first and the activity-promoting console last: Playstation 2; XBox 360; Nintendo DS and the Wii (played while standing). They had a 5 minute resting period between each of the video game consoles. Water was available during the resting period.

Statistical Analyses

Height, weight, age, gender, and BMI, were calculated for each participant. Data from accelerometers worn by participants were analyzed through standard kinematic equations ($\Sigma \Delta A / \Delta t$ in a 0.1-second epoch) (12). To address our primary hypothesis that EE and movement decreases while watching television with sound and screen ON compared to OFF, in lean and obese children, we numerically compared energy expenditure determined by indirect calorimetry and movement determined by using PAMS while participant were at rest, with screen/sound settings in the following combinations: ON/ON, ON/OFF, OFF/ON and OFF/OFF. The same approach was used to address our secondary hypothesis that EE and movement increases when playing the *same game* with an activity-promoting video game console compared to a sedentary video game console, in lean and obese children. Energy expenditure and movement while children played the four different video game consoles were compared numerically. To compare changes in energy expenditure and movement, analysis of variance with post hoc paired *t* tests (Turkey/Kramer) were used. Statistical analyses were conducted with StatView 5.0 (SAS Institute, Cary, NC). Data are expressed as mean $\pm$ standard deviation unless otherwise stated. Statistical significance was defined at $P < 0.05$ unless otherwise stated.

Results

The protocol was tolerated well by all the children. For the entire group (Table 1), the children (10 ± 1 years of age; 11 boys and 8 girls) were of varying height (144 ± 11 cm) and varying weight (44 ± 17 Kg); BMI was 20 ± 5 Kg/m². Eleven of the children were lean according to their BMI (mean BMI percentile: 48 ± 29 ; mean BMI z score: -0.08 ± 0.85), and 8 children were obese or overweight (mean BMI percentile: 96 ± 3 ; mean BMI z score: 1.8 ± 0.34). Eighteen children were white/not of Hispanic origin and 1 child was Hispanic.

Values for the REE and energy expenditure during the various activities are shown in table 1. There was an increase in energy expenditure for all activities compared to resting energy expenditure.

To address our primary hypothesis, that EE and movement decreases while watching television with sound and screen ON compared to OFF, in lean and obese children, we numerically compared energy expenditure and movement during the different television activities. From table 1 it is clear that any of the television activities increased energy expenditure over REE significantly. There was not significant difference between the TV activities. When corrected for fat free mass, there was not a significant difference in energy expenditure between the obese and lean (Fig 1). There was however, a trend for higher energy expenditure in the lean group as seen in Table 1. We examined movement at the back, trunk and thighs during TV activities. There was a significant difference in movement between all of the TV activities and REE, however the movement among screen/sound was not significantly different but there was a trend to move less when the children were watching TV ON/ON (Fig 2).

To address our secondary hypothesis, that the EE and movement increases when playing the *same game* with an activity-promoting video game console compared to a sedentary video game console, in lean and obese children we numerically compared energy expenditure and movement while the children played the 4 different video game consoles. The energy expenditure was ~50% higher when playing Nintendo Wii compared to the sedentary video games. There was not significant difference in EE among the other video game consoles. Even more, the EE of playing sedentary video game consoles was not statistically significant when compared to watching TV (Table 1). The trend for higher energy expenditure in the lean as seen for the TV activities persisted while playing video games.

We examined movement at the back, trunk and thighs while playing video games. There was a significant difference in movement when playing Nintendo Wii ($p<0.0001$) compared to the other consoles, TV watching and REE. There was not a significant difference in movement when comparing TV watching and sedentary video games (Fig 3).

Discussion

Activity-promoting video games have become widely available and popular (13). These new generation video games have been shown to increase energy expenditure when compared to sedentary video games (7, 8, and 14). Nevertheless, the comparisons between activity-promoting and sedentary video game consoles have utilized different games. This is an important factor that can lead to inaccurate energy expenditure differences between active and sedentary video gaming, especially if the former is recommended as a possible intervention for weight management in children. The game used in the majority of these studies is the Wii Sports package (tennis, bowling and boxing) (Nintendo Company Ltd., Kyoto, Japan) that is included with the console. This game is played with a wireless remote and require significant movement to operate the video game, compared to the sedentary consoles that, despite of the game being played, require minimal effort. Hence, a more accurate comparison is to compare the same video game in the sedentary and active video game consoles.

Another long standing sedentary activity is the increasingly use of screen time among children. In particular, television watching has increased over the last few years and this has been recognized as one main factor contributing to the obesity epidemic (15, 16, and 17). Whether our children watch television or play sedentary video games to stay at home away from inclement weather or unsafe environment, these have become two major components of our modern society obesity epidemic. Integrating an activity-promoting-video game could potentially increase energy expenditure, in a society that has failed to reduce screen time. If active gaming is a stimulating way to encourage children to move and stay away of the

sedentaryness of television and traditional video games, then it could be accepted as a primary prevention at the community level.

The objective of the present study was to examine the effect of television watching and the use of activity-promoting video games on energy expenditure and movement in lean and obese children. We found that energy expenditure was 50% greater during active gaming than during sedentary gaming and was two-fold higher compared to resting energy expenditure. Sedentary gaming showed no difference from television watching in energy expenditure and movement.

Our findings are clear that children will burn more calories when playing activity-promoting video games. If a child plays 8 hours of video games a week (18), the average energy expenditure could be close to 1000 calories (average 142 calories/day) playing the activity-promoting video games vs. ~ 480 calories (average 68 calories/day) for the sedentary video games. Previously we examined the EE of treadmill walking in a very similar group of children (19). If children walk 8 hours a week at 0.5 mph they could burn approximately 145 calories/day. This is comparable to playing the activity-promoting video game; however active gaming might be a more fun and engaging activity for a child. These findings suggest that the activity-promoting video games indeed increase EE in a significant manner compared to sedentary video games and television watching, however not as high as 3-fold like previously reported (14). We believe that our results are more accurate since children played the same video game in the active and sedentary consoles.

Our data shows that television watching does not decrease energy expenditure compared to resting energy expenditure. On the contrary, there is a very small significant increase in EE when watching television. We acknowledge that thermic effect of food (TEF) can increase EE close to 5%; however the increase seen while children watched TV was ~ 15–20% even after accounting for TEF. Nevertheless, we do not believe that this minor increase in EE is clinically significant and should still need to be considered a sedentary activity. The EE seen with television watching is not different from sedentary video-games, indicating that both these activities are equally minimal exothermic and are important factors contributing to obesity in children. Hence, reductions in the time of these sedentary-activities continue to be a good way to minimize weight gain in children. (20)

Similarly, our acceleration data correlates with energy expenditure. It clearly shows that there is a trend for less movement when lean and obese children play sedentary video games or spend time watching TV. We did not find a significant difference in the amount of movement or EE between the two groups. Previous studies have shown that obese children expend the same amount of energy doing the same activities as lean children but weight more than their lean counterpart; indicating that obese children gain their weight due to a reduced physical activity level (21, 22). This means that obese children will burn more calories by simply increasing their level of activity.

Our study has shown that television and traditional video games contribute equally to inactivity in children. If we cannot reduce screen time, we should shift our efforts to change sedentary to active screen time in children. The use of active-promoting video games has proved to be a good option, in a society where screen time plays an inevitable role.

Decreased physical activity in *both groups* of children has shown to have not only effects on weight but on metabolic parameters such as blood pressure, glucose metabolism and lipids (23, 24). Unfortunately, the detrimental consequences of the lack of physical activity are already being seen in children at an early age (25).

We recognize the study has limitations. First, the experiment was conducted in a laboratory rather than at home. We do not think that a home-based study would have substantially altered our primary finding that activity-promoting video gaming increases energy expenditure above sedentary video gaming and television watching. We did not randomize the order of the video game part between study participants. Randomization of the video game activities or longer washout periods could extend the length of the study protocol from 3 hours to 6 hours, making it more difficult for young children to participate. There is potential for a newness factor and a learning curve, however the present study is a cross-sectional study trying to investigate if the use of activity-promoting video games increases EE. We think these data are sufficiently robust to warrant prospective, randomized studies in this area. Finally, the children received a small breakfast, which might have increased energy expenditure above REE by ~5%. This is ethically mandatory to prevent the children from feeling excessively hungry. To minimize the thermic effect of food, participants continued with the TV part immediately after breakfast in a randomized order. Overall we think that the limitations of our study did not invalidate our results.

Conclusions

As we become a more modern society, sedentary screen time continues to increase dramatically. This trend reflects children's current high levels of inactivity and obesity rates. The question on how to promote physical activity in our younger generations is still not completely answered. We believe that playing activity-promoting video games is a useful tool to increase physical activity in children.

Active gaming has been shown to be similar in intensity to light to moderate physical activity such as walking, skipping and jogging (26). Our study shows that sedentary video games and television watching have a small effect on children's energy expenditure. On the other hand, activity-promoting video games are fun and engaging resources for children to become more active and burn more calories equivalent to low-intensity walking. Even though video games should not replace traditional free play and sports, at our children current level of weekly gaming, active gaming has the potential to increase daily energy expenditure and serve as a tool to promote active children.

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Abbreviations

REE	Resting Energy Expenditure
EE	Energy Expenditure

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Fig. 1.
Energy expenditure per Kg fat-free mass in lean v. overweight/obese children Values shown are mean $\pm$ SD
* $p < 0.05$
** $p < 0.005$

Fig. 2.
Log-transformed acceleration by TV state
Values shown are mean ± SEM
* p< 0.0001

Fig. 3.
Acceleration by activity
Values shown are mean $\pm$ SEM
* $p < 0.005$
** $p < 0.0001$

Table 1

Characteristics of lean and overweight study participants and Mean Energy Expenditure during different activities. Values shown are mean $\pm$ SD.

	Group (n=19)	Lean (n=11)	Overweight (n=8)
Age, mean $\pm$ SD, y	10 $\pm$ 1	9.9 $\pm$ 1.3	11 $\pm$ 1.3
Height, mean $\pm$ SD, cm	144 $\pm$ 11	140 $\pm$ 9.4	151 $\pm$ 14.5
Gender, male/female, n	11/8	6/5	5/3
Weight, mean $\pm$ SD, Kg	44 $\pm$ 17	33 $\pm$ 6.5	59.5 $\pm$ 14.5
BMI, mean $\pm$ SD, Kg/m ²	20 $\pm$ 5	16.8 $\pm$ 1.8	25.7 $\pm$ 3.3
BMI, percentile, mean $\pm$ SD	68 $\pm$ 33	48 $\pm$ 29	96 $\pm$ 3
BMI z score, mean $\pm$ SD	0.7 $\pm$ 1	-0.08 $\pm$ 0.85	1.8 $\pm$ 0.34
Energy expenditure by body weight, mean $\pm$ SD, Kcal/kg/h			
REE	1.47 $\pm$ 0.24 ^a	1.61 $\pm$ 0.19 ^{a,c}	1.29 $\pm$ 0.18 ^a
TV ON/ON	1.93 $\pm$ 0.45	2.20 $\pm$ 0.30 ^c	1.56 $\pm$ 0.34
TV ON/OFF	1.97 $\pm$ 0.46	2.25 $\pm$ 0.34 ^c	1.59 $\pm$ 0.32
TV OFF/ON	2.01 $\pm$ 0.47	2.30 $\pm$ 0.33 ^c	1.61 $\pm$ 0.31
TV OFF/OFF	1.99 $\pm$ 0.47	2.27 $\pm$ 0.36 ^c	1.62 $\pm$ 0.33
PS2	2.07 $\pm$ 0.65	2.45 $\pm$ 0.58 ^c	1.56 $\pm$ 0.31
Xbox 360	2.02 $\pm$ 0.65	2.39 $\pm$ 0.57 ^c	1.50 $\pm$ 0.30
Nintendo DS	1.96 $\pm$ 0.54	2.31 $\pm$ 0.34 ^c	1.47 $\pm$ 0.33
Nintendo Wii	3.05 $\pm$ 0.93 ^b	3.05 $\pm$ 0.71 ^{b,c}	2.42 $\pm$ 0.85 ^b

Energy Expenditure by Indirect Calorimeter

^a REE is significantly different from all other states, $P < 0.0005$ for Group and Normal, $P < 0.05$ for Overweight/Obese

^b Nintendo Wii is significantly different from all other states, $P < 0.0001$ for Group and Normal, $P < 0.01$ for Overweight/Obese

^c EE/weight is significantly different for all states between Normal and Overweight/Obese, $P < 0.005$