

Effects of active video games on body composition: a randomized controlled trial^{1–5}

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ABSTRACT

Background: Sedentary activities such as video gaming are independently associated with obesity. Active video games, in which players physically interact with images on screen, may help increase physical activity and improve body composition.

Objective: The aim of this study was to evaluate the effect of active video games over a 6-mo period on weight, body composition, physical activity, and physical fitness.

Design: We conducted a 2-arm, parallel, randomized controlled trial in Auckland, New Zealand. A total of 322 overweight and obese children aged 10–14 y, who were current users of sedentary video games, were randomly assigned at a 1:1 ratio to receive either an active video game upgrade package (intervention, $n = 160$) or to have no change (control group, $n = 162$). The primary outcome was the change from baseline in body mass index (BMI; in kg/m^2). Secondary outcomes were changes in percentage body fat, physical activity, cardiorespiratory fitness, video game play, and food snacking.

Results: At 24 wk, the treatment effect on BMI (-0.24 ; 95% CI: -0.44 , -0.05 ; $P = 0.02$) favored the intervention group. The change (\pm SE) in BMI from baseline increased in the control group (0.34 ± 0.08) but remained the same in the intervention group (0.09 ± 0.08). There was also evidence of a reduction in body fat in the intervention group (-0.83% ; 95% CI: -1.54% , -0.12% ; $P = 0.02$). The change in daily time spent playing active video games at 24 wk increased (10.03 min; 95% CI: 6.26 , 13.81 min; $P < 0.0001$) with the intervention accompanied by a reduction in the change in daily time spent playing nonactive video games (-9.39 min; 95% CI: -19.38 , 0.59 min; $P = 0.06$).

Conclusion: An active video game intervention has a small but definite effect on BMI and body composition in overweight and obese children. This trial was registered in the Australian New Zealand Clinical Trials Registry at <http://www.anzctr.org.au/> as ACTRN12607000632493. *Am J Clin Nutr* 2011;94:156–63.

INTRODUCTION

Childhood obesity is linked to a myriad of negative health effects including an increased incidence of type 2 diabetes and heightened risk of cardiovascular disease (1–3). Childhood obesity has reached epidemic proportions in developed countries. In New Zealand, one-third of children are currently overweight or obese (4), which mirrors rates seen in Western countries (5). Decreases in physical activity and the increased consumption of energy-dense foods are thought to contribute to these high levels of obesity (6).

The increased time spent in sedentary screen-based activities, such as watching television, playing video games, and using computers, has also been implicated as contributing to high rates of overweight and obesity (7). Screen time accounts for the largest proportion of children's sedentary time (8). Screen activities are thought to encourage sedentary lifestyles in young people and draw them away from health-promoting activities (9). An inverse and small relation between using video games (10), watching television (11), and daily physical activity has been reported. Screen-based activities are also noted to increase the exposure to food advertising and increase the consumption of energy-dense snack foods (12). A reduction of sedentary behavior is undoubtedly an important approach for improving body composition in children and young people (13); however, most studies have tried to reduce television or computer use through education or restriction approaches (14, 15). Because of the pervasiveness of screen-based technologies and the fact that children value these activities (16), population health researchers need to consider alternative and novel interventions that treat technology as part of the solution rather than as the problem (17).

One such approach is the promotion of active video games, which are electronic games that allow players to physically in-

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teract (by using arm, leg, or whole-body movements) with images on screen in a variety of activities such as sports (eg, football, boxing, and martial arts) and other activities (eg, dancing and washing windows). Active video game play is intermittent in nature, and playing these games over short periods of time results in light- to moderate-intensity physical activity (9, 18). Preliminary data from 3 small trials have examined the effect of active games on physical activity levels with mixed results. Two of the 3 trials showed some modest improvement in physical activity; however, these studies were all of short duration (19). Thus, the sustained effects on physical activity and other health outcomes such as weight have yet to be determined. The objective of this trial was to evaluate the effect of active video games over a 6 mo period on weight, body composition, physical activity, and physical fitness.

SUBJECTS AND METHODS

Design

A standard, 2-arm, parallel, randomized controlled trial was conducted. Full details of the study protocol have been published elsewhere (20). A brief description of study procedures is provided.

Participants

Ethical approval was granted from the regional ethics committee (NTY/07/09/099). Participants were recruited through schools and various community locations in Auckland, New Zealand, between February 2008 and June 2009. Consenting schools, churches, community groups, after-school, and school-holiday programs allowed the researchers to give a verbal presentation outlining the aims of the study. Interested children provided their contact details to study staff. Eligibility criteria were assessed via the telephone with a parent of the participant parent before a baseline assessment. If eligible, children were posted participant information and informed-consent documentation and booked to attend a baseline assessment at a recreation facility close to their places of residence.

Trial eligibility criteria were as follows: aged 10–14 y, overweight or obese (according to the International Obesity Task Force international cutoffs for child obesity) (21), owned a PlayStation2 or 3 gaming console (Sony Computer Entertainment Inc, Tokyo, Japan) but no active video games, including the EyeToy (Sony) or Nintendo Wii (Nintendo Co, Ltd, Kyoto, Japan), and played ≥ 2 h of video games/wk. Participants were excluded if they had contraindications to performing physical activity (such as a medical condition). One child per household was eligible to take part in the study.

Randomization

Eligible children were randomly assigned at a 1:1 ratio by a computerized central system to either receive the trial intervention or have no change (the control). Stratified blocked randomization with variable block sizes (ie, a multiple of 2 arms) was used to maintain a balance across important prognostic factors. The following 2 stratification factors were considered: sex and ethnicity. Because of the nature of intervention, it was not possible to blind participants, but allocation concealment up to the point of randomization was maintained. YJ generated the random-allocation sequence, and LF was responsible for enrolling participants and assigning them to groups.

Intervention

Subjects randomly assigned to the intervention received an upgrade (hardware and games) of existing gaming technology that enabled them to play active video games at home. The Sony PlayStation EyeToy (Sony) was used, which employs a USB motion-capture camera to place a picture of the gamer on screen, which the gamer then interacts with. The upgrade consisted of an EyeToy camera, dance mat, and a selection of active video games (eg, Play3, Kinetic, Sport, and Dance Factory; Sony). Games were selected on the basis of being current releases and offering a variety of activity options. The upgrade package was delivered to participants 1 wk after the baseline assessment. Children were encouraged to meet current physical activity recommendations (60 min of moderate-to-vigorous physical activity on most days of the week) (22) by 1) supplementing periods of inactivity with active video game play and 2) substituting periods of traditional nonactive video game play with the active version. To ensure the sustainability of the intervention, children were sent a package of new active video games at 12 wk. In total, children received 5 different active video games throughout the duration of the intervention.

Control

The control group continued with their normal video game play. Upon completion of the study, participants in the control group received the active video games upgrade package at no cost. The control group did not receive any information about increasing physical activity, healthy eating, or weight loss.

Procedure

Assessments were conducted at baseline and 12- and 24-wk by trained researchers who followed standard quality-controlled procedures. For logistical reasons, participants attended a central location for assessment but were assessed individually. At each time point, participants had their height, weight and waist circumference measured, underwent bioelectrical impedance analysis, and completed a field test of physical fitness (20-m shuttle test) (23). The test duration and timing were comparable for both groups. Participants were given an Actigraph accelerometer (model AM7164-2.2C; Pensacola, FL) to wear for the following 7 d to provide an objective assessment of their free-living physical activity. Each participant was assigned the same device throughout the study. During the same period, each participant completed a diary in which they detailed their accelerometer wear, self-reported video game (active and nonactive) use, and frequency and quantity of consumption of prespecified snack foods (24). Study staff collected the accelerometers and completed diaries from the homes of participants. A serious adverse event was defined as any event that required hospitalization and was determined at 12 and 24 wk.

Outcomes

The primary outcome was the change in body mass index [BMI; in kg/m^2 and z score (z BMI)] from baseline to 24 wk. Anthropometric data were measured by using standard practices (25). Body weight (in kg) was measured with Salter scales to one decimal point. Height was measured to the nearest 0.1 cm with a stadiometer. Two measurements were taken for height and weight. A third measure was taken if the second measure was not ≤ 1 cm for height or ≤ 0.1 kg for weight of the first measurement. The mean of



2 measurements or the median of 3 measurements were used for analysis. z BMI was derived separately at each time point by using data from the 2002 New Zealand National Children's Nutrition Survey (4) before calculating the change in z BMI. Secondary outcomes were assessed as the change from baseline to 12 and 24 wk and included percentage body fat, waist circumference (cm), physical fitness measured as the maximal oxygen uptake [$\dot{V}O_{2\max}$ ($\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)], average daily time (min) spent in light-to-vigorous activities, average daily time (min) spent in active and nonactive video games, and average daily total energy (kJ) consumed from snacks.

Waist circumference was measured twice (as for height and weight) to the nearest 0.1 cm with a standard anthropometric tape at the maximal circumference. Body fat was assessed by using standardized analysis procedures of bioelectrical impedance (26) with the ImpediMed DF50 Bioimpedance Monitor (ImpediMed, Queensland, Australia). Children were euhydrated and required to void their bladder before measurement. The equation of Rush et al (27) was used to calculate fat mass, fat-free mass, and percentage body fat for all participants.

Cardiovascular fitness was assessed by using the 20-m shuttle test (23), which is a standardized field assessment of cardiovascular fitness in children that requires participants to run continuously between 2 lines, which are 20 m apart, in time to recorded beeps. The output can be used to determine $\dot{V}O_{2\max}$ in this age group (28).

Participants were instructed to wear the accelerometer on their right hip during waking hours for 7 d after each assessment. Exceptions to this were any activities that involving water (eg, water sports and showering). A 10-s epoch period was used, and data were converted to 1-min intervals for analysis. Published criteria for handling accelerometer data were used (29); thus, valid accelerometer data had to include ≥ 600 valid minutes and ≥ 4 valid days (including one weekend day) available for analysis (30). A data-reduction program developed by the research team was used. There is currently no consensus for the treatment of accelerometer data. In the current study, accelerometer data were converted into daily time spent in light [1.5–2.9 metabolic equivalent tasks (METs)], moderate (3–5.9 METs), and vigorous (≥ 6 METs) physical activity by using the Freedson equation (31).

During the 7 d after each assessment, participants provided self-reports of their daily time spent playing all video games by using a diary developed and tested in a previous pilot study (24). Participants were required to indicate the day and duration of playing both active video games (all brands) and traditional nonactive video games.

Participants completed a snack food diary to self-report the frequency and quantity of snack foods consumed for 7 consecutive days, which were defined as "something you eat between your main meals (breakfast, lunch, and dinner)". The diary consisted of pictures of 29 common categories of snack foods and drinks (eg, pizza, fruit, muesli bars, milk, and water). For each food or drink, 3 pictures were presented that showed different snack serving sizes. Participants indicated the number of servings of the respective food and serving size they had consumed on each day. If a participant snacked on a food that was not listed in the snack food diary, they chose the closest food they could find from the options available and reported the quantity and serving size eaten. Each serving size was assigned a caloric value (kJ). The caloric value of all reported snacks was summed and divided by 7 d to give the average daily total energy consumed from snacks (kJ). The diary was developed and tested in a previous pilot study (24).

Sample-size calculation

A target sample size of 330 participants (165 subjects per group) was estimated to provide $\geq 90\%$ power at a 5% level of significance (2-sided) to detect a 0.8 difference in the change in BMI from baseline to the end of intervention period between the 2 groups, with assumption of an SD of 2.0 and allowance for a 20% loss to follow up. The estimated difference in BMI assumed a difference in weight between groups at the end of intervention of ≈ 2 kg given an estimated average height of 1.58 m. This sample size also provided $\geq 90\%$ power to detect an estimated 3–5 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ difference in peak $\dot{V}O_{2\max}$ with assumption of an SD of 7 $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.

Statistical analyses

All statistical analyses were performed with SAS version 9.1.3 (SAS Institute Inc, Cary, NC) and R (The R Foundation for Statistical Computing, Vienna, Austria version 2.10.0) (32) software. Statistical tests were 2-tailed, and a 5% significance level was maintained throughout the analyses. Treatment evaluations were performed on the principle of intention to treat for the primary outcome and by using the approach of the last observation carried forward when data were missing. A modified intention-to-treat analysis approach was used for all secondary outcomes by including all randomly assigned participants who provided at least one valid postbaseline measure, with the assumption that data were missing at random. The change in BMI (in kg/m^2 and z BMI) from baseline was assessed at 12- and 24-wk by using mixed-model repeated-measures analysis, with adjustment for baseline outcome measures on age, sex, and ethnicity. The intervention effect was evaluated over the whole 24-wk period if there was no significant interaction between the treatment and visit. If applicable, this approach could have potentially increased the efficiency of analysis with repeated measures. Similar regression analyses were carried out for all secondary outcomes. Preplanned estimates of heterogeneity were conducted for BMI and z BMI according to ethnic group (Māori, Pacific, and New Zealand European or other) by using the same repeated-measures analysis.

A sensitivity analysis was conducted on the primary outcome by using the modified intention-to-treat approach to assess the robustness of trial effects.

RESULTS

Three hundred twenty-seven children were registered as meeting the initial inclusion screening criteria. Five potential participants were excluded before the random assignment because of not meeting the eligibility criteria (**Figure 1**). Both groups were similar at baseline (**Table 1**). The mean (\pm SD) age of all participants was 11.6 ± 1.1 y and 87 subjects (27%) were girls. The majority of participants (57%) were classified as New Zealand European or other, whereas 26% of participants were Pacific, and 17% of participants were Māori.

Primary outcome

A statistically significant treatment effect was shown for the change from baseline in BMI (-0.24 ; 95% CI: $-0.44, -0.05$; $P = 0.02$) and z BMI (-0.06 ; 95% CI: $-0.12, 0.00$; $P = 0.04$) at the end of the 24-wk intervention period. The findings favored the



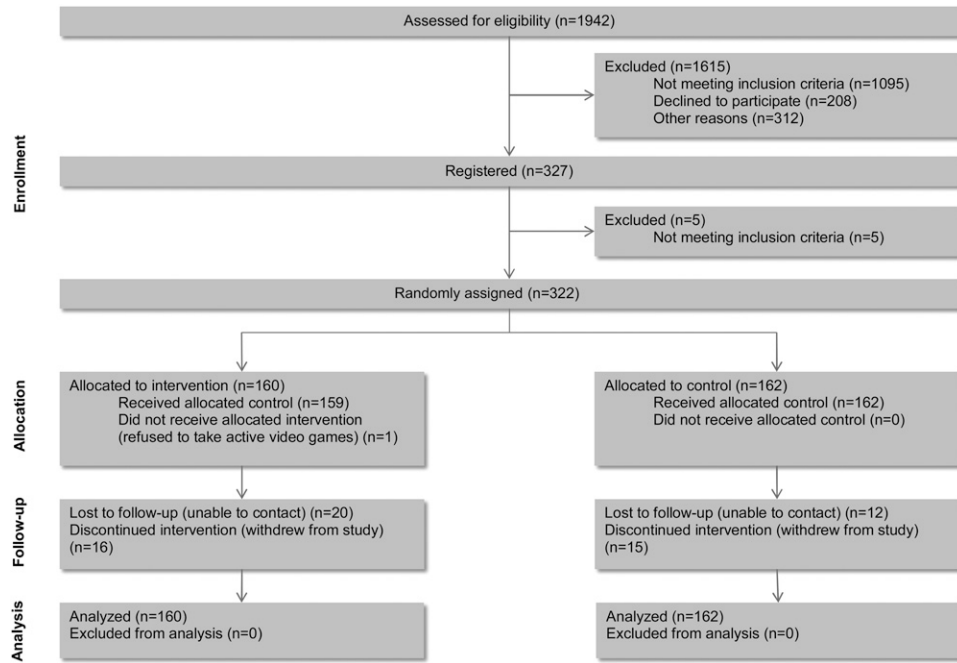


FIGURE 1. Flow of participants through the study.

intervention group (Table 2). There was no statistical evidence that ethnicity modified treatment effects on BMI (Figure 2A) or zBMI (Figure 2B).

The sensitivity analysis conducted on the primary outcome showed a consistent intervention effect for the change in BMI and zBMI at 24 wk with a difference of -0.33 (95% CI: $-0.57, -0.08$;

TABLE 1
Baseline and follow-up characteristics of all study participants¹

Characteristic	Baseline (n = 322)		12 wk (n = 245)		24 wk (n = 231)	
	Intervention	Control	Intervention	Control	Intervention	Control
Age (y)	11.6 ± 1.1 ²	11.6 ± 1.1	—	—	—	—
Sex (n [%])						
Girls	44 (27.5)	43 (26.5)	—	—	—	—
Boys	116 (72.5)	119 (73.5)	—	—	—	—
Ethnicity (n [%])						
Māori	27 (16.9)	28 (17.3)	—	—	—	—
Pacific	41 (25.6)	43 (26.5)	—	—	—	—
NZ Euro/other	92 (57.5)	91 (56.2)	—	—	—	—
Height (m)	1.6 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	1.6 ± 0.1
Weight (kg)	63.0 ± 13.6	63.3 ± 15.2	62.45 ± 13.5	63.4 ± 15.0	63.0 ± 12.3	64.8 ± 14.4
BMI (kg/m ²)	25.6 ± 4.1	25.8 ± 4.3	24.9 ± 4.0	25.5 ± 4.3	24.8 ± 3.6	25.8 ± 4.2
zBMI	1.3 ± 1.1	1.3 ± 1.1	1.1 ± 1.2	1.3 ± 1.1	1.1 ± 1.1	1.3 ± 1.0
Waist circumference (cm)	87.3 ± 10.5	88.0 ± 10.8	85.6 ± 10.6	86.9 ± 11.7	84.4 ± 10.8	88.0 ± 10.7
Percentage body fat	32.1 ± 6.5	32.5 ± 6.4	30.8 ± 6.9	32.7 ± 6.4	29.8 ± 7.2	31.1 ± 6.3
Body fat (kg)	20.5 ± 7.2	20.8 ± 7.6	19.7 ± 7.5	21.2 ± 8.1	19.0 ± 7.1	20.3 ± 7.0
Fat-free mass (kg)	42.2 ± 8.1	42.4 ± 9.5	42.6 ± 7.8	42.3 ± 8.5	43.5 ± 7.6	44.1 ± 8.9
$\dot{V}O_2$ max (mL · kg ⁻¹ · min ⁻¹)	27.0 ± 4.8	27.2 ± 5.2	28.2 ± 5.3	27.9 ± 5.5	28.9 ± 5.7	27.8 ± 5.3
Average daily time spent in MVPA (min)	91.0 ± 38.4	91.0 ± 37.0	85.8 ± 38.4	86.3 ± 41.0	84.4 ± 36.3	83.3 ± 36.3
Average daily time spent in LPA (min)	676.3 ± 117.8	672.4 ± 116.6	660.8 ± 114.4	687.3 ± 102.4	680.5 ± 105.1	689.7 ± 93.0
Average daily activity counts per minute (counts/min)	461.3 ± 150.6	466.6 ± 147.5	449.7 ± 141.9	438.5 ± 154.4	437.5 ± 128.8	433.9 ± 141.6
Average daily time of active video game play (min)	8.5 ± 24.0	7.8 ± 40.0	15.5 ± 26.3	2.9 ± 15.2	10.2 ± 23.9	2.6 ± 16.0
Average daily time of nonactive video game play (min)	63.6 ± 86.5	62.2 ± 65.6	34.1 ± 55.0	47.8 ± 76.5	29.0 ± 47.2	36.2 ± 52.1
Average daily total energy consumed from snacks (kJ)	4372.2 ± 3524	4454.3 ± 2993	2969.4 ± 3361	3176.3 ± 2934	2373.1 ± 2862	2963.2 ± 3067

¹ NZ Euro, New Zealand European; $\dot{V}O_2$ max, maximal oxygen uptake; MVPA, moderate-to-vigorous physical activity; LPA, light physical activity; zBMI, BMI z score. All values are based on observed data.

² Mean ± SD (all such values).

TABLE 2Estimates of intervention effect on changes in body composition, cardiovascular fitness, physical activity, video game use, and snacking behavior at 24 wk¹

Change from baseline outcome	Intervention	Control	Difference	Lower 95% CI	Upper 95% CI	P
BMI (kg/m ²)	0.09	0.34	-0.24	-0.44	-0.04	0.02
zBMI	0.01	0.07	-0.06	-0.12	-0.03	0.03
Weight (kg)	2.03	2.75	-0.72	-1.33	-0.10	0.02
Waist circumference (cm)	-0.35	0.86	-1.21	-2.45	0.03	0.22
Percentage body fat	-0.99	-0.16	-0.83	-1.54	-0.12	0.02
Fat mass (kg)	0.11	0.91	-0.80	-1.36	-0.24	0.005
$\dot{V}O_2$ max (mL · kg ⁻¹ · min ⁻¹)	1.42	0.84	0.58	-0.34	1.49	0.60
Average daily time spent in MVPA (min)	-4.77	-6.42	1.65	-5.77	9.07	0.66
Average daily time of active video game play (min)	5.78	-4.25	10.03	6.26	13.81	<0.0001
Average daily time of nonactive video game play (min)	-37.44	-28.05	-9.39	-19.38	0.59	0.07
Average daily total energy consumed from snacks (kJ)	-1798	-1411	-390	-937	163	0.17

¹ $\dot{V}O_2$ max, maximal oxygen uptake; MVPA, moderate-to-vigorous physical activity; zBMI, BMI z score. The model was adjusted for the baseline outcome measure, age, sex, and preferred ethnicity. Differences were changes from baseline with intervention compared with changes from baseline without intervention and were calculated by repeated-measures mixed-model regression analysis.

$P = 0.009$) and -0.08 (95% CI: $-0.15, -0.01$; $P = 0.02$), respectively, between the 2 groups.

Secondary outcomes

There was a significant treatment effect for the change from baseline in percentage body fat (-0.83% ; 95% CI: $-1.54\%, -0.12\%$; $P = 0.02$) and body fat (-0.80 kg; 95% CI: $-1.36, -0.24$ kg; $P = 0.005$) favoring the intervention group. The difference in the change in waist circumference at 24 wk was -1.21 cm (95% CI: $-2.45, 0.03$ cm; $P = 0.2$) between the 2 groups.

The change in the average daily time spent playing active video games increased by 10 min (95% CI: 6.26, 13.81 min; $P < 0.0001$) at the end of the intervention compared with in the control group. The change in the average daily time spent in nonactive video games was decreased at 24 wk in favor of the intervention group but was not significant (-9.39 min; 95% CI: $-19.38, 0.59$ min; $P = 0.06$).

For accelerometry data, no differences existed between groups for the number of valid weekend days of recording at each time

point. Compliance with wearing the device reduced over time, with 92%, 66%, and 58% of participants providing valid data for analysis at the respective time points. No significant treatment effect was shown for the change in average daily time spent in moderate-to-vigorous physical activity measured by an accelerometer (1.65 min; 95% CI $-5.77, 9.07$ min) or for physical fitness (0.58 mL · kg⁻¹ · min⁻¹; 95% CI: $-0.34, 1.49$ mL · kg⁻¹ · min⁻¹) at 24 wk. The average self-reported daily total energy consumed from snack food decreased (-387 kJ; 95% CI: $-937, 163$ kJ; $P = 0.17$) in favor of the intervention group, but the result was not significant.

A total of 8 serious adverse events were reported in 6 participants [hospitalization because of seasonal influenza (3 events), hip surgery related to a chronic condition, a blood clot, observation after a fall, diagnosis with type 1 diabetes, and an ankle injury]. Two participants in the intervention group and 4 participants in the control group experienced a serious adverse event. None of the serious adverse events were deemed related to the study intervention, and participants with a serious adverse event were included in analyses.

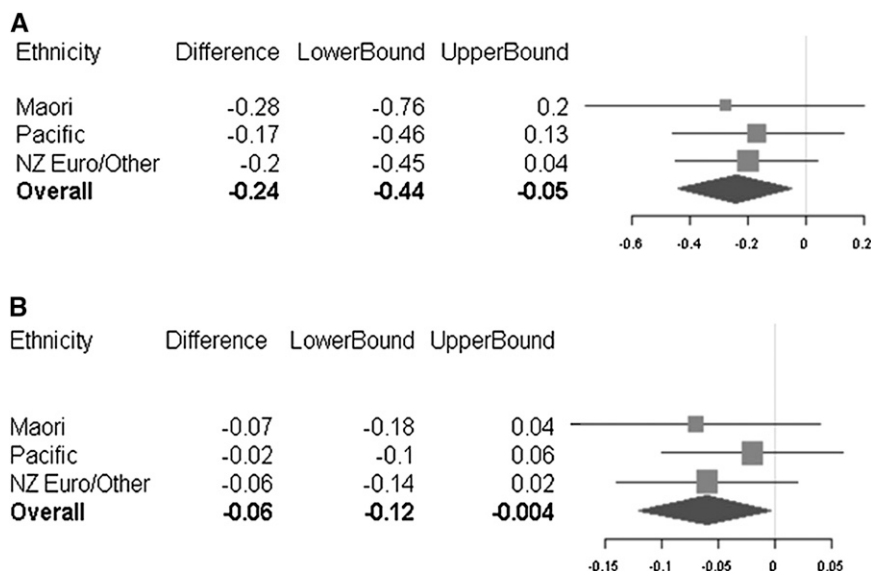


FIGURE 2. A: Forest plot for the change in BMI by ethnic subgroup [Māori, $n = 55$; Pacific, $n = 84$; and New Zealand European or other (NZ Euro/Other), $n = 183$]. B: Forest plot for change in BMI z score by ethnic subgroup (Māori, $n = 55$; Pacific, $n = 84$; and NZ Euro/Other, $n = 183$).

Associations between physical activity and body composition

A series of paired correlations were conducted between body-composition variables and physical activity (moderate-to-vigorous physical activity) as well as physical fitness. BMI was inversely associated with the time spent in moderate-to-vigorous physical activity at baseline (-0.18 ; $P < 0.01$) and 24 wk (-0.18 ; $P = 0.02$) only. BMI and physical fitness were inversely associated at all 3 time points with correlations ranging from -0.36 ($P < 0.01$) at baseline to -0.46 ($P < 0.01$) at 12 and 24 wk. Fat mass was inversely associated with the time spent in moderate-to-vigorous physical activity at all 3 time points with correlations ranging from -0.34 ($P < 0.001$) at baseline to -0.15 ($P < 0.05$) and -0.28 ($P < 0.001$) at 12 and 24 wk, respectively. Fat mass was also inversely associated with physical fitness at all 3 time points [-0.37 ($P < 0.001$) at baseline; -0.44 ($P < 0.001$) at 12 wk, and -0.46 ($P < 0.001$) at 24 wk].

DISCUSSION

This home-based active video game intervention resulted in a small (≈ 0.24) but definite difference in BMI over 6 mo compared with usual care. There was also a small difference in fat percentage. Although the effect on BMI was small, it was consistent with slowing weight gain so that children grow into their height, the management approach recommended in clinical guidelines (33). As such, the intervention may be a useful addition to the armamentarium of strategies, although it is unlikely to be clinically useful if used in isolation. There was no difference between groups in the change of physical activity measured by the accelerometer. Both groups showed a similar small decrease in overall levels of physical activity from baseline to 12 and 24 wk. Moreover, there was no difference between groups in measured physical fitness. The intervention did have an effect on the targeted sedentary behavior, with the intervention group playing less non-active (approximately -9 min/d) and more active video games per day (approximately $+10$ min/d) than did the control group.

The effects of the intervention on BMI in the study were at the lower end of those reported in a previous review (13) of studies that focused on reducing sedentary behavior in children, which reported mean differences in the absolute change in BMI from -0.21 to -1.11 from different interventions. However, 9 of 12 interventions included in the review were multifactorial, labor, and resource intensive. The intervention evaluated in the current study was a single-component intervention, which was simple to implement and relatively inexpensive (the cost of active video games is comparable with traditional video games), and parents may have greater success promoting the use of these games rather than gaming abstinence. Greater effects are likely to be achieved in the future with multicomponent interventions aimed at reducing all leisure-based screen time, including video games, television watching, and computer use.

BMI is a heuristic measure of body weight on the basis of the weight and height of a person. In adolescence, BMI increases as height and weight increases. In the current study, children in both groups were, on average, the same height with minimal difference over the study period; however, the difference in weight favored the intervention group with ≈ 1 kg less weight gain compared with that in the control group.

Findings (19) from previous small pilot studies that examined the effect of active video games on physical activity levels in the short term (≤ 12 wk) have been mixed. Two of 3 trials reported modest improvements in physical activity, whereas one showed no effect. Our data were consistent with the latter study. There are several possible explanations for this lack of effect. First, despite being overweight or obese, children in the current study were quite active at baseline and exceeded the guidelines for physical activity in this population (22), which may have created a high ceiling effect.

Second, our findings were more consistent with a previous study aimed at reducing television watching and computer use (34), which showed no significant between-group changes over time in physical activity. Evidence from a meta-analysis (35) of interventions aimed at reducing pediatric obesity suggested a small increase in physical activity (effect size: 0.12; 95% CI: 0.04, 0.20) and a small reduction in sedentary behavior (effect size: -0.29 ; 95% CI: -0.35 , -0.22); however many of the interventions incorporated multiple components (cognitive behavior and lifestyle change) rather than the single-intervention approach used in the current study.

Third, measurement issues need to be considered. The accelerometer was placed on the child's hip and, therefore, may not have captured the full range of movement exhibited when playing active video games, such as upper body movement (18). Physical activity can be viewed as a latent time series of activity type and intensity, which varies greatly over short periods of time and from which researchers sample and summarize (36). Therefore, it is possible that sampling 3 discrete periods of activity was insufficient to capture the intervention's overall effect on physical activity. More frequent and continuous measurements of physical activity may best address this issue. Finally, there is no consensus on management of accelerometer data. Although we used the Freedson equation (31) to convert activity counts into time spent in light, moderate, and vigorous activity, we also explored the effect of the intervention on raw accelerometer data (average daily activity counts) and showed no difference in the change between groups from baseline.

Children in the intervention group played more active video games and fewer nonactive video games. This change in non-active video game play, which may have had an effect on energy intake by minimizing cues to eat snack foods, was reflected in the self-reported reductions in snack food data. Because of small difference in fat loss between the groups and the measurement error associated with both behaviors, we could not be certain which accounted for the effects; however, it is possible that changes in diet or physical activity could explain the change.

A strength of this trial was that, to our knowledge, it was the largest of its kind to show an effect of an active video game intervention on BMI in children. The original sample-size calculation was based on an estimated difference in BMI of 0.8. Although the observed effect was smaller, there was sufficient power to detect the observed change because the SD was less than estimated, and the repeated-measures analysis increased the efficiency. Other strengths of this trial included the randomized study design, real-life setting, comparatively long follow-up, and the objective measurement of physical activity. A number of limitations should also be borne in mind. First, the assessments were not blinded, although height, weight, and physical activity were measured objectively. Second, the snack food and video game diaries were developed and piloted (24) for this study (because there was no existing measure to assess the time spent in nonactive



and active video game play); the diaries have not been validated against other measures. Third, the results for percentage body fat were based on bioelectrical impedance analysis, which was below optimal accuracy thresholds for this approach; however, this would not have led to the overestimation of treatment effects. Fourth, because some children were recruited through schools, there may have been a potential for contamination; however, this was unlikely because of the delivery of intervention in the homes of participant, the positive effect of the intervention on BMI compared with that of the control, and the significant differences observed in active video game play between groups.

In conclusion, this study showed that active video games had a small but definite effect on BMI and the improvement of body composition in overweight and obese children. Our findings suggested that interventions to displace sedentary behaviors have the potential to improve the body composition of children. Additional work is needed to determine how to best augment the effects of such interventions to achieve a greater magnitude of an effect on body weight.

The study findings have implications for reducing sedentary behavior at various levels. Because of the pervasiveness of technology and the appeal of traditional video games, at an individual level, parents may have more success encouraging the displacement of less-active video games with more-active ones rather than trying to stop children and young people from using these games altogether. This may be particularly important in countries where outdoor access is limited because of overcrowding (eg, China) or because of prolonged periods of winter (eg, Northern Europe). From a policy perspective, physical activity guidelines that provide recommendations on recreational screen time (television watching and computer use) might be expanded to promote the substitution of nonactive video games with active ones. Finally, researchers and health professionals might consider working with industry partners to encourage and assist with the development of new and exciting active video games that appeal to a broad range of age groups and redress the imbalance of nonactive to active video games.

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