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# To remove or to replace traditional electronic games? A crossover randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children aged 10–12 years

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## ABSTRACT

**Objective:** To evaluate the impact of (1) the removal of home access to traditional electronic games or (2) their replacement with active input electronic games, on daily physical activity and sedentary behaviour in children aged 10–12 years.

**Design:** Crossover randomised controlled trial, over 6 months.

**Setting:** Family homes in metropolitan Perth, Australia from 2007 to 2010.

**Participants:** 10-year-old to 12-year-old children were recruited through school and community media. From 210 children who were eligible, 74 met inclusion criteria, 8 withdrew and 10 had insufficient primary outcome measures, leaving 56 children (29 female) for analysis.

**Intervention:** A counterbalanced randomised order of three conditions sustained for 8 weeks each: no home access to electronic games, home access to traditional electronic games and home access to active input electronic games.

**Main outcome measures:** Primary outcome was accelerometer assessed moderate/vigorous physical activity (MVPA). Secondary outcomes included sedentary time and diary assessed physical activity and sedentary behaviours.

**Results:** Daily MVPA across the whole week was not significantly different between conditions. However, compared with home access to traditional electronic games, removal of all electronic games resulted in a significant increase in MVPA (mean 3.8 min/day, 95% CI 1.5 to 6.1) and a decrease in sedentary time (4.7 min/day, 0.0 to 9.5) in the after-school period. Similarly, replacing traditional games with active input games resulted in a significant increase in MVPA (3.2 min/day, 0.9 to 5.5) and a decrease in sedentary time (6.2 min/day, 1.4 to 11.4) in the after-school period. Diary reports supported an increase in physical activity and a decrease in screen-based sedentary behaviours with both interventions.

**Conclusions:** Removal of sedentary electronic games from the child's home and replacing these with active electronic games both resulted in small, objectively

## ARTICLE SUMMARY

### Article focus

- Physical activity (PA) and sedentary behaviour are important contributors to health.
- Children spend a considerable portion of their day in screen-based leisure including playing electronic games.
- The effect of removing sedentary electronic games from children's homes, or replacing them with active electronic games is not known.

### Key messages

- In our study, replacing sedentary electronic games with active electronic games increased activity and decreased sedentary time in the after-school period to a similar extent as removing all home access to sedentary electronic games.
- Replacing sedentary electronic games with active electronic games may be more sustainable but should be part of a comprehensive approach to screen-based leisure.

### Strengths and limitations of this study

- This is the first randomised controlled study to assess the effect of removing electronic games from the family home on children's activity.
- The study employed a robust design and used valid, objective measures of PA and sedentary behaviour supplemented with self-report measures.
- Longer term studies are needed to assess whether the small effects observed over 8 weeks are sustained.

measured improvements in after-school activity and sedentary time. Parents can be advised that replacing sedentary electronic games with active electronic games is likely to have the same effect as removing all electronic games.

**Trial Registration:** Australia and New Zealand Clinical Trials Registry (ACTRN 12609000279224)

## INTRODUCTION

It is well recognised that physical activity (PA) is beneficial for children's health,[1] yet children live in a world that is increasingly technological and sedentary.[2] Health professionals and parents are concerned that increasing electronic game use may be impacting the health of children through a reduction in PA and increase in sedentary time.[3 4] Electronic games are played on various devices including dedicated consoles (eg, Microsoft Xbox, Sony PlayStation 3, Nintendo Wii) and hand-held players (eg, Nintendo DS, PlayStationPSP) as well as non-dedicated technologies such as computers, tablets and smartphones. International evidence shows that the majority of children in affluent countries now have substantial daily exposure to electronic games. For example in the UK, approximately half of the children spend over an hour per day using computer games alone.[5] In the USA, children's use of video games has tripled in the past 10 years.[6] Indeed, estimates of the daily exposure of children to electronic games in countries such as the UK, the USA and Australia range from 38 min/day to 90 min/day.[6–8]

While it is known that traditional electronic games are little better than watching television, in terms of body movement and energy expenditure,[9 10] whether electronic games actually displace PA (ie, would children run outside and play if electronic games were not available) has not been established. Cross-sectional studies have shown negative, but weak, relationships between time spent playing traditional electronic games and overall PA level, with a similar relationship for obesity.[11] However, until now, no study has removed electronic game access entirely from the home and examined the effect on activity. More recently, the new generation 'active' electronic games, such as Sony PlayStation EyeToy and Move, dance mats and Microsoft Xbox Kinect, have added to the controversy. Laboratory studies have shown that some of these active games can result in meaningful increases in muscle activity, movement and energy expenditure while others result in less activity.[12 13] Findings from the few available home-based interventions comparing access to traditional electronic games alone with supplemental access to active electronic games have been mixed: with some evidence for improvements in body fatness,[14] and fitness in overweight children,[15] though there was no effect on objectively measured PA for a sample including both overweight and normal weight children.[16] The long-term efficacy of active games in promoting PA remains questionable,[13 17] but with potential promise.[18]

With no clear evidence either way, the public-health response until now has been to develop recommendations to restrict all children's screen-based leisure (television, computers and all electronic games), typically to a maximum of 2 h a day.[19 20] Compliance with these guidelines has been poor,[21 22] which may be due to the difficulties experienced by parents when trying to implement the guidelines. Options for parents include removing electronic games from the family home or replacing traditional electronic games with active electronic games. Until now, there has been no study evaluating the effect of both these approaches. Therefore, this study sought to explore, through a crossover randomised controlled trial, the effect of either removing electronic games from the children's home environment or replacing traditional sedentary electronic games with active input electronic games on children's PA and sedentary behaviour.

## METHODS

### Study participants

This study was conducted in Perth, Western Australia in 2007–2010, with the trial registered (Australia and New Zealand Clinical Trials Registry (ACTRN 12609000279224)) and the detailed study protocol published.[23] In summary, 10-year-old to 12-year-old children were recruited through mass media (radio, newspapers), community newsletters and local school notices. This age group was selected as they are able to provide detailed information in diaries and questionnaires,[24] have a high use of electronic games[6] and are developing activity and sedentary behaviour patterns preadolescence, which may track into adulthood.[25 26] Recruitment was staggered as well as spread over 3 years to account for seasonal variation and external events and targeted to enable participation of equal numbers of males and females and children representative of a spread of socioeconomic status, electronic game experience and motor competence. Children and their parents were provided with a detailed written description of the study purpose, procedure, benefits and risks, and were given the opportunity to ask research staff for clarification prior to signing assent (children) and consent (parents) to participate. Inclusion criteria were being 10–12 years of age at the start of the study and able to access the electronic games provided in the study on most days of the week. Children were excluded if they had a diagnosed disorder (parent reported) likely to impact their study participation, movement or electronic game use (other than developmental coordination disorder), lived in a shared care arrangement where the child spent a substantial amount of time in different houses and was unable to maintain game condition access, or lived remote to the University campus.

Ethical approval was provided by the Curtin University Human Research Ethics Committee.

### Intervention

There were three levels of electronic game access. 'No games' involved all dedicated electronic game devices being removed from the family home with a contract by each child that electronic games were to be avoided where possible on other devices and locations. 'Traditional games' involved the provision of a Sony PlayStation 2 with a range of non-violent games requiring game pad input. 'Active games' involved the provision of a Sony PlayStation 2 with EyeToy and dance mat input devices and a range of non-violent games. For each condition, children selected six games and were allowed to change games mid intervention. A condition period of 8 weeks was chosen for each intervention as it has been found to be sufficient to show physical and psychological changes. A period of eight weeks also allows for children to accommodate to each condition and is not so long to adversely affect recruitment and compliance in the 'no games' condition.

### Study design

A challenge for the design of this study was to select a design which provided a 'no games' condition with high internal and external validity. A traditional parallel arms randomised and controlled trial would have had low external validity as the children volunteering would not have been representative. From our discussions with children, the removal of all electronic games was only acceptable to the majority of children if the same children could get access to a range of new games and equipment. This is why a within-subjects design was chosen. To control for an order effect, children were randomised to a balanced ordering of the three electronic game conditions. This is why a crossover design was chosen (see figure 1).

### Sample size

For power calculations, daily moderate/vigorous physical activity (MVPA) was estimated at 115+30 min, with a minimum effect size of 15 min considered important based on effects in prior studies.[27] If the variation in the PA level between repeated time points in each individual is normally distributed with a SD of 30 min, and the true effect of a game condition is 15 min, a study with 72 subjects would reject the null hypothesis that this response difference is zero with probability (power) 0.986. The type I error probability associated with this test of this null hypothesis is 0.05. If the type I error is lowered to 0.01 to account for 'repeated' contrasts between conditions, the power is 0.943.[28] We allowed for a 10% attrition in data. The study was curtailed earlier than planned as new electronic game technologies (Sony PlayStation 3 and Microsoft Xbox Kinect) became popular in late 2010 in Perth making it unfeasible to recruit children to the older game technology. Data from nine children who participated in the 2007 pilot study using the same activity and condition protocol were included to provide the best estimate of intervention effects.

### Recruitment and study procedure

Following screening, participants were randomly allocated to an order of conditions by selection of an opaque sealed envelope. A balance of orders across the year was achieved by having sets of the six possible order permutations in each year's cohort. After informed consent/assent from the parent and child, a research officer visited the home and instructed the parent and child in baseline assessments. The baseline visit included an explanation of the accelerometer along with a PA recall diary (see outcomes measures for detail). Baseline data were also collected on the child's height, weight, socioeconomic status, motor coordination and electronic game experience. The research officer returned after 10 days to collect baseline assessments and set up the electronic game condition. This involved either removal of all electronic games or setting up electronic game equipment and instructing the parent and child in its use. Follow-up phone calls were made the next day and after 6 days to ensure that the game equipment was working correctly. Towards the end of the 6th week in each condition, the research officer visited again to set up the PA assessments (accelerometer and diary). After 8 weeks in each condition, the research officer returned, collected the completed activity diary and accelerometer and set up the next condition. Assessments were scheduled to avoid school and public holidays where possible. Individualised reports were provided to participants on study completion. The research officers involved with the setting up of each condition were not involved in the subsequent analyses of the primary and secondary outcomes.

### Outcome measures

#### PA and sedentary time by accelerometry

The primary outcome was the mean daily minutes of MVPA over the whole week. Time spent in moderate-to-vigorous, light and sedentary intensity PA was assessed over 7 days using Actical accelerometers worn on the hip. Actical is a widely used and validated accelerometer in studies of children and adolescents.[29–31] The accelerometers were set to record at 15 s epoch intervals.[32] As per established standard practices with accelerometry, a minimum of 4 days (at least 1 weekend day) was regarded as a valid recording.[33] The minimum recording time required for a day to be considered valid was 500 min.[7] Data were visually checked individually for missing values. Non-wear time, regarded as 120 min of consecutive zeros (based on pilot data showing that children could accumulate more than 60 min of consecutive zero counts when watching television), was removed prior to analyses. Activity intensity thresholds based on Colley and Tremblay[34] were used to convert the raw counts into

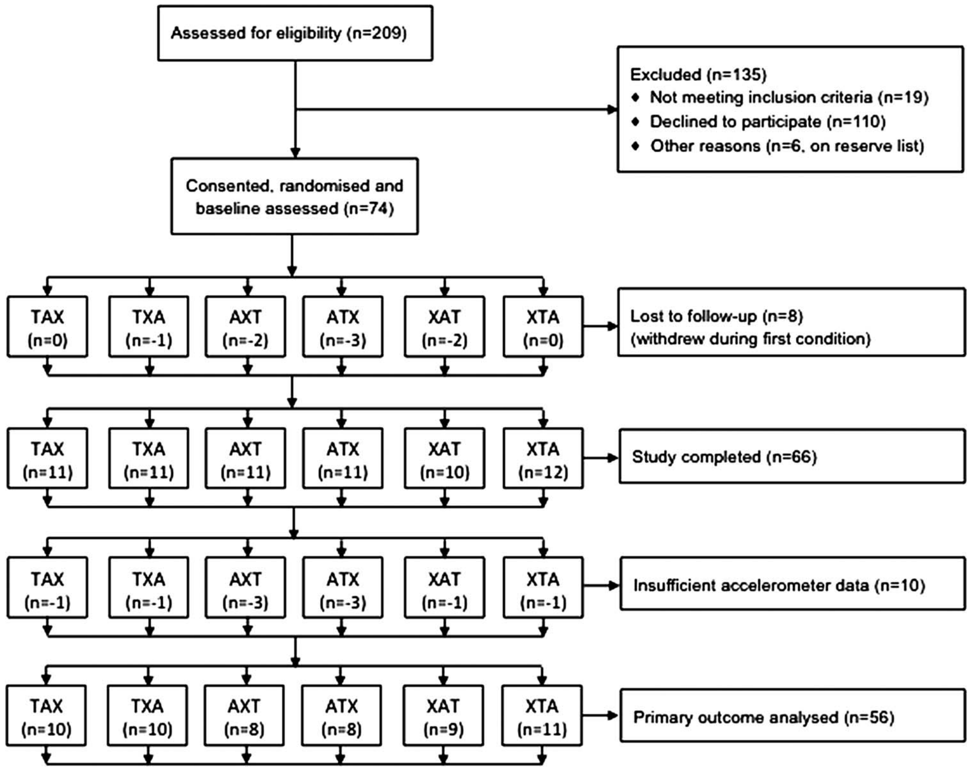


**Figure 1** CONSORT diagram of flow of participants. Order of conditions is shown with T, traditional electronic games; A, active electronic games; X, not electronic games.

minutes of sedentary, light, moderate and vigorous intensity PA. Minutes spent in each of these intensity categories were calculated for an average day over the whole week. As there are known to be variations depending on the type of day[35] and time of the day[36] which may be masked in whole week analysis, analysis was also conducted on school days, weekend days and the after-school period (from 15:30 to 18:00). The after-school period was chosen as this has been suggested to be an important time in the child's day for both discretional PA and sedentary leisure time.[37] Measures of the pattern of sedentary, light and moderate-to-vigorous activity were also calculated for the same time periods.[38] A Custom LabView program was used to process the data.

### PA and sedentary behaviours by diary

To provide descriptive information on the type of activities performed and understand any changes in accelerometer determined exposure, participants used a modified version of the previous-day physical activity recall (PDPAR) in the form of a diary for 7 days.[39] The predominant activity was recorded for each 30 min block during waking hours. Use of the PDPAR over several consecutive days, in the form of a diary, has also been shown to be valid, against measures of accelerometry, and feasible.[40] The participants also used this diary to make a note of whether and why the accelerometer was removed for any period during the day. Active leisure, sedentary leisure and various components of sedentary leisure were assessed across the whole week, school days, weekend days and during the after-school period using custom macros in Excel.

### Covariates

Age, sex, body mass index (BMI) and electronic game experience were considered for potential modification of condition effects. Prior PA research has identified significant differences between summer and winter seasons and interactions with sex (more reduction in PA in winter in girls).[41] The potential seasonal effect was allowed for in the design by having a balanced ordering of game conditions and a staggered start to cover the whole school year. Previous electronic game experience which could confound the effect of the game condition was measured using a questionnaire based on our prior studies and a large USA study and used in analysis.[42]

## Statistical analyses

Data were analysed using mixed-model repeated measures analyses to estimate the magnitude of two condition contrasts for each outcome (no games vs traditional electronic games, and active electronic games vs traditional electronic games) using measures from participants with valid data from at least two of the three conditions, adjusting for period and, in the case of accelerometry data, accelerometer wear time. Eleven participants were missing valid accelerometry data for one condition (4 traditional, 2 no games and 5 active games), and there were no participants missing data for more than one condition. These missing values were accounted for in the linear mixed model, which uses a likelihood-based estimation procedure resulting in non-biased estimates by imputation of missing responses based on the surrounding responses and modelled covariance structure. Testing for a treatment by period interaction with statistical significance set at p<0.1 was used to determine whether a carryover effect existed. To verify the absence of influential outliers, initial screening was performed by graphical examination of condition differences plotted against averages, and standardised residuals from each model were plotted against fitted values.

Statistical analysis was performed using Stata/IC V.10.1 for Windows (StataCorp LP, College Station Texas, USA). All statistical tests were two-tailed with α=0.05. Analysis was by intention to treat, though per protocol analysis was also conducted, with the 33 participants who used active games for more than 15 min/day during the active e-game condition.

## RESULTS

### Participants

Figure 1 shows the participant flow chart. Eight participants provided baseline data but withdrew during their first condition (6 male, mean age 10.5 years, height 1.48 m, weight 48.3 kg, socioeconomic status range 5th to 9th centile, 4 condition orders). Ten participants completed the study but had insufficient accelerometer data after all three conditions (5 male, mean age 11.4 years, height 1.48 m, weight 43.8 kg, socioeconomic status range 3rd to 10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female) who completed the study and had sufficient accelerometry data for planned analyses had a mean (SD) age of 11.3 (0.8) years. Participant height (1.50 (0.08) m), weight (41.3 (10.3) kg) and zBMI (−0.1 (1.2)) were similar to the national distribution for this age.[8] Nearly all children had home access to electronic games (91%) and reported playing electronic games in the last month (95%), with 61% reporting playing at least 2–3 times a week. Duration of playing sessions was most commonly <30 min (41%), though 31% usually played for 30–60 min and 24% usually played for 1–2 h. Participant socioeconomic status based on location of family home[43] ranged from the second to the tenth Australian centile. Participant motor coordination status ranged from poor to excellent (MAND[44] 2007:NDI 62–125; MABC-2[45] 2009–10: 9–98%), approximating a general population. There were no deviations from randomised allocation.

### Accelerometry

Daily accelerometer wear time was around 827.8 min over the week, and was somewhat shorter on weekend days than school days (788.9 vs 827.8 min). With home access to traditional games, regarded as the norm for most families at the start of this study, daily MVPA was less than 1 h (mean 54.1 min, 95% CI 47.5 to 60.7), whereas daily sedentary time was around 8.5 h (522.7 min, 509.4 to 535.9). Table 1 shows that in comparison to traditional games, removal of all electronic games resulted in no significant change in daily MVPA over the whole week. However, it did result in a 3.8 min/day (95% CI 1.5 to 6.1, p=0.001) increase in MVPA in the after-school period. A similar, though non-significant, increase in MVPA was observed over the whole school day. The removal of all electronic games resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day (0.0 to 9.5, p=0.05) in sedentary time in the after-school period, which was matched with a small, non-significant decrease in sedentary time over the whole week and a larger, non-significant decrease on weekend days. Replacing traditional games with active input games had similar findings (table 1). This exchange resulted in no significant change in MVPA over the whole week but a 3.2 min/day (0.9 to 5.5, p=0.007) increase in MVPA in the after-school period, with a similar though non-significant pattern of MVPA over the whole school day. Replacing electronic games with active input games also resulted in a small, non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Furthermore, replacement of traditional games with active input games resulted in a significant decrease in sedentary time in the after-school period of 6.2 min/day (1.4 to 11.1, p=0.012). A small, non-significant decrease in sedentary time over the whole week and a larger, non-significant decrease on weekend days were also observed.

Removing or replacing traditional electronic games had no significant effect on exposures to bouts of MVPA lasting at least 10 min, bouts of sustained sedentary time lasting at least 30 min, or brief bursts at any intensity lasting less than 5 min and breaks in sedentary time (data not shown).

Figure 2 provides a visual summary of the key daily differences in accelerometer determined activity and sedentary time for the after-school period.

### Diary

According to the diary records, in the traditional games condition, children spent, on average, 1.5 h/day on active leisure and transport (mean 78 min, 95% CI 63 to 93) and 4.5 h/day on all sedentary leisure (non-screen and screen: 267 min, 243 to 292). Leisure time spent on screen-based activities made up more than half of the reported sedentary leisure (163 min, 139 to 187). Television viewing was the largest contributor (107 min, 85 to 129), followed by sedentary electronic games (44 min, 37 to 50) and non-gaming computer use (24 min, 15 to 32).

**Table 1** Accelerometer determined the daily minutes of MVPA, light activity and sedentary time over the whole week, weekend days, school days and the 15:30–18:00 after-school period, adjusted for condition order and wear time

| (n=56) | No games (X) | Traditional games (T) Mean (95% CI) | Active games (A) | Remove (X-T) Difference (95% CI), p values | Replace (A-T) |
|---|---|---|---|---|---|
| MVPA | | | | | |
| Week | 55.8 (49.2 to 62.3) | 54.1 (47.5 to 60.7) | 56.1 (49.5 to 62.8) | 1.7 (−3.2 to 6.6), 0.493 | 2.0 (−3.0 to 7.1), 0.428 |
| School day | 60.9 (53.9 to 67.8) | 58.2 (51.2 to 65.2) | 61.5 (54.4 to 68.5) | 2.6 (−2.4 to 7.7), 0.306 | 3.2 (−2.0 to 8.4), 0.228 |
| Weekend day | 43.2 (34.3 to 52.2) | 42.8 (33.7 to 51.9) | 43.0 (33.9 to 52.2) | 0.4 (−9.1 to 9.9), 0.933 | 0.2 (−9.5 to 10.0), 0.966 |
| 15:30–18:00 school day | 12.9 (10.3 to 15.5) | 9.1 (6.4 to 11.7) | 12.3 (9.6 to 14.9) | **3.8 (1.5 to 6.1), 0.001** | **3.2 (0.9 to 5.5), 0.007** |
| Light PA | | | | | |
| Week | 242.5 (230.8 to 254.2) | 240.3 (228.5 to 252.2) | 245.6 (233.7 to 257.5) | 2.2 (−9.4 to 13.7), 0.712 | 5.3 (−6.6 to 17.2), 0.385 |
| School day | 241.3 (229.9 to 252.7) | 242.3 (230.7 to 253.9) | 243.8 (232.1 to 255.4) | −1.0 (−11.8 to 9.8), 0.854 | 1.5 (−9.6 to 12.6), 0.794 |
| Weekend day | 245.5 (228.7 to 262.3) | 235.3 (218.3 to 252.4) | 250.2 (233.0 to 267.4) | 10.2 (−9.1 to 29.5), 0.302 | 14.9 (−4.9 to 34.6), 0.140 |
| 15:30–18:00 school day | 48.8 (45.3 to 52.4) | 48.0 (44.4 to 51.5) | 50.9 (47.2 to 54.5) | 0.9 (−2.9 to 4.6), 0.649 | 2.9 (−1.0 to 6.8), 0.142 |
| Sedentary | | | | | |
| Week | 518.7 (505.6 to 531.7) | 522.7 (509.4 to 535.9) | 515.4 (502.1 to 528.7) | −4.0 (−16.8 to 8.8), 0.540 | −7.2 (−20.4 to 5.9) 0.282 |
| School day | 531.1 (518.3 to 543.9) | 532.7 (519.7 to 545.7) | 528.3 (515.2 to 541.3) | −1.6 (−13.7 to 10.4), 0.790 | −4.5 (−16.9 to 8.0), 0.483 |
| Weekend day | 487.6 (468.3 to 507.0) | 498.5 (478.8 to 518.2) | 483.1 (463.3 to 503.0) | −10.8 (−32.9 to 11.3), 0.336 | −15.3 (−37.9 to 7.3), 0.184 |
| 15:30–18:00 school day | 88.0 (83.3 to 92.7) | 92.7 (88.0 to 97.5) | 86.5 (81.7,91.2) | **−4.7 (−9.5 to 0.0), 0.050** | **−6.2 (−11.1 to −1.4), 0.012** |

MVPA, moderate/vigorous physical activity.
Statistically significant results are highlighted in bold text.

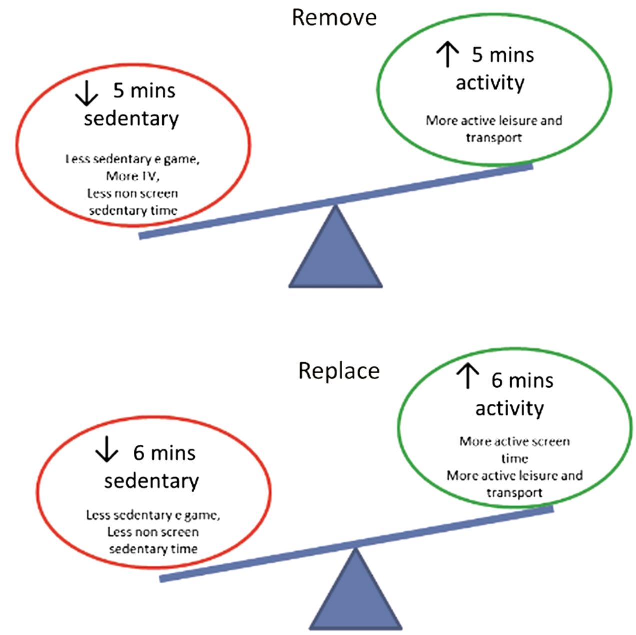


**Figure 2** Summary of impact of removing or replacing traditional electronic games in terms of objectively measured activity time (moderate/vigorous physical activity and light) and sedentary time during the after-school period along with the diary determined changes in activities.

Participants reported exposure to active electronic games during the 'active games' condition of 19 min/day, suggesting reasonable compliance with this condition. Similarly, participants reported exposure to traditional electronic games during the 'traditional games' condition of 34 min/day. Participant median exposure to sedentary electronic games was 0 min during the 'no games' and 'active games' conditions. Similarly, participant median exposure to active electronic games was 0 min during the 'no games' and 'traditional games' conditions, suggesting compliance with avoiding non-protocol games.

The diary records also provide context to the changes observed in accelerometry in the after-school period (table 2). When looking at the after-school period alone, the removal of electronic games resulted in a significant decrease of 14 min/day in sedentary leisure and a corresponding 12 min/day increase in active leisure and transport. The breakdown of this came from a significant reduction of 12 min/day of screen sedentary leisure (8 min (median) of which was sedentary electronic game exposure), a non-significant reduction of 3 min/day in non-screen sedentary leisure and a non-significant reduction in non-game computer use by 1 min/day. Television viewing was reported to increase by 3 min/day, though this was not significant.

Again, when looking at the after-school period, replacing traditional electronic games with active electronic games resulted in an overall decrease of 21 min/day in sedentary leisure and a corresponding non-significant increase of 3 min/day in active leisure and

**Table 2** Diary reported daily minutes of active leisure, sedentary leisure and components of sedentary leisure in the 15:30–18:00 after-school period, adjusted for condition order

| | No games (X) Mean, 95% CI | Traditional games (T) | Active games (A) | Remove (X-T) Mean, 95% CI | Replace (A-T) p value |
|---|---|---|---|---|---|
| Active leisure and transport | 42<br>34 to 50 | 30<br>22 to 38 | 33<br>25 to 42 | **12**<br>**3 to 21**<br>**0.013** | 3<br>−6 to 12<br>0.510 |
| Sedentary leisure | 68<br>58 to 77 | 82<br>72 to 92 | 61<br>51 to 71 | **−14**<br>**−25 to −4**<br>**0.008** | **−21**<br>**−32 to −10**<br>**<0.001** |
| Non-screen sedentary leisure | 34<br>27 to 42 | 37<br>30 to 45 | 30<br>22 to 38 | −3<br>−11 to 4<br>0.436 | −7<br>−15 to 1<br>0.075 |
| Screen sedentary leisure | 33<br>24 to 43 | 45<br>35 to 54 | 31<br>21 to 40 | **−12**<br>**−21 to −2**<br>**0.022** | **−14**<br>**−24 to −4**<br>**0.007** |
| TV | 28<br>19 to 37 | 25<br>16 to 34 | 25<br>16 to 34 | 3<br>−5 to 11<br>0.485 | 0<br>−8 to 9<br>0.954 |
| Non-game computing | 4<br>1 to 7 | 5<br>2 to 8 | 4<br>1 to 7 | −1<br>−4 to 2<br>0.489 | −1<br>−4 to 2<br>0.378 |
| Sedentary electronic games* | 0<br>(0 to 0) | 8<br>(0 to 14) | 0<br>0 to 0 | **<0.001** | **<0.001** |
| Active electronic games* | 0<br>(0 to 0) | 0<br>(0 to 0) | 8<br>(0 to 12) | **<0.001** | **<0.001** |

*Median (95% CI for median), Wilcoxon sign-rank test for condition differences.
Statistically significant results are highlighted in bold text.

transport along with 8 min/day (median) of active input game time, that is, an overall increase of activity time of about 11 min/day. The reduced sedentary time was achieved through a significant decrease of 14 min/day in sedentary screen leisure and a 7 min/day non-significant reduction in non-screen sedentary leisure. No significant changes in television viewing (0 min/day) or non-game computer use (−1 min/day) were reported when active input games were introduced. The diary reported changes in both the removal and replacement of traditional electronic game conditions provide the context to the accelerometer measured activity differences during the after-school period (see text within figure 2).

## DISCUSSION

This randomised controlled study showed that removing access to sedentary electronic games in children's homes, or replacing them with active electronic games, resulted in small but significant increases in PA and reductions in sedentary time during after-school time. No significant effects on overall daily or weekly activity or sedentary time were observed.

This is the first randomised controlled study, in the real-world setting of the home, to assess the two alternatives parents have for reducing the time their children spend on sedentary electronic games: removal or replacement with something more active. The study findings suggest that parents choosing either option may see a small improvement, more activity and less sedentariness, in the after-school period. Our study corroborates previous research that has shown this time to be a 'critical window' for intervening with PA[46] and supports more recent qualitative findings that suggest it is also an important time in the day to reduce children's screen viewing.[37] The magnitude of effect, approximately 5 min more activity and 5 min less sedentary time, is similar to improvements observed in other home-based studies. Maddison *et al*[14] found a self-reported 10-min increase in active games use and a self-reported reduction in sedentary electronic games use when children were provided with active electronic games in addition to traditional electronic games in a 6-month study. While Baranowski *et al*[16] observed no objectively measured increase in daily MVPA or decrease in daily sedentary time in their home-based study, day type or specific day periods were not studied.

On its own, the magnitude of the change observed is unlikely to be of clinical importance; however, it needs to be seen in the context of electronic games being part of the rapidly growing exposure that children have to screen-based leisure. While time spent viewing television appears to be stable,[6] leisure time exposure to console-based electronic games and computing is increasing rapidly,[6] as is the increase in mobile smartphones and touch screen tablets that are used for electronic gaming, social networking, video viewing and internet surfing.[47] Therefore, small changes across a variety of these platforms could result in a more substantial clinical impact. While our study focused on the home setting, school offers another opportunity for more active technologies.[48] Children sit for a long time at school and there is potential to further reduce sedentariness by engaging with technologies such as sit-stand desks or active-input electronic media as part of lessons.[35]

The strengths of the study include the strong within-subjects randomised controlled trial design with staggered starts and counterbalanced orders to control for extraneous factors. The participants were representative of a general population of 10-year-old to 12-year-old children in terms of sex, weight, motor coordination, electronic game experience and socioeconomic status, informing the likely broad impact of replacement as a public-health intervention. The study was also grounded in the naturalistic setting of the family home. While active-input technologies have been tested by children in the laboratory and found to increase energy expenditure, this does not account for what happens in practice when the active games are among a milieu of other distractions.[17] Furthermore, this is the first study to examine the effects of fully removing electronic games from the home. The study also used active electronic game technology with a known capacity to increase whole body movement and energy expenditure, rather than the Wii which children can play with only hand movements. Some Wii-based games have been found to be little different to traditional sedentary electronic games.[49] The study also provided a substantial range and variation in game offerings, addressing the known issue of active games being less engaging,[49] although it was difficult at times to keep participants engaged as the most popular game genre—killing—was excluded from the study on ethical grounds. The other key strength of the study is that it used an objective measure of PA and sedentary time and supplemented this with self-reported diary measures to aid the understanding and interpretation of results.

The main weakness was the need to curtail the study 1 year early due to electronic game technology changes, specifically the widespread introduction during late 2010 of new active electronic game devices Xbox Kinect and PlayStation Move. These new technologies and the active games available on these devices were qualitatively different and could not simply replace the older devices in the same protocol. This meant children were unwilling to agree to the original protocol, and thus recruitment ceased. The inability to recruit participants for the final planned year resulted in a reduced sample size which was partly compensated for by using data from nine subjects who participated in the protocol in 2007. The reduced numbers meant that we were unable to determine whether the 10–15 min change in sedentary and light intensity activity on weekends was real. The withdrawal of participants and the lack of adequate accelerometry data on some participants are other obvious limitations. A further limitation was that while the diaries suggested compliance to both conditions was good, we did not have a way of measuring precisely how much the active games were used.[17]

The accelerometer data presented here showed small improvements in whole body movement, which may be useful for a range of physiological effects, one of which is energy expenditure. However, the actual energy expenditure, and thus the likely impact on obesity, should also be determined. The small improvements seen at a group level may mask varied changes for individuals, with the potential for the exposure of some individuals to be markedly affected. Thus, the effect modification of factors such as sex, age, electronic game experience, attitudes to technology and PA, motor competence and weight status should also be examined.

Given the strong evidence for detrimental effects of too little PA and too much sedentary time,[50 51] in particular too much screen time[3] and the potential interaction between these in children,[21] there is a mounting need to understand childhood behaviours and intervene. Children in this study were sedentary for just over 8 h/day and reported spending approximately 3 h/day on screen-based leisure, on the low side but comparable with international findings.[6 47] Given this high sedentary exposure, healthcare practitioners should use all available opportunities to encourage children (and their parents) to be more active and less sedentary. Sigman[3] has recently called for the medical community to take a more proactive approach to reducing children's screen time exposure. In the increasingly electronic media-enmeshed world of youth, it is unrealistic for parents to remove access to screen-based leisure completely, and therefore parents and health professionals alike need to work with technology to assist its development in ways which are health enhancing rather than health reducing. It was encouraging in this study that the replacing option resulted in at least as good an outcome as the removing option, and this may potentially result in more successful long-term outcomes due to better sustained compliance.

## CONCLUSION

Screen-based leisure is a major component of sedentary behaviour and interventions should be targeted to television, computer and electronic game use. This study has shown that replacing sedentary electronic games with active electronic games will provide at least as good an activity outcome and perhaps be easier for the parent and child to sustain than removing electronic game technology from the home.

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