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Home-based exergaming among children with overweight and obesity: a randomized clinical trial

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Summary

Background: Given children's low levels of physical activity and high prevalence of obesity, there is an urgent need to identify innovative physical activity options.

Objective: This study aims to test the effectiveness of exergaming (video gaming that involves physical activity) to reduce children's adiposity and improve cardiometabolic health.

Methods: This randomized controlled trial assigned 46 children with overweight/obesity to a 24-week exergaming or control condition. Intervention participants were provided a gaming console with exergames, a gameplay curriculum (1 h per session, three times a week) and video chat sessions with a fitness coach (telehealth coaching). Control participants were provided the exergames following final clinic visit. The primary outcome was body mass index (BMI) z-score. Secondary outcomes were fat mass by dual energy X-ray absorptiometry and cardiometabolic health metrics.

Results: Half of the participants were girls, and 57% were African–American. Intervention adherence was 94.4%, and children's ratings of acceptability and enjoyment were high. The intervention group significantly reduced BMI z-score excluding one control outlier (intervention [standard error] vs. control [standard error]: −0.06 [0.03] vs. 0.03 [0.03], $p = 0.016$) with a marginal difference in intent-to-treat analysis (−0.06 [0.03] vs. 0.02 [0.03], $p = 0.065$). Compared with control, the intervention group improved systolic blood pressure, diastolic blood pressure, total cholesterol, low-density lipoprotein-cholesterol and moderate-to-vigorous physical activity (all p values <0.05).

Conclusions: Exergaming at home elicited high adherence and improved children's BMI z-score, cardiometabolic health and physical activity levels. Exergaming with social support may be promoted as an exercise option for children.

Keywords: African–Americans, coaching, technology, weight loss.

Abbreviations: BMD, bone mineral density; BMI, body mass index; BP, blood pressure; DXA, dual energy X-ray absorptiometry; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MVPA, moderate-to-vigorous physical activity

Nearly 20% of US children ages 6 to 11 years are affected by obesity (1). Young children with obesity are developing early signs of cardiovascular disease (2). Declining physical activity during childhood and into adolescence contributes to significant weight gain (3). Meta-analyses indicate that increasing children's physical activity over a 24-week period significantly reduces body mass index (BMI) z-score (4) and improves cardiometabolic risk factors (5). However, only 42% of 6- to 11-year-olds and 8% of 12- to 15-year-olds meet national physical activity guidelines of 60 min of daily moderate-to-vigorous physical activity (MVPA) (6); therefore, identifying enjoyable, sustainable physical activity options is a public health priority.

Exergames (i.e. video games that require physical activity) transform sedentary screen time into physically active screen time. Systematic reviews and meta-analyses indicate that players can reach light to moderate intensity physical activity while exergaming (7–10). However, there are contradictory findings on the extent to which exergames can reduce children's adiposity or improve cardiovascular disease risk factors in the home setting (11–15). The inconsistency in findings may be that prior home-based trials lacked a theoretical basis and used exergames as the sole tool for physical activity promotion, resulting in sharp declines in exergaming after a few weeks.

The present GameSquad trial used exergaming as one tool within a behaviour change intervention that was grounded in social cognitive theory (16), which conceptualizes behavioural change as the result of links among behaviours (e.g. exergame play), the environment (e.g. parental and coach support) and psychosocial variables (e.g. self-efficacy and quality of life). Exergames are often played with family members (17), and social interaction during group-based exergame play is a key predictor of weight loss (18). Exergames encourage exercise through supportive words on the screen like 'Flawless' and 'Almost' to boost players' self-efficacy (one's belief about personal control (16)), which predicts exercise adherence (19). The GameSquad intervention provided social support by requiring children to play with or against a family member or friend and by requiring children and parents to attend telehealth counselling sessions designed to promote self-efficacy and to reduce perceived barriers.

The goal of this parallel randomized controlled trial was to test the effectiveness of the exergaming intervention to reduce adiposity and improve cardiometabolic health in children with overweight and obesity. Given that the intervention was grounded in behavioural theory with the use of social support and telehealth counselling, the primary hypothesis was that children randomized to the exergame intervention would decrease BMI z-score compared with a control group. Secondary hypotheses were that the children in the exergaming intervention would improve cardiometabolic risk factors (20), body composition (fat mass and bone mineral density [BMD]), health behaviours (physical activity and diet) (20) and psychosocial health compared with the control group.

Methods

Participants

Parents were recruited for their child's participation through email, school newsletters, social media, news media, doctors' offices and community events. Of 96 children whose parents completed an online screening survey, 46 met eligibility criteria and were randomly assigned (see Fig. 1). Inclusion criteria included being between the ages of 10 and 12 years, having a BMI percentile ≥85th, living in a household with high-speed internet connection and having at least one family member or friend willing to play the exergame with the participant for 3 h week^{-1}. Exclusion criteria included being pregnant; having impairments that prevent normal ambulation; or having an indication of cardiac abnormality or previous or current symptoms of cardiovascular disease, musculoskeletal injury or epileptic seizures. All study procedures were approved by the Pennington Biomedical Research Center Institutional Review Board.

Procedures

Interested parents completed a screening form online followed by a phone screen. Eligible children were scheduled for a screening visit where the child provided written assent and the parent/legal guardian provided written consent. Participants were provided with an accelerometer to wear for 7 d and scheduled a baseline clinic visit to occur at least 8 d later. During the baseline clinic visit, participants returned the accelerometer and underwent study measurements.

The participant was randomly assigned to the GameSquad intervention or a control condition, revealed by an interventionist ('fitness coach') using an opaque sealed envelope after completion of baseline measurements. A biostatistician generated the allocation sequence using biased coin randomization based on the BMI z-score collected at the screening visit to ensure balance across conditions. Participants returned for an end-of-study clinic visit at week 24, occurring within 72 to 168 h following the final gaming session (for intervention participants) to observe cumulative rather than acute effects of the exergaming. All data assessors and investigators were blinded to participant's condition.

Each participant randomized to GameSquad was provided a Kinect® and Xbox 360® gaming console (Microsoft, Redmond, WA, USA), a 24-week Xbox Live subscription and four exergames (*Your Shape: Fitness Evolved 2012*, *Just Dance 3*, *Disneyland Adventures* and *Kinect Sports Season 2*). Two fitness coaches visited the parent and child at home within 7 d of randomization to deliver and set up the gaming equipment and play the first gaming challenge together.

The GameSquad intervention encouraged participants to meet a goal of 60 min d^{-1} of MVPA for 24 weeks. Participants were asked to play exergames 3 d week^{-1} with a family member or friend to help them meet this MVPA goal. Each exergaming participant received a booklet that provided a standardized gameplay curriculum to play three challenges each

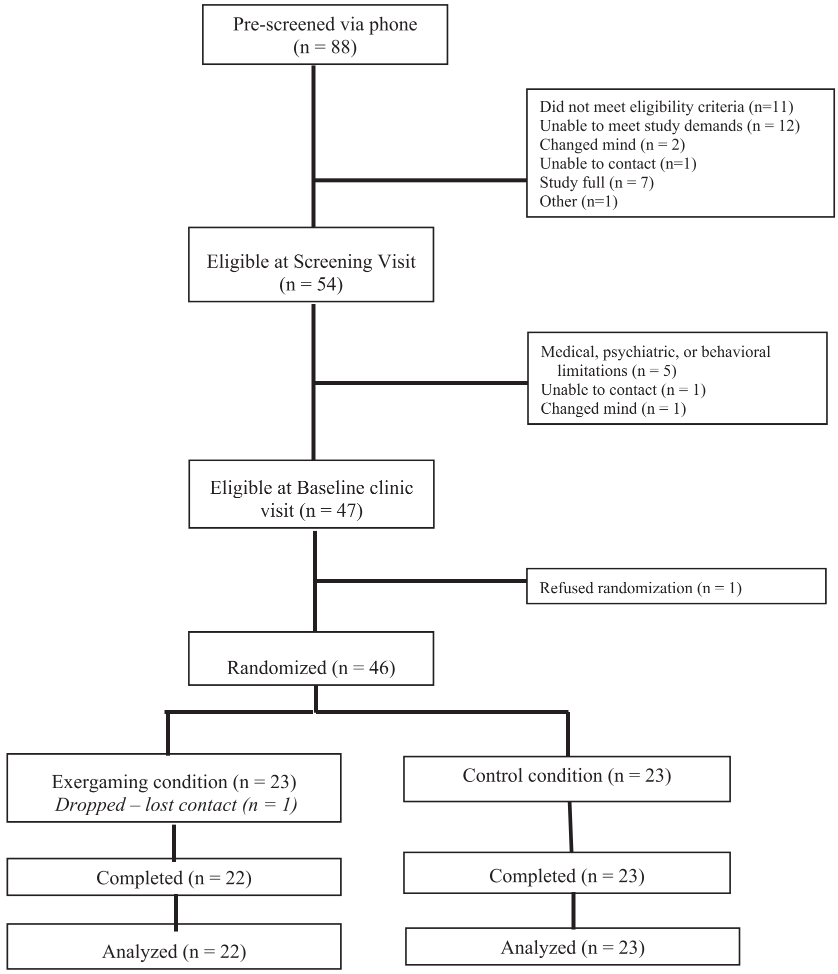

Figure 1 CONSORT participant flow for the GameSquad trial.

week with increasing intensity, difficulty and duration (10 min per session in week 1, increasing by 10 min each session and sustained at 60 min per session after week 6). In this booklet, children with parental assistance recorded exergame play start and stop time for each challenge, which was used to calculate compliance and adherence. The maximum duration of 60 min per exergaming session was selected to meet the physical activity guidelines ($\geq$1 h d^{-1} physical activity) (21) and to not exceed screen time guidelines ($\leq$2 h d^{-1} recreational screen time (22) with co-viewing/participation with a parent (23)).

The telehealth component consisted of each participant and a parent in the exergaming condition meeting with a fitness coach over video chat via the exergame console, on a weekly basis for the first 6 weeks and biweekly thereafter. Participants in the GameSquad intervention were provided a Fitbit Zip (Fitbit, San Francisco, California, USA) to wear during the 24-week period. Steps per day were wirelessly uploaded and reviewed by the fitness coach. The fitness coach followed a script for the virtual meetings that reviewed child's steps per day, recorded gameplay data from the child's booklet and helped the child and parent to create solutions to barriers for physical activity. The script focused on building the child's self-efficacy and social support for physical activity (e.g. 'I'm really proud of you'; 'Having friends and family can help you stay motivated. What buddies can be physically active with you?').

Participants assigned to the control condition were asked to maintain their normal level of physical activity for 24 weeks and were provided the Xbox console and exergames following their final clinic visit. All participants received \$25 at baseline and \$25 at follow-up to compensate for travel costs.

Measures

Screening

The screening visit included a physical examination by a physician or nurse practitioner including Tanner staging for sexual maturity, height and weight measurement, resting electrocardiogram and a brief readiness interview to confirm study eligibility. Parents provided child's birth certificate to confirm date of birth and reported child's biological sex, race and medical history including pre-existing medical conditions.

Anthropometry

Height and weight were measured on a wall-mounted stadiometer and digital scale, respectively, with the average of two measurements used in the analysis. BMI z-score, BMI percentile over 95th and weight-for-age z-score were calculated based on the child's age, sex, height and weight based on the 2000 CDC Growth Charts (24).

Adiposity

A dual energy X-ray absorptiometry (DXA) scan was completed with a GE iDXA whole-body scanner (GE Medical Systems, Milwaukee, WI, USA) to measure total fat mass and % fat mass. BMD (g cm^{-2}) was also calculated for the whole body and by region (trunk, spine and leg). The scans were analysed with Encore V.13.60.033. All female participants (n = 21) completed a urine pregnancy test prior to the DXA scan.

Cardiometabolic risk factors

Resting blood pressure (BP) was assessed using a standard sphygmomanometer after the participant rested for 5 min in a quiet room. The average of two systolic and diastolic measurements was used for analysis, and BP percentiles were calculated based on age, sex and height (25). A blood draw following an 8-h fast was performed by a trained phlebotomist following standard venipuncture standards. Samples were assessed for total cholesterol, triglycerides, glucose and high-density lipoprotein (HDL)-cholesterol. Low-density lipoprotein (LDL)-cholesterol was estimated using the Friedewald equation: LDL = total cholesterol − [{triglycerides/5} + HDL].

Physical activity

Physical activity was measured with an ActiGraph GT3X+ accelerometer on the right hip (ActiGraph of Ft. Walton Beach, FL, USA) for 7 d between the screening visit and the baseline clinic visit and for 7 d prior to the end-of-study clinic visit. Accelerometry data were included in the analysis if the participant had data for at least 10 h d^{-1} with at least 4 d week^{-1} including one weekend day. Sedentary, light, moderate and vigorous intensity physical activity were classified based on the criteria of Evenson *et al*. (26).

Dietary intake

Participants completed the National Cancer Institute's Self-administered 24-h Dietary Recall (ASA24-Kids) on a web-based program, with parental assistance as needed. Total caloric intake and intake of fat, carbohydrates and protein were examined. Dietary components were examined based on the American Heart Association ideal cardiovascular health metrics (20).

Psychosocial measures

Psychosocial measures were collected using REDCap, a HIPAA-compliant online data capture tool (27). Quality of life was used as a global measure of physical, psychological and social well-being and measured using the KIDSCREEN-10 index (28). Two instruments were selected to assess tenets of social cognitive theory: the 21-item Friendship Quality Questionnaire was used to measure children's peer support (29) and self-efficacy for physical activity was measured using the physical activity portion of the Self-Efficacy for Healthy Eating and Physical Activity measure (30).

Acceptability surveys

An acceptability survey adapted from a prior exergaming trial (31) was emailed to intervention parents for children to complete at weeks 4 and 12 and administered at week 24 clinic visit. Questions included injuries during game play and intervention enjoyment/acceptability.

Power calculation

An a priori power calculation was used to estimate the sample size needed to detect a significant difference by condition in BMI z-score using a mixed model controlling for significant covariates (e.g. sex and age). The recommendation was for −0.09 BMI z-score change relative to the control group based on prior exergaming (15) and exercise trials (4), requiring 23 participants per group allowing for up to 10 drop-outs (18).

Statistical analysis

Age was calculated based on date of birth and baseline clinic visit date. Mixed effects models were used to examine differences by condition in each outcome variable, controlling for baseline value, age and sex. One participant was designated as lost to follow-up after week 3 of the intervention; despite multiple contact attempts by phone, mail and e-mail, she did not return for follow-up assessment. A total of 45 participants completed the final study visit and were included in intent-to-treat analysis. One control participant decreased BMI z-score by 3.3 standard deviations below the mean change in the control group. Therefore, analyses were repeated excluding this outlier. For the physical activity models, 34 participants were included who had complete accelerometry data at both time points, and these models controlled for average daily wear-time. The α level (two-sided) was set at 0.05. Statistical analysis was conducted using SAS version 9.4 (SAS Institute, Inc.).

Results

Study enrolment and data collection occurred from October 2015 to September 2016. Participants were 11.2 ± 0.8 years of age, including 46% girls and 57% African–American, 41% White and 2% other. Tanner stage was 2.6 ± 1.2 (range: 1 to 5). See Table 1 for clinical characteristics of the sample. Parent-reported medical conditions in children included anaemia (n = 1), asthma (n = 6), type 2 diabetes (n = 1) and impaired hearing (n = 2). Based on the American Heart Association criteria (20), most children had ideal BP, fasting glucose and smoking status, whereas 20 had poor or intermediate cholesterol levels, 42 had intermediate physical activity levels (more than 0 but less than 60 min d^{-1}) and all children had poor or intermediate diet score.

Adherence to exergaming sessions (completed vs. expected minutes per week) was 94.4%, and compliance (completed vs. expected days per week) was 88.5%. At the readiness interview, 10 parents reported concerns that space at home was insufficient for exergame play; ultimately 19 children played the exergames in a living room, two in the child's bedroom and one in a family gaming room. Reported reasons for non-compliance included schoolwork, sports practice and being sick. Compliance to video chat sessions was 92.7%, and 9.8% of these sessions

Table 1 Baseline body composition and cardiometabolic risk factors overall and by intervention assignment

	Overall (n = 46)	Intervention (n = 23)	Control (n = 23)
Anthropometry			
BMI, z-score	2.08 (0.44)	2.06 (0.46)	2.10 (0.42)
BMI, % over 95th	120.6 (22.4)	120.8 (26.3)	120.5 (18.4)
Weight, z-score	2.29 (0.66)	2.28 (0.69)	2.29 (0.65)
DXA			
Fat mass, kg	29.8 (9.6)	30.4 (11.6)	29.3 (7.4)
Fat mass, %	43.1 (4.9)	42.0 (5.9)	44.1 (3.4)
BMD whole body, g m^{-2}	1.0 (0.1)	1.0 (0.1)	1.0 (0.2)
Trunk	0.9 (0.1)	0.9 (0.2)	0.8 (0.1)
Spine	0.9 (0.2)	0.9 (0.2)	0.9 (0.1)
Leg	1.1 (0.2)	1.1 (0.2)	1.0 (0.1)
CV risk factors			
SBP, %	40.0 (23.2)	36.4 (11.6)	43.7 (25.9)
DBP, %	60.9 (20.1)	58.5 (17.8)	63.3 (22.4)
Cholesterol, mg dL^{-1}	160.6 (37.2)	154.1 (36.8)	167.0 (37.3)
HDL-cholesterol, mg dL^{-1}	50.1 (9.1)	48.9 (9.1)	51.3 (9.2)
LDL-cholesterol, mg dL^{-1}	94.4 (30.5)	89.4 (31.2)	99.3 (29.6)
Triglycerides, mg dL^{-1}	80.7 (50.2)	79.1 (49.1)	82.3 (52.4)
Glucose, mg dL^{-1}	89.2 (5.3)	89.7 (4.8)	88.8 (5.8)
Physical activity	(n = 45)	(n = 23)	(n = 22)
MVPA, min d^{-1}	35.1 (17.8)	35.0 (17.8)	35.1 (18.3)
Dietary intake	(n = 42)	(n = 20)	(n = 22)
kcal d^{-1}	1801.8 (887.3)	1700.0 (905.4)	1894.4 (881.2)

Mean value (standard deviation). BMD, bone mineral density; BMI, body mass index; CV, cardiovascular; DBP, diastolic blood pressure; DXA, dual energy X-ray absorptiometry; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MVPA, moderate-to-vigorous physical activity; SBP, systolic blood pressure.

instead occurred over the phone due to faulty Internet connection. Telehealth sessions averaged 14.5 ± 5.2 min in length. Among those randomized to the intervention group, two children reported an injury during gameplay (bruise to the ankle or wrist).

Primary outcome

Compared with the control group, the intervention group significantly reduced BMI z-score when the outlier was excluded (intervention [standard error] vs. control [standard error]: −0.06 [0.03] vs. 0.03 [0.03], $p = 0.016$) and marginally reduced BMI z-score in intent-to-treat analysis (−0.06 [0.03] vs. 0.02 [0.03], $p = 0.065$).

Secondary outcomes

Compared with the control group, the intervention group improved systolic BP percentile (−5.0 [5.1] vs. 10.9 [5.0], $p = 0.036$), diastolic BP percentile (−7.4 [4.3] vs. 8.3 [4.2], $p = 0.017$), total cholesterol (−7.1 [3.5] vs. 6.7 [3.5] mg dL^{-1}, $p = 0.011$) and LDL-cholesterol (−4.9 [3.1] vs. 7.4 [3.1] mg dL^{-1}, $p = 0.010$). There was a significant reduction in weight z-score favouring the intervention group ($p = 0.049$). There was no intervention effect for change in fat mass, % fat mass, BMD, glucose or HDL-cholesterol. The intervention group gained half as much fat mass (0.8 ± 0.5 kg) compared with the control group (1.7 ± 0.5 kg). Findings were similar with the outlier excluded. See Table 2.

The intervention group engaged in significantly more minutes per day of MVPA (3.6 [3.4] vs. −7.8 [3.2], $p = 0.028$) compared with the control group at week 24. The change by condition in total caloric intake did not reach significance (−297 [215] vs. 279 [200] kcal d^{-1}, $p = 0.069$). Baseline self-reported energy intake (1894 ± 881 kcal d^{-1}) aligned with recommended dietary guidelines for this age group (32). The intervention group consumed significantly fewer carbohydrates (−44.6 [25.6] vs. 45.5 [23.7] g d^{-1}, $p = 0.017$). Findings were similar with the outlier excluded. The intervention group improved self-efficacy towards physical activity compared with the control group (−44.6 [25.6] vs. 45.5 [23.7], $p = 0.01$). There was no difference by condition in quality of life or peer support.

Intervention acceptability

Children reported playing exergames primarily with a parent ($n = 12$), alone ($n = 6$) or with siblings or someone else ($n = 4$). Children's favourite game was *Kinect Sports* ($n = 18$) followed by *Just Dance 3* ($n = 3$) and *Your Shape: Fitness Evolved 2012* ($n = 1$). The majority of children found the exergaming acceptable and enjoyable (see Table S1), and 19 children rated the physical intensity of playing the exergames as moderate to hard. Children reported wearing the Fitbit every day or just about every day ($n = 19$), a few times a week ($n = 2$) or every now and then ($n = 1$). Twenty children were moderately to extremely satisfied with the Fitbit, and two were slightly satisfied. Half of the children reported buying additional games during the intervention, but these games were primarily non-active games (10 of the 14 games purchased).

Discussion

This 24-week home-based exergaming intervention reduced BMI z-score and improved cardiometabolic health among children with overweight and obesity. These results expand upon a home-based exergaming trial that effectively reduced BMI z-score and body fat over a 6-month period (15). By contrast, three trials that provided children with exergames to play at home did not change children's adiposity or physical activity levels (11–13); one potential explanation for lack of effectiveness may be the rapid decline in children's exergame play after the first few weeks of intervention. The present GameSquad intervention retained excellent adherence for children's exergaming (94% over 24 weeks) by employing social support including regular video chats with a fitness coach and a gaming curriculum and step tracker to motivate children's physical activity.

The present study observed meaningful improvements in children's systolic and diastolic BP, total cholesterol and LDL-cholesterol. These results align with observations that 24 weeks of physical activity intervention can induce measurable changes in children's cardiometabolic health (5). These improvements in cardiometabolic risk factors were achieved with a BMI z-score difference of 0.08 units, which is similar in magnitude to a 24-week home-based exergaming intervention among 322 10- to 14-year-olds with overweight and obesity (15) and to a systematic review on lifestyle obesity treatments for children (4). There is no direct evidence on what BMI z-score change constitutes a clinically meaningful change, with an expert panel suggesting a reduction of −0.20 to 0.25 BMI z-score (33) and other studies indicating −0.15 BMI z-score reduction (34).

There were no significant treatment effects on DXA-measured body composition including fat mass, % fat mass or BMD, although the intervention group gained half as much fat mass compared with the control group. The lack of statistical significance may be

Table 2 Change in body composition and cardiometabolic risk factors from baseline to week 24 by intervention assignment

	Intent to treat (n = 45)			Without outlier (n = 44)		
	Intervention	Control		Intervention	Control	
	Adjusted mean difference	Adjusted mean difference	p value	Adjusted mean difference	Adjusted mean difference	p value
Anthropometry						
BMI, z-score	−0.06 (0.03)	0.02 (0.03)	0.065	−0.06 (0.03)	0.03 (0.03)	**0.016**
BMI, % over 95th	−2.2 (1.1)	0.6 (1.1)	0.098	−2.1 (1.1)	0.9 (1.1)	0.070
Weight, z-score	−0.10 (0.05)	0.04 (0.05)	**0.049**	−0.09 (0.05)	0.07 (0.04)	**0.022**
DXA						
Fat mass, kg	0.8 (0.5)	1.7 (0.5)		0.9 (0.5)	1.8 (0.5)	
Fat mass, %	−0.5 (0.4)	−0.3 (0.4)		−0.5 (0.4)	−0.3 (0.4)	
BMD whole body, g cm^{-2}	0.03 (0.01)	0.03 (0.01)		0.03 (0.01)	0.03 (0.01)	
Trunk, g cm^{-2}	0.03 (0.01)	0.03 (0.01)		0.03 (0.01)	0.04 (0.01)	
Spine, g cm^{-2}	0.04 (0.01)	0.04 (0.01)		0.04 (0.01)	0.04 (0.01)	
Leg, g cm^{-2}	0.04 (0.01)	0.03 (0.01)		0.04 (0.01)	0.03 (0.01)	
CV risk factors						
SBP, %	−5.0 (5.1)	10.9 (5.0)	**0.036**	−4.8 (5.1)	11.3 (5.1)	**0.033**
DBP, %	−7.4 (4.3)	8.3 (4.2)	**0.017**	−7.4 (4.4)	8.5 (4.4)	**0.018**
Cholesterol, mg dL^{-1}	−7.1 (3.5)	6.7 (3.5)	**0.011**	−6.8 (3.6)	7.1 (3.6)	**0.011**
HDL-cholesterol, mg dL^{-1}	−1.9 (1.4)	−0.7 (1.3)		−0.7 (1.4)	−1.9 (1.4)	
LDL-cholesterol, mg dL^{-1}	−4.9 (3.1)	7.4 (3.1)	**0.010**	−4.6 (3.1)	7.8 (3.1)	**0.010**
Triglycerides, mg dL^{-1}	−3.0 (6.9)	1.4 (6.7)		−2.9 (6.9)	1.0 (6.9)	
Glucose, mg dL^{-1}	0.5 (1.1)	0.4 (1.1)		0.5 (1.1)	0.5 (1.1)	
Physical activity						
MVPA, min d^{-1}	3.6 (3.4)	−7.8 (3.2)	**0.028**	3.4 (3.4)	−8.0 (3.3)	**0.023**
Dietary intake						
kcal d^{-1}	−297.2 (215.0)	269.5 (200.0)	0.069	−316.4 (211.3)	215.6 (200.4)	0.084

Adjusted estimates (standard error) from mixed effect models controlling for age, sex, baseline value and accelerometer wear-time (for physical activity only). The p values <0.20 are reported and p values <0.05 are indicated in bold text. BMD, bone mineral density; BMI, body mass index; CV, cardiovascular; DBP, diastolic blood pressure; DXA, dual energy X-ray absorptiometry; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MVPA, moderate-to-vigorous physical activity; SBP, systolic blood pressure.

because the study was powered to detect differences in BMI z-score but not these secondary outcomes. By contrast, a prior 12-week lab-based, supervised exergaming study (180 min $week^{-1}$ of exergaming) in 41 adolescent girls aged 14 to 18 years significantly reduced abdominal subcutaneous adipose tissue and increased BMD in the trunk and spine, compared with a self-directed care control condition (35). The present trial focused on children 10–12 years of age; as indicated in the present data and others (36), children (especially girls) accumulate fat mass during this peripubertal period as sexual maturation induces hormonal, biological and behavioural changes that contributes to fat accumulation (36). Therefore, a focus on attenuating fat gain (rather than fat loss *per se*) may be a reasonable approach in the peripubertal age range. While the intervention did not change bone density, the potential detrimental relationship of fat mass on bone development in children warrants further attention as evidence indicates that adults with higher fat mass have lower BMD (37).

The children's baseline MVPA (35 ± 18 min d^{-1}) did not meet physical activity guidelines (60 min d^{-1}) (21) and was lower than accelerometry data from a nationally representative sample of children ages 6–11 years (95 min MVPA a day) and 12–15 years (45 min MVPA a day) (6). Intervention participants' overall MVPA increased by 11 min d^{-1} over the control group between baseline and week 24, and children remained engaged with the intervention across the 24-week period. A change of 11 min d^{-1} of MVPA after 6 months of intervention is important given that the ages of 10 to 12 years are typically characterized by a rapid decline in MVPA (6). This magnitude of change aligns with a prior trial of exergaming in a physical education classroom that increased children's MVPA by 9 min per session compared with standard physical education (38), although the trial was small (n = 4). One study of 60 children observed 6 min d^{-1} increase in vigorous physical activity and no difference in MVPA following 10 weeks of home-based exergaming, although this change did not significantly differ from the wait list control group (12). By contrast, other studies observed no change in daily MVPA after 3 (39) to 6 months (11,15) of in-home exergaming, although exergaming use dramatically declined in the first few weeks in trials that did not provide additional support for MVPA (11,39).

Self-efficacy towards physical activity significantly improved during the intervention, aligning with prior exergaming trials that improved youths' self-efficacy (40). Dietary intake also changed, with the intervention consuming marginally fewer calories and fewer carbohydrates compared with the control group. This finding aligns with a 24-week exergaming intervention in which the intervention group reduced self-reported daily energy intake from snack food compared with a passive video game control group, although the change was not statistically significant (15). The findings also align with a systematic review indicating that adolescents with obesity reduced, or did not change, energy intake following acute bouts of exercise (41).

Two adverse events (bruising) were reported in the GameSquad trial, which is similar to prior exergaming studies reporting minor bruises, hand lacerations and back pain (42,43). Prolonged or overly aggressive play has produced injuries in prior exergaming case studies (8). However, a study comparing injury rates during running vs. exergaming observed 2.44 injuries per 100 h of running vs. no injuries during 201 h of exergaming (44). No exergaming-related serious adverse events have been reported in systematic reviews (43,45). Future trials should report on adverse events to inform recommendations for exergame play (8), including proper endurance and strength training (46).

A unique aspect of the GameSquad intervention was the inclusion of fitness coaches, who provided telehealth counselling complemented with real-time monitoring of steps per day using a commercially available step tracker. While the fitness coaches were research staff members with bachelor degrees in kinesiology, the coaching role could be fulfilled by a variety of para-professionals or lay health providers. In other words, this home-based intervention could be deployed by a variety of entities if adequate social support and structure are provided to the children and families. A key driver of intervention success is the child's active engagement within the behaviour change intervention (47). Telehealth directly involves the child in communicating, monitoring and counselling on exercise. As exercise counselling becomes integrated into primary care delivery, telehealth should be further explored to deliver tailored exercise counselling and support to children with obesity.

Limitations

While there was sufficient power to detect a difference in the primary outcome, the study would have benefited from a larger sample size to reduce variability. Video chat compliance was objectively captured by the fitness coach, but gaming adherence and compliance were reliant on the child and parental report at each gaming session. Coach monitoring at each video chat may have reduced memory recall bias, but social desirability bias is possible. It is not possible to isolate specific intervention components (e.g. time spent in MVPA during exergaming vs. other activities, the role of coach and parental support) that contributed to the difference in BMI z-score and cardiometabolic health. Therefore, future research should examine these influences to identify the most effective strategies to achieve clinically meaningful improvements in children's adiposity and cardiometabolic health. Finally, future trials should conduct follow-up assessments to test for the sustainability of exergame play following the end of the intervention as well as potential sustained effects on children's cardiometabolic health and health behaviours.

Conclusion

Interactive gaming coupled with telehealth fitness counselling was an acceptable, effective tool to foster physical activity in children with obesity who are in need of sustainable physical activity options.

Conflict of interest statement

The authors have indicated that they have no potential conflicts of interest to disclose. A. E. S. wrote the first draft of the manuscript. There was no honorarium, grant or other form of payment to anyone to produce the manuscript.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Children's Acceptability of the GameSquad Intervention.