



To remove or to replace traditional electronic games? A within subject randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children.

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-002629
Article Type:	Research
Date Submitted by the Author:	23-Jan-2013
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Primary Subject Heading:	Public health
Secondary Subject Heading:	Sports and exercise medicine, Epidemiology, Paediatrics
Keywords:	child, physical activity, sedentary behaviour, accelerometry, screentime

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To remove or to replace traditional electronic games? A within subject randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children.

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Word count: 4057

Abstract word count: 300

Number of tables: 2

Number of figures: 2

Number of references: 47

Keywords children, physical activity, sedentary behaviour, accelerometry, screentime

ARTICLE SUMMARY

Article Focus:

- Physical activity 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 home, 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 to 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 physical activity and sedentary behaviour supplemented with self-report measures.
- Longer term studies are needed to assess whether the small effects observed over eight weeks are sustained.

ABSTRACT

Objective To evaluate the impact of a) the removal of home access to traditional electronic games, or b) their replacement, with active input electronic games on physical activity and sedentary behaviour in children.

Design Within subjects randomised controlled trial, over 6 months.

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

Participants 10-12 year old children were recruited through school and community media. From 210 children who were eligible, 75 met inclusion criteria, 10 withdrew, and 9 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 outcomes were accelerometer assessed physical activity and sedentary time. Secondary outcomes included diary assessed physical activity and sedentary behaviours.

Results Compared with home access to traditional electronic games, removal of all electronic games resulted in a significant increase in MVPA (mean 3.8min/day, 95% confidence interval 1.5-6.1) and a decrease in sedentary time (4.7min/day, 0.0-9.5) in the after school period. Similarly, replacing traditional games with active input games resulted in a significant increase in MVPA (3.2min/day, 0.9-5.5) and a decrease in sedentary time (6.2min/day, 1.4-11.4) in the after school period. Diary reports supported an increase in physical activity and decrease in screen based sedentary behaviours with both interventions.

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3 **Conclusion** Removal of sedentary electronic games from the child's home and replacing
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5 these with active electronic games resulted in both small objectively measured
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7 improvements in after school activity and sedentary time. Parents can be advised that
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9 replacing sedentary games with active electronic games is likely to have the same effect as
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11 removing all electronic games.
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15 **Trial Registration** Australia and New Zealand Clinical Trials Registry (ACTRN
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INTRODUCTION

It is well recognised that physical activity 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 physical activity and increase in sedentary time.^{3, 4}

International evidence shows the majority of children in affluent countries now have substantial daily exposure to electronic games. For example in the UK, approximately half of children spend over an hour per day on computer games alone.⁵ In the United States, children's use of video games has tripled in the past 10 years to a current average of 73 minutes per day.⁶ Indeed, screen based media as a whole has been estimated to occupy up to 5 hours per day for British children.⁷

Whilst it is known that traditional electronic games are little better than watching television, in terms of body movement and energy expenditure,^{8, 9} whether electronic games actually displace physical activity (i.e. 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 physical activity level, with a similar relationship for obesity.¹⁰ However, to date, 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, Nintendo Wii and Xbox Kinect have added to the controversy. Laboratory studies have shown that some of these active games can result in meaningful increases in muscle movement and energy expenditure whilst others are less active.^{11, 12} Findings from the few available home-based interventions comparing access to

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3 traditional electronic games alone with supplemental access to active electronic games have
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5 been mixed: with some evidence for improvements in body fatness,¹³ and fitness in
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7 overweight children,¹⁴ though no effect on objectively measured physical activity for a
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9 sample including both overweight and normal weight children.¹⁵ The long term efficacy of
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11 active games in promoting physical activity remains questionable,^{12, 16} but with potential
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13 promise.¹⁷
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18 With no clear evidence either way, the public health response to date has been to develop
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20 recommendations to restrict all children's screen based leisure (TV, computers and all
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22 electronic games), typically to maximum of 2hrs a day.^{18, 19} Compliance with these
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24 guidelines has been poor,^{20, 21} suggesting difficulties for parents. Options for parents include
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26 removing electronic games from the family home or replacing traditional electronic games
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28 with active electronic games. To date there has been no study evaluating the efficacy of
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30 both these approaches. Therefore this study sought to explore, through a within subjects
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32 randomised controlled trial, the effect of either removing electronic games from the
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34 children's home environment or replacing traditional sedentary electronic games with
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36 active input electronic games on children's physical activity and sedentary behaviour.
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42 **METHODS**

43 **Study design methods and participants**

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46 This study used a within subjects randomised controlled trial design and was conducted in
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48 Perth, West Australia in 2007-2011. The detailed design of the study protocol has been
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50 previously described.²² In summary, 10-12 year old children were recruited through mass
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52 media, community newsletters and local school notices. This age group was selected as they
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3 are able to provide detailed information in diary and questionnaires, have a high use of
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5 electronic games and are developing activity patterns pre-adolescence, which may track
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7 into adulthood. Recruitment was staggered over three years to account for seasonal
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9 variation and targeted to enable participation of equal numbers of males and females, and
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11 children representative of a spread of socio-economic status, electronic game experience
12
13 and motor competence. Children and their parents were provided with a detailed written
14
15 description of the study purpose, procedure, benefits and risks, and were given the
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17 opportunity to ask research staff for clarification prior to signing assent (children) and
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19 consent (parents) to participate. Inclusion criteria were being 10-12 years of age at the start
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21 of the study and able to access electronic games on most days of the week. Children were
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23 excluded if they had a diagnosed disorder likely to impact their study participation,
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25 movement or electronic game use (other than developmental coordination disorder), lived
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27 in a shared care arrangement where the child spent a significant amount of time in different
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29 houses and was unable to maintain game condition access, or lived remote to the University
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31 campus.
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39 **Intervention**

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42 There were three levels of electronic game access. 'No games' involved all electronic games
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44 being removed from the family home with a contract that electronic games were to be
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46 avoided where possible at other locations. 'Traditional games' involved the provision of a
47
48 Sony PlayStation 2 with a range of non-violent games requiring game pad input. 'Active
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50 games' involved the provision of a Sony PlayStation 2 with EyeToy and dance mat input
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52 devices and a range of non-violent games. For each condition children selected 6 games and
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54 were allowed to change games mid intervention. A condition period of 8 weeks was chosen
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3 for each intervention as it has been found to be sufficient to show physical and
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5 psychological changes. Eight weeks also allows for children to accommodate to each
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7 condition and is not so long to adversely affect recruitment and compliance in the 'no
8
9 games' condition. From our pilot study and discussions with children, the removal of all
10
11 electronic games was acceptable as a way of getting access to a range of new games and
12
13 equipment for four months. This is why a within subjects design was chosen.
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16 17 18 **Sample size**

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20 For power calculations, daily moderate/vigorous physical activity was estimated at 115+30
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22 min with a minimum effect size of 15 min considered important based on effects in prior
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24 studies.²³ If the variation in the physical activity level between repeated time points in each
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26 individual is normally distributed with standard deviation 30 min, and the true effect of
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28 game condition is 15 min, a study with 72 subjects would reject the null hypothesis that this
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30 response difference is zero with probability (power) 0.986. The Type I error probability
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32 associated with this test of this null hypothesis is 0.05. If the Type I error is lowered to 0.01
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34 to account for 'repeated' contrasts between conditions, the power is 0.943.²⁴ We allowed
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36 for a 10% attrition in data. The study was curtailed earlier than planned as new electronic
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38 game technologies became popular in late 2010 making it unfeasible to recruit children to
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40 the older game technology.
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47 48 **Recruitment and study procedure**

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50 Following screening, participants were randomly allocated to an order of conditions by
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52 selection of an opaque sealed envelope. A balance of orders across the year was achieved
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54 by having sets of the 6 possible order permutations in each year cohort. After informed
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3 consent/assent from parent and child, a research officer visited the home and instructed the
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5 parent and child in baseline assessments. The baseline visit included an explanation of the
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7 accelerometer along with a physical activity recall diary (see outcomes measures for detail).
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10 At baseline data was also collected on the child's height, weight, socioeconomic status,
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12 motor coordination and electronic game experience. The research officer returned after 10
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14 days to collect baseline assessments and set up the electronic game condition. This involved
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16 either removal of all electronic games or setting up electronic game equipment and
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18 instructing parent and child in its use. Follow-up phone calls were made the next day and
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20 after 6 days to ensure game equipment was working correctly. Towards the end of the 6th
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22 week in each condition, the research officer visited again to set up the physical activity
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24 assessments (accelerometer and diary). After 8 weeks in each condition the research officer
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26 returned, collected the completed activity diary and accelerometer and set up the next
27
28 condition. Assessments were scheduled to avoid school and public holidays where possible.
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30 Individualised reports were provided to participants on study completion. The research
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32 officers involved with the setting up each condition were not involved in the subsequent
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34 analyses of the primary and secondary outcomes.
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41 **Outcome measures**

42 *Primary - Physical activity and sedentary time by accelerometry*

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45 Time spent in moderate to vigorous, light and sedentary intensity physical activity was
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47 assessed over 7 days using Actical accelerometers worn on the hip. Actical is a widely used
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49 and validated accelerometer in studies of children and adolescents.²⁵⁻²⁷ The accelerometers
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51 were set to record at 15 second epoch intervals.²⁸ As per established standard practices
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53 with accelerometry, a minimum of 4 days (at least one weekend day) was regarded as a
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3 valid recording.²⁹ The minimum recording time required for a day to be considered valid was
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5 500 minutes.³⁰ Data were individually visually checked for missing values. Non-wear time,
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7 regarded as 120 minutes of consecutive zero's, was removed prior to analyses. Activity
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9 intensity thresholds based on Colley *et al.*³¹ were used to convert the raw counts into
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11 minutes of sedentary, light, moderate and vigorous intensity physical activity (MVPA).
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13 Minutes spent in each of these intensity categories were calculated for an average day over
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15 the whole week. As there are known to be variations depending on the type of day³² and
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17 time of the day³³ which may be masked in whole week analysis, analysis was also conducted
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19 on school days, weekend days, and the afterschool period (from 3.30 to 6.00pm). The after
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21 school period was chosen as this has been suggested to be an important time in the child's
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23 day for both discretionary physical activity and sedentary leisure time.³⁴ Measures of the
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25 pattern of sedentary, light and moderate-to-vigorous activity were also calculated for the
26
27 same time periods.³² A custom LabView program was used to process the data.
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34 *Secondary - Physical activity and sedentary behaviours by diary*

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37 To provide descriptive information on the type of activities performed and understand any
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39 changes in accelerometer determined exposure, participants used a modified version of the
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41 previous-day physical activity recall (PDPAR) in the form of a diary for 7 days.³⁵ The
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43 predominant activity was recorded for each 30 minute block during waking hours. Use of
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45 the PDPAR over several consecutive days, in the form of a diary has also been shown to be
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47 valid, against measures of accelerometry, and feasible.³⁶ The participants also used this
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49 diary to make a note of whether and why the accelerometer was removed for any period
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51 during the day. Active leisure, sedentary leisure and various components of sedentary
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3 leisure were assessed across the whole week, school days, weekend days and during the
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5 after school period using custom macros in Excel.
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8 *Covariates*

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11 Age, sex, BMI and electronic game experience were considered for potential modification of
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13 condition effects. Prior physical activity research has identified significant differences
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15 between summer and winter seasons and interactions with sex (more reduction in PA in
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17 winter in girls).³⁷ The potential seasonal effect was allowed for in the design by having a
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19 balanced ordering of game conditions and a staggered start to cover the whole school year.
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21
22 Previous electronic game experience which could confound the effect of the game condition
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24 was measured using a questionnaire based on our prior studies and a large USA study and
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26 used in analysis.³⁸
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33 **Statistical Analyses**

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36 Data were analysed using mixed-model repeated measures analyses to estimate the
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38 magnitude of two condition contrasts for each outcome (no games versus traditional e-
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40 games, and active e-games versus traditional e-games) using measures from participants
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42 with valid data from at least two of the three conditions, adjusting for period and, in the
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44 case of accelerometry data, accelerometer wear time. To verify the absence of influential
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46 outliers, initial screening was performed by graphical examination of condition differences
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48 plotted against averages, and standardised residuals from each model were plotted against
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50 fitted values.
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3 Statistical analysis was performed using Stata/IC 10.1 for Windows (StataCorp LP, College
4 Station TX, USA). All statistical tests were 2-tailed with $\alpha=0.05$. Analysis was by intention-to-
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Statistical analysis was performed using Stata/IC 10.1 for Windows (StataCorp LP, College Station TX, USA). All statistical tests were 2-tailed with $\alpha=0.05$. 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. At baseline, the 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.³⁹ 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 <30min (41%), though 31% usually played for 30-60min and 24% usually played for 1-2hrs. Participant socioeconomic status based on location of family home⁴⁰ ranged from the second to tenth Australian centile. Participant motor coordination status ranged from poor to excellent (MAND⁴¹ 2007:NDI 62-125; MABC-2⁴² 2009-10: 9-98%), approximating a general population.

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 827.8min). With home access to traditional games, regarded as the norm for most families at the start of this study, daily

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3 MVPA was less than one hour (mean 54.1 min, 95% confidence interval 47.5-60.7) whereas
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5 daily sedentary time was around eight and a half hours (522.7 min, 509.4-535.9).
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8 Table 1 shows that in comparison to traditional games, removal of all electronic games
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10 resulted in a 3.8 min/day (1.5-6.1, $p=0.001$) increase in MVPA in the after school period.
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12 Similar, though non-significant, increases in MVPA were observed over the whole week and
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14 on school days. The removal of all electronic games resulted in a small non-significant
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16 increase in light activity over the whole week, with a larger though still non-significant
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18 increase on weekend days. Removal of all electronic games also resulted in a significant
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20 increase on weekend days. Removal of all electronic games also resulted in a significant
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22 decrease of 4.7 min/day (0.0-9.5, $p=0.05$) in sedentary time in the after school period, which
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24 was matched with a small non-significant decrease in sedentary time over the whole week
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26 and a larger non-significant decrease on weekend days.
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3 Replacing traditional games with active input games had similar findings (Table 1). This
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5 exchange resulted in a 3.2 min/day (0.9-5.5, $p=0.007$) increase in MVPA in the after school
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7 period, with a similar though non-significant pattern of MVPA over the whole week and on
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9 school days. Replacing electronic games with active input games also resulted in a small
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11 non-significant increase in light activity over the whole week, with a larger though still non-
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13 significant increase on weekend days. Furthermore, replacement of traditional games with
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15 active input games resulted in a significant decrease in sedentary time in the after school
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17 period (6.2 min/day (1.4-11.1, $p=0.012$)). A small non-significant decrease in sedentary time
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19 over the whole week and a larger non-significant decrease on weekend days were also
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21 observed.
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Table 1: Accelerometer determined daily minutes of MVPA, light activity and sedentary time over the whole week, weekend days, school days and 3.30-6pm 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 (49.2,62.3)	54.1 (47.5,60.7)	56.1 (49.5,62.8)	1.7 (-3.2,6.6) 0.493	2.0 (-3.0,7.1) 0.428
School day	60.9 (53.9,67.8)	58.2 (51.2,65.2)	61.5 (54.4,68.5)	2.6 (-2.4,7.7) 0.306	3.2 (-2.0,8.4) 0.228
Weekend day	43.2 (34.3,52.2)	42.8 (33.7,51.9)	43.0 (33.9,52.2)	0.4 (-9.1,9.9) 0.933	0.2 (-9.5,10.0) 0.966
3.30-6pm school day	12.9 (10.3,15.5)	9.1 (6.4,11.7)	12.3 (9.6,14.9)	3.8 (1.5,6.1) 0.001	3.2 (0.9,5.5) 0.007
LIGHT PA					
Week	242.5 (230.8,254.2)	240.3 (228.5,252.2)	245.6 (233.7,257.5)	2.2 (-9.4,13.7) 0.712	5.3 (-6.6,17.2) 0.385
School day	241.3 (229.9,252.7)	242.3 (230.7,253.9)	243.8 (232.1,255.4)	-1.0 (-11.8, 9.8) 0.854	1.5 (-9.6, 12.6) 0.794
Weekend day	245.5 (228.7,262.3)	235.3 (218.3,252.4)	250.2 (233.0,267.4)	10.2 (-9.1,29.5) 0.302	14.9 (-4.9,34.6) 0.140
3.30-6pm school day	48.8 (45.3,52.4)	48.0 (44.4,51.5)	50.9 (47.2,54.5)	0.9 (-2.9,4.6) 0.649	2.9 (-1.0,6.8) 0.142
SEDENTARY					
Week	518.7 (505.6,531.7)	522.7 (509.4,535.9)	515.4 (502.1,528.7)	-4.0 (-16.8,8.8) 0.540	-7.2 (-20.4,5.9) 0.282
School day	531.1 (518.3,543.9)	532.7 (519.7,545.7)	528.3 (515.2,541.3)	-1.6 (-13.7,10.4) 0.790	-4.5 (-16.9, 8.0) 0.483
Weekend day	487.6 (468.3,507.0)	498.5 (478.8, 518.2)	483.1 (463.3,503.0)	-10.8 (-32.9,11.3) 0.336	-15.3 (-37.9,7.3) 0.184
3.30-6pm school day	88.0 (83.3,92.7)	92.7 (88.0,97.5)	86.5 (81.7,91.2)	-4.7 (-9.5,0.0) 0.050	-6.2 (-11.1,-1.4) 0.012

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3 Removing or replacing traditional electronic games had no significant effect on exposures to
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5 bouts of MVPA lasting at least 10min, bouts of sustained sedentary time lasting at least
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7 30min, or brief bursts at any intensity lasting less than 5 min and breaks in sedentary time
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9 (data not shown).
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12 Figure 2 provides a visual summary of the key daily differences in accelerometer determined
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14 activity and sedentary time, for the after school period.
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17 18 **Diary**

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20 According to diary records, in the traditional games condition, children spent on average,
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22 one and a half hours per day on active leisure and transport (mean 78min, 95% confidence
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24 intervals 63-93) and four and a half hours per day on all sedentary leisure (non-screen and
25
26 screen: 267min, 243-292). Leisure time spent on screen-based media made up more than
27
28 half of reported sedentary leisure (163min, 139-187). TV viewing was the largest contributor
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30 (107min, 85-129), followed by sedentary electronic games (44min, 37-50) and non gaming
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32 computer use (24min, 15-32).
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38 Reported non exposure to sedentary electronic games during the 'no games' (median 0 min)
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40 and 'active games' (0min) conditions and to active electronic games during the 'no
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42 games'(0min) and 'traditional games' (0min) conditions confirmed compliance with avoiding
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44 non protocol games. Reported exposure to active electronic games during the 'active
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46 games' condition was 19 min/day suggesting reasonable compliance with this condition.
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50 Similarly, reported exposure to traditional electronic games during the 'traditional games'
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52 condition was 34 min/day
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Table 2: Diary reported daily minutes of active leisure, sedentary leisure, and components of sedentary leisure in the 3.30-6pm after school period, adjusted for condition order.

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

¹median (95%CI for median), Wilcoxon sign-rank test for condition differences

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2
3 The diary records also provide context to the changes observed in accelerometry in the after
4 school period (Table 2). When looking at the after school period alone, the removal of electronic
5 games resulted in a significant decrease of 14 min/day in sedentary leisure and a corresponding
6 12 min/day increase in active leisure and transport. The breakdown of this came from a significant
7 reduction of 12 min/day of screen sedentary leisure (8 min (median) of which was sedentary
8 electronic game exposure), a non significant reduction of 3 min/day in non screen sedentary
9 leisure and a non significant reduction in non-game computer use by 1 min/day. TV viewing was
10 reported to increase by 3 min/day, though this was not significant.

11
12 Again, when looking at the after school period, replacing traditional electronic games with active
13 electronic games resulted in an overall decrease of 21 min/day in sedentary leisure and a
14 corresponding non significant increase of 3 min/day in active leisure and transport along with
15 8min/day (median) of active input game time: ie an overall increase of activity time of about 11
16 min/day. The reduced sedentary time was achieved through a significant decrease of 14 min/day
17 in sedentary screen leisure and a 7 min/day non significant reduction in non-screen sedentary
18 leisure. No significant changes in TV viewing (0 min/day), or non-game computer use (-1 min/day)
19 were reported when active input games were introduced. The diary reported changes in both the
20 removal and replacement of traditional electronic games conditions provide the context to the
21 accelerometer measured activity differences during the after school period (see text within Figure
22 2).

23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 **DISCUSSION**

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54 This randomised controlled study showed that removing access to sedentary electronic games in
55 children's homes, or replacing them with active electronic games, resulted in small but significant
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3 increases in physical activity and reductions in sedentary time in after school time. No significant
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5 effects on overall daily or weekly activity or sedentary time were observed.
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9 This is the first randomised controlled study, in the real world setting of the home, to assess the
10
11 two alternatives parents have for reducing the time their children spend on sedentary electronic
12
13 games: removal or replacement with something more active. The study findings suggest that
14
15 parents choosing either option may see a small improvement, more activity and less
16
17 sedentariness, in the after school period. Our study corroborates previous research that has
18
19 shown this time to be a 'critical window' for intervening with physical activity⁴³ and supports
20
21 more recent qualitative findings that suggest it is also an important time in the day to reduce
22
23 children's screen viewing.³⁴ The magnitude of effect, approximately 5 minutes more activity and 5
24
25 minutes less sedentary time, is similar to improvements observed in other home based studies.
26
27
28
29 Maddison et al¹³ found a self reported 10 minute increase in active games use when they were
30
31 provided in addition to traditional games in a 6 month study. Whilst Baranowski et al¹⁵ observed
32
33 no objectively measured increase in daily MVPA or decrease in daily sedentary time in their home
34
35 based study, day type or specific day periods were not studied.
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40 On its own the magnitude of the change observed is unlikely to be of clinical importance, however
41
42 it needs to be seen in the context of electronic games being part of the rapidly growing exposure
43
44 that children have to screen based media. Whilst traditional television viewing appears to be
45
46 stable,⁶ leisure time exposure to console based electronic games and computing is increasing
47
48 rapidly,⁶ as is the increase in mobile smart phones and touch screen tablets that are used for e-
49
50 gaming, social networking, video viewing, and internet surfing.⁷ Therefore small changes across a
51
52 variety of these platforms could result in a more significant clinical impact. Whilst our study
53
54 focussed on the home-setting, school offers another opportunity for more active technologies.⁴⁷
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3 Children sit for a long time at school and there is potential to further reduce sedentariness by
4
5 engaging with technologies such as sit-stand desks, or active-input electronic media as part of
6
7 lessons.³²
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10
11 The strengths of the study include the strong within subjects randomised controlled trial design
12
13 with staggered starts and counterbalanced orders to control extraneous factors. The participants
14
15 were representative of a general population of 10-12 year old children in terms of sex, weight,
16
17 motor coordination, electronic game experience and socio-economic status, informing the likely
18
19 broad impact of replacement as a public health intervention. The study was also grounded in the
20
21 naturalistic setting of the family home. Whilst active-input technologies have been tested by
22
23 children in the laboratory and found to increase energy expenditure, this does not account for
24
25 what happens in practice when the active games are amongst a milieu of other distractions.¹⁶
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28
29 Furthermore, this is the first study to examine the effects of fully removing electronic games from
30
31 the home. The study also used active electronic game technology with a known capacity to
32
33 increase whole body movement and energy expenditure, rather than the Wii which children can
34
35 play with only hand movement. Some Wii based games have been found to be little different to
36
37 traditional sedentary electronic games.⁴⁴ The study also provided a substantial range and variation
38
39 in game offerings, addressing the known issue of active games being less engaging,⁴⁴ although it
40
41 was difficult at times to keep participants engaged as the most popular game genre – killing – was
42
43 excluded from the study on ethical grounds. The other key strength of the study is that it used an
44
45 objective measure of physical activity and sedentary time and supplemented this with self-
46
47 reported diary measures to aid understanding and interpretation of results.
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54 The main weakness was the need to curtail the study one year early due to technology changes,
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56 which meant we were unable to determine whether the 10-15 minute change in sedentary and
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3 light intensity activity on weekends was real. Further, whilst the diaries suggested compliance to
4
5 both conditions was good, we did not have a way of measuring precisely how much the active
6
7 games were used.¹⁶
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10
11 The accelerometer data presented here showed small improvements in whole body movement,
12
13 which may be useful for a range of physiological effects, one of which is energy expenditure.
14
15 However the actual energy expenditure, and thus the likely impact on obesity, should also be
16
17 determined. The small improvements seen at a group level may mask varied changes for
18
19 individuals, with the potential for the exposure of some individuals to be markedly effected. Thus
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21 the effect modification of factors such as sex, age, electronic game experience attitudes to
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23 technology and physical activity, motor competence and weight status should also be examined.
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29 Given the strong evidence for detrimental effects of too little physical activity and too much
30
31 sedentary time,^{45, 46} in particular too much screen time³ and the potential interaction between
32
33 these in children,²⁰ there is a mounting need to understand childhood behaviours and intervene.
34
35 Children in this study were sedentary for just over 8 hours per day and reported spending
36
37 approximately three hours per day on screen based leisure, on the low side but comparable with
38
39 international findings.^{6,7} Given this high sedentary exposure, health care practitioners should use
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41 all available opportunities to encourage children (and their parents) to be more active and less
42
43 sedentary. Sigman³ has recently called for the medical community to take a more proactive
44
45 approach to reducing children's screen time exposure. With the increasingly electronic media
46
47 enmeshed world of youth, it is unrealistic for parents to remove access to screen based media
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49 completely and therefore parents and health professionals alike need to work with technology to
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51 assist its development in ways which are health enhancing rather than health reducing. It was
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53 encouraging in this study that the replacing option resulted in at least as good an outcome as
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3 removing, and this may potentially result in more successful long term outcomes due to better
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5 sustained compliance.
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8 **CONCLUSION**

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11 Screen based media is a major component of leisure sedentary behaviour and interventions
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13 should be targeted to TV, computer and electronic game use. This study has shown that replacing
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15 sedentary with active electronic games will provide at least as good an activity outcome and
16
17 perhaps be easier for parent and child to sustain than removing technology from the home.
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25 *Acknowledgements:* We thank all the children and their families for their dedication. We thank D
26
27 Metcalf, A Campbell, R Collins, J Coleman, D Gill and J Chua for help with data collection and
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29 processing.
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Contributors: All authors had full access to the data and can take responsibility for the integrity of
the data and accuracy of the data analyses. LS conceived and managed the study; LS, RA and AS
designed the study; AS analysed the data; LS and RA drafted the manuscript; LS, RA and AS edited,
critically revised and approved the manuscript.

Funding: The study was funded by a National Health and Medical Research Council of Australia
project grant (533526). LS is on a fellowship funded by the National Health and Medical Research
Council of Australia. The funding body had no influence on the analysis and reporting of the study.

Competing interests: none declared. All authors have completed the Unified Competing Interest
form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author)
and declare: LS had financial support from an NHMRC senior research fellowship for the

1
2
3 submitted work, no financial support for RA or AS; no financial relationships with any
4
5 organisations that might have an interest in the submitted work in the previous 3 years; no other
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7 relationships or activities that could appear to have influenced the submitted work.
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11 *Ethical approval:* The study had ethical approval from the Human Research Ethics Committee of
12
13 Curtin University (approval number HR131/2006). All participating children and their parents gave
14
15 informed assent/consent.
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19 *Data sharing:* no additional data available
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24 does grant on behalf of all authors, a worldwide licence to the Publishers and its licensees in
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Figure Legends:

Figure 1. CONSORT Diagram of flow of Participants

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

For peer review only



CONSORT 2010 checklist of information to include when reporting a randomised trial*

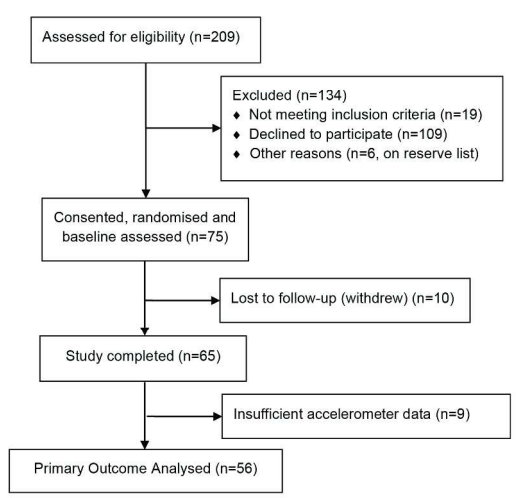
Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2,3
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	5
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	5
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	na
Participants	4a	Eligibility criteria for participants	6
	4b	Settings and locations where the data were collected	6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	8-9
	6b	Any changes to trial outcomes after the trial commenced, with reasons	na
Sample size	7a	How sample size was determined	7
	7b	When applicable, explanation of any interim analyses and stopping guidelines	na
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	7
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	7
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	7
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	na
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	8

1			
2		assessing outcomes) and how	
3			
4		11b If relevant, description of the similarity of interventions	na
5	Statistical methods	12a Statistical methods used to compare groups for primary and secondary outcomes	10-11
6		12b Methods for additional analyses, such as subgroup analyses and adjusted analyses	10-11
7			
8	Results		
9	Participant flow (a	13a For each group, the numbers of participants who were randomly assigned, received intended treatment, and	Fig 1
10	diagram is strongly	were analysed for the primary outcome	
11	recommended)	13b For each group, losses and exclusions after randomisation, together with reasons	Fig 1
12	Recruitment	14a Dates defining the periods of recruitment and follow-up	5
13		14b Why the trial ended or was stopped	na
14			
15	Baseline data	15 A table showing baseline demographic and clinical characteristics for each group	In text, 11
16	Numbers analysed	16 For each group, number of participants (denominator) included in each analysis and whether the analysis was	NA
17		by original assigned groups	(crossover)
18			
19	Outcomes and	17a For each primary and secondary outcome, results for each group, and the estimated effect size and its	
20	estimation	precision (such as 95% confidence interval)	Table 1
21		17b For binary outcomes, presentation of both absolute and relative effect sizes is recommended	na
22	Ancillary analyses	18 Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing	na
23		pre-specified from exploratory	
24			
25	Harms	19 All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	na
26			
27	Discussion		
28	Limitations	20 Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	16-17
29	Generalisability	21 Generalisability (external validity, applicability) of the trial findings	15-17
30	Interpretation	22 Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	15-17
31			
32	Other information		
33	Registration	23 Registration number and name of trial registry	3
34	Protocol	24 Where the full trial protocol can be accessed, if available	5
35	Funding	25 Sources of funding and other support (such as supply of drugs), role of funders	18
36			

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

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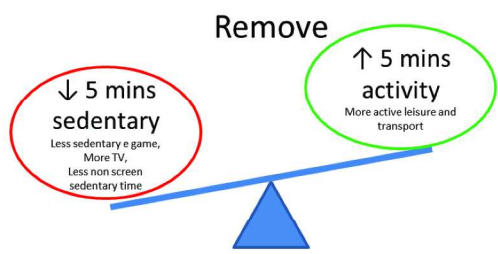
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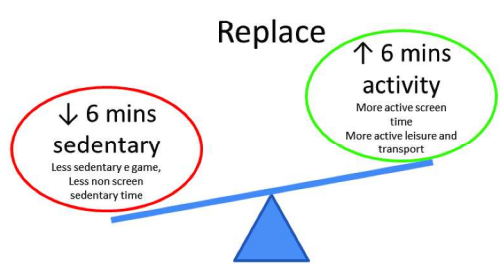
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To remove or to replace traditional electronic games? A cross-over randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children aged 10-12 years.

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-002629.R1
Article Type:	Research
Date Submitted by the Author:	03-May-2013
Complete List of Authors:	Straker, Leon; Curtin University, Department of Physiotherapy Abbott, Rebecca; University of Exeter, Medical School Smith, Anne; Curtin University, School of Physiotherapy
Primary Subject Heading:	Public health
Secondary Subject Heading:	Sports and exercise medicine, Epidemiology, Paediatrics, Public health
Keywords:	child, physical activity, sedentary behaviour, accelerometry, screentime

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To remove or to replace traditional electronic games? A cross-over randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children.

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Word count: 4467

Abstract word count: 300

Number of tables: 2

Number of figures: 2

Number of references: 50

Keywords children, physical activity, sedentary behaviour, accelerometry, screentime

ABSTRACT

Objective To evaluate the impact of a) the removal of home access to traditional electronic games, or b) their replacement with active input electronic games, on daily physical activity and sedentary behaviour in children aged 10-12 years.

Design Cross-over randomised controlled trial, over 6 months.

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

Participants 10-12 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 3.8min/day, 95% CI 1.5 to 6.1) and a decrease in sedentary time (4.7min/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 (3.2min/day, 0.9 to 5.5) and a decrease in sedentary time (6.2min/day, 1.4 to 11.4) in the after school period. Diary reports supported an increase in

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3 physical activity and decrease in screen based sedentary behaviours with both
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5 interventions.
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8 **Conclusion** Removal of sedentary electronic games from the child's home and replacing
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10 these with active electronic games both resulted in small objectively measured
11
12 improvements in after school activity and sedentary time. Parents can be advised that
13
14 replacing sedentary games with active electronic games is likely to have the same effect as
15
16 removing all electronic games.
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20 **Trial Registration** Australia and New Zealand Clinical Trials Registry (ACTRN
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22 12609000279224)
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INTRODUCTION

It is well recognised that physical activity 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 physical activity and increase in sedentary time.^{3,4} Electronic games are played on various devices including dedicated consoles (e.g. Microsoft Xbox®, Sony PlayStation 3®, Nintendo Wii®) and hand held players (e.g. Nintendo DS®, PlayStationPSP®) as well as non-dedicated technologies such as computers, tablets and smart phones. International evidence shows the majority of children in affluent countries now have substantial daily exposure to electronic games. For example in the UK, approximately half of children spend over an hour per day using computer games alone.⁵ In the United States, 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 UK, USA and Australia range from 38min/day to 90min/day.⁶⁻⁸

Whilst 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 physical activity (i.e. 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 physical activity level, with a similar relationship for obesity.¹¹ However, to date, 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

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3 controversy. Laboratory studies have shown that some of these active games can result in
4
5 meaningful increases in muscle activity, movement and energy expenditure whilst others
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7 result in less activity.^{12, 13} Findings from the few available home-based interventions
8
9 comparing access to traditional electronic games alone with supplemental access to active
10
11 electronic games have been mixed: with some evidence for improvements in body fatness,
12
13 ¹⁴ and fitness in overweight children, ¹⁵ though no effect on objectively measured physical
14
15 activity for a sample including both overweight and normal weight children.¹⁶ The long term
16
17 efficacy of active games in promoting physical activity remains questionable,^{13, 17} but with
18
19 potential promise.¹⁸

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21
22 With no clear evidence either way, the public health response to date has been to develop
23
24 recommendations to restrict all children's screen based leisure (television, computers and
25
26 all electronic games), typically to maximum of 2hrs a day.^{19, 20} Compliance with these
27
28 guidelines has been poor,^{21, 22} which may be due to difficulties experienced by parents when
29
30 trying to implement the guidelines. Options for parents include removing electronic games
31
32 from the family home or replacing traditional electronic games with active electronic games.
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34 To date there has been no study evaluating the effect of both these approaches. Therefore
35
36 this study sought to explore, through a cross-over randomised controlled trial, the effect of
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38 either removing electronic games from the children's home environment or replacing
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40 traditional sedentary electronic games with active input electronic games on children's
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42 physical activity and sedentary behaviour.
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METHODS

Study design methods and participants

This study used a within subjects cross-over randomised controlled trial design and was conducted in Perth, Western Australia in 2007-2010. The detailed design of the study protocol has been previously described.²³ In summary, 10-12 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 diary and questionnaires,²⁴ have a high use of electronic games⁶ and are developing activity and sedentary behaviour patterns pre-adolescence which may track into adulthood.^{25, 26} Recruitment was staggered over three years to account for seasonal variation and targeted to enable participation of equal numbers of males and females, and children representative of a spread of socio-economic 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 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 6 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. 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. From our pilot study and discussions with children, the removal of all electronic games was acceptable as a way of getting access to a range of new games and equipment for four months. This is why a within subjects design was chosen.

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 physical activity level between repeated time points in each individual is normally distributed with standard deviation 30 min, and the true effect of 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

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3 to account for 'repeated' contrasts between conditions, the power is 0.943.²⁸ We allowed
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5 for a 10% attrition in data. The study was curtailed earlier than planned as new electronic
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7 game technologies (Sony PlayStation 3[®] and Microsoft Xbox Kinect[®]) became popular in late
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9 2010 in Perth making it unfeasible to recruit children to the older game technology. Data
10
11 from 9 children who participated in the 2007 pilot study using the same activity and
12
13 condition protocol were included to provide the best estimate of intervention effects.
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16 17 18 **Recruitment and study procedure** 19

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21 Following screening, participants were randomly allocated to an order of conditions by
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23 selection of an opaque sealed envelope. A balance of orders across the year was achieved
24
25 by having sets of the 6 possible order permutations in each year cohort. After informed
26
27 consent/assent from parent and child, a research officer visited the home and instructed the
28
29 parent and child in baseline assessments. The baseline visit included an explanation of the
30
31 accelerometer along with a physical activity recall diary (see outcomes measures for detail).
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33 At baseline data were also collected on the child's height, weight, socioeconomic status,
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35 motor coordination and electronic game experience. The research officer returned after 10
36
37 days to collect baseline assessments and set up the electronic game condition. This involved
38
39 either removal of all electronic games or setting up electronic game equipment and
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41 instructing parent and child in its use. Follow-up phone calls were made the next day and
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43 after 6 days to ensure game equipment was working correctly. Towards the end of the 6th
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45 week in each condition, the research officer visited again to set up the physical activity
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47 assessments (accelerometer and diary). After 8 weeks in each condition the research officer
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49 returned, collected the completed activity diary and accelerometer and set up the next
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51 condition. Assessments were scheduled to avoid school and public holidays where possible.
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3 Individualised reports were provided to participants on study completion. The research
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5 officers involved with the setting up each condition were not involved in the subsequent
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7 analyses of the primary and secondary outcomes.
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10 **Outcome measures**

11 *Physical activity and sedentary time by accelerometry*

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14 The primary outcome was the mean daily minutes of MVPA over the whole week. Time
15
16 spent in moderate to vigorous, light and sedentary intensity physical activity was assessed
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18 over 7 days using Actical accelerometers worn on the hip. Actical is a widely used and
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20 validated accelerometer in studies of children and adolescents.²⁹⁻³¹ The accelerometers
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22 were set to record at 15 second epoch intervals.³² As per established standard practices
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24 with accelerometry, a minimum of 4 days (at least one weekend day) was regarded as a
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26 valid recording.³³ The minimum recording time required for a day to be considered valid was
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28 500 minutes.⁷ Data were individually visually checked for missing values. Non-wear time,
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30 regarded as 120 minutes of consecutive zero's (based on pilot data showing children could
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32 accumulate more than 60 minutes of consecutive zero counts when watching television),
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34 was removed prior to analyses. Activity intensity thresholds based on Colley *et al.*³⁴ were
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36 used to convert the raw counts into minutes of sedentary, light, moderate and vigorous
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38 intensity physical activity. Minutes spent in each of these intensity categories were
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40 calculated for an average day over the whole week. As there are known to be variations
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42 depending on the type of day³⁵ and time of the day³⁶ which may be masked in whole week
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44 analysis, analysis was also conducted on school days, weekend days, and the afterschool
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46 period (from 3.30 to 6.00pm). The after school period was chosen as this has been
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48 suggested to be an important time in the child's day for both discretionary physical activity
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3 and sedentary leisure time.³⁷ Measures of the pattern of sedentary, light and moderate-to-
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5 vigorous activity were also calculated for the same time periods.³⁸ custom LabView
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7 program was used to process the data.
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10 *Physical activity and sedentary behaviours by diary*

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14 To provide descriptive information on the type of activities performed and understand any
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16 changes in accelerometer determined exposure, participants used a modified version of the
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18 previous-day physical activity recall (PDPAR) in the form of a diary for 7 days.³⁹ The
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20 predominant activity was recorded for each 30 minute block during waking hours. Use of
21
22 the PDPAR over several consecutive days, in the form of a diary has also been shown to be
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24 valid, against measures of accelerometry, and feasible.⁴⁰ The participants also used this
25
26 diary to make a note of whether and why the accelerometer was removed for any period
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28 during the day. Active leisure, sedentary leisure and various components of sedentary
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30 leisure were assessed across the whole week, school days, weekend days and during the
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32 after school period using custom macros in Excel.
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38 *Covariates*

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41 Age, sex, BMI and electronic game experience were considered for potential modification of
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43 condition effects. Prior physical activity research has identified significant differences
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45 between summer and winter seasons and interactions with sex (more reduction in PA in
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47 winter in girls).⁴¹ The potential seasonal effect was allowed for in the design by having a
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49 balanced ordering of game conditions and a staggered start to cover the whole school year.
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Previous electronic game experience which could confound the effect of the game condition

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3 was measured using a questionnaire based on our prior studies and a large USA study and
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5 used in analysis.⁴²
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8 **Statistical Analyses**

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11 Data were analysed using mixed-model repeated measures analyses to estimate the
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13 magnitude of two condition contrasts for each outcome (no games versus traditional
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15 electronic games, and active electronic games versus traditional electronic games) using
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17 measures from participants with valid data from at least two of the three conditions,
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19 adjusting for period and, in the case of accelerometry data, accelerometer wear time.
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21 Statistical significance for a carryover effect (treatment by period interaction) was set at
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23 $p < 0.1$. To verify the absence of influential outliers, initial screening was performed by
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25 graphical examination of condition differences plotted against averages, and standardised
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27 residuals from each model were plotted against fitted values.
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33 Statistical analysis was performed using Stata/IC 10.1 for Windows (StataCorp LP, College
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35 Station TX, USA). All statistical tests were 2-tailed with $\alpha = 0.05$. Analysis was by intention-to-
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37 treat, though per protocol analysis was also conducted, with the 33 participants who used
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39 active games for more than 15 min/day during the active e-game condition.
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43 **RESULTS**

44 **Participants**

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47 Figure 1 shows the participant flow chart. Eight participants provided baseline data but
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49 withdrew during their first condition (6 male, mean age 10.5 years, height 1.48m , weight
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51 48.3kg , socioeconomic status range 5th to 9th centile, 4 condition orders). Ten participants
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53 completed the study but had insufficient accelerometer data after all three conditions (5
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3 male, mean age 11.4 years, height 1.48m, weight 43.8kg, socioeconomic status range 3rd to
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5 10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female)
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7 who completed the study and had sufficient accelerometry data for planned analyses had a
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9 mean (sd) age of 11.3 (0.8) years. Participant height (1.50 (0.08) m), weight (41.3 (10.3) kg)
10
11 and zBMI (-0.1 (1.2)) were similar to the national distribution for this age.⁸ Nearly all
12
13 children had home access to electronic games (91%) and reported playing electronic games
14
15 in the last month (95%), with 61% reporting playing at least 2-3 times a week. Duration of
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17 playing sessions was most commonly <30min (41%), though 31% usually played for 30-
18
19 60min and 24% usually played for 1-2hrs. Participant socioeconomic status based on
20
21 location of family home⁴³ ranged from the second to tenth Australian centile. Participant
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23 motor coordination status ranged from poor to excellent (MAND⁴⁴ 2007:NDI 62-125; MABC-
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25 2⁴⁵ 2009-10: 9-98%), approximating a general population.
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32 Accelerometry

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35 Daily accelerometer wear time was around 827.8 min over the week, and was somewhat
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37 shorter on weekend days than school days (788.9 vs 827.8min). With home access to
38
39 traditional games, regarded as the norm for most families at the start of this study, daily
40
41 MVPA was less than one hour (mean 54.1 min, 95% CI 47.5 to 60.7) whereas daily sedentary
42
43 time was around eight and a half hours (522.7 min, 509.4 to 535.9).
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46
47 Table 1 shows that in comparison to traditional games, removal of all electronic games
48
49 resulted in no significant change in daily MVPA over the whole week. However it did result
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51 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
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53 similar, though non-significant, increase in MVPA was observed over the whole school day.
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57 The removal of all electronic games resulted in a small non-significant increase in light
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3 activity over the whole week, with a larger though still non-significant increase on weekend
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5 days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day
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7 (0.0 to 9.5, $p=0.05$) in sedentary time in the after school period, which was matched with a
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9 small non-significant decrease in sedentary time over the whole week and a larger non-
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11 significant decrease on weekend days. Replacing traditional games with active input games
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13 had similar findings (Table 1). This exchange resulted in no significant change in MVPA over
14
15 the whole week but a 3.2 min/day (0.9 to 5.5, $p=0.007$) increase in MVPA in the after school
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17 period, with a similar though non-significant pattern of MVPA over the whole school day.
18
19 Replacing electronic games with active input games also resulted in a small non-significant
20
21 increase in light activity over the whole week, with a larger though still non-significant
22
23 increase on weekend days. Furthermore, replacement of traditional games with active input
24
25 games resulted in a significant decrease in sedentary time in the after school period of 6.2
26
27 min/day (1.4 to 11.1, $p=0.012$). A small non-significant decrease in sedentary time over the
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29 whole week and a larger non-significant decrease on weekend days were also observed.
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Table 1: Accelerometer determined daily minutes of MVPA, light activity and sedentary time over the whole week, weekend days, school days and 3.30-6pm 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 (49.2,62.3)	54.1 (47.5,60.7)	56.1 (49.5,62.8)	1.7 (-3.2,6.6) 0.493	2.0 (-3.0,7.1) 0.428
School day	60.9 (53.9,67.8)	58.2 (51.2,65.2)	61.5 (54.4,68.5)	2.6 (-2.4,7.7) 0.306	3.2 (-2.0,8.4) 0.228
Weekend day	43.2 (34.3,52.2)	42.8 (33.7,51.9)	43.0 (33.9,52.2)	0.4 (-9.1,9.9) 0.933	0.2 (-9.5,10.0) 0.966
3.30-6pm school day	12.9 (10.3,15.5)	9.1 (6.4,11.7)	12.3 (9.6,14.9)	3.8 (1.5,6.1) 0.001	3.2 (0.9,5.5) 0.007
LIGHT PA					
Week	242.5 (230.8,254.2)	240.3 (228.5,252.2)	245.6 (233.7,257.5)	2.2 (-9.4,13.7) 0.712	5.3 (-6.6,17.2) 0.385
School day	241.3 (229.9,252.7)	242.3 (230.7,253.9)	243.8 (232.1,255.4)	-1.0 (-11.8, 9.8) 0.854	1.5 (-9.6, 12.6) 0.794
Weekend day	245.5 (228.7,262.3)	235.3 (218.3,252.4)	250.2 (233.0,267.4)	10.2 (-9.1,29.5) 0.302	14.9 (-4.9,34.6) 0.140
3.30-6pm school day	48.8 (45.3,52.4)	48.0 (44.4,51.5)	50.9 (47.2,54.5)	0.9 (-2.9,4.6) 0.649	2.9 (-1.0,6.8) 0.142
SEDENTARY					
Week	518.7 (505.6,531.7)	522.7 (509.4,535.9)	515.4 (502.1,528.7)	-4.0 (-16.8,8.8) 0.540	-7.2 (-20.4,5.9) 0.282
School day	531.1 (518.3,543.9)	532.7 (519.7,545.7)	528.3 (515.2,541.3)	-1.6 (-13.7,10.4) 0.790	-4.5 (-16.9, 8.0) 0.483
Weekend day	487.6 (468.3,507.0)	498.5 (478.8, 518.2)	483.1 (463.3,503.0)	-10.8 (-32.9,11.3) 0.336	-15.3 (-37.9,7.3) 0.184
3.30-6pm school day	88.0 (83.3,92.7)	92.7 (88.0,97.5)	86.5 (81.7,91.2)	-4.7 (-9.5,0.0) 0.050	-6.2 (-11.1,-1.4) 0.012

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3 Removing or replacing traditional electronic games had no significant effect on exposures to
4
5 bouts of MVPA lasting at least 10min, bouts of sustained sedentary time lasting at least
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7 30min, or brief bursts at any intensity lasting less than 5 min and breaks in sedentary time
8
9 (data not shown).
10

11
12 Figure 2 provides a visual summary of the key daily differences in accelerometer determined
13
14 activity and sedentary time, for the after school period.
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17 18 **Diary**

19
20 According to diary records, in the traditional games condition, children spent on average,
21
22 one and a half hours per day on active leisure and transport (mean 78min, 95% CI 63 to 93)
23
24 and four and a half hours per day on all sedentary leisure (non-screen and screen: 267min,
25
26 243 to 292). Leisure time spent on screen-based activities made up more than half of
27
28 reported sedentary leisure (163min, 139 to 187). Television viewing was the largest
29
30 contributor (107min, 85 to 129), followed by sedentary electronic games (44min, 37 to 50)
31
32 and non-gaming computer use (24min, 15 to 32).
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38 Participants reported exposure to active electronic games during the 'active games'
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40 condition of 19 min/day, suggesting reasonable compliance with this condition. Similarly,
41
42 participants reported exposure to traditional electronic games during the 'traditional games'
43
44 condition of 34 min/day. Participant median exposure to sedentary electronic games was
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46 zero minutes during the 'no games' and 'active games' conditions. Similarly, participant
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48 median exposure to active electronic games was zero minutes during the 'no games' and
49
50 'traditional games' conditions, suggesting compliance with avoiding non protocol games.
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Table 2: Diary reported daily minutes of active leisure, sedentary leisure, and components of sedentary leisure in the 3.30-6pm after school period, adjusted for condition order.

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

¹median (95%CI for median), Wilcoxon sign-rank test for condition differences

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3 The diary records also provide context to the changes observed in accelerometry in the after
4 school period (Table 2). When looking at the after school period alone, the removal of electronic
5 games resulted in a significant decrease of 14 min/day in sedentary leisure and a corresponding
6 12 min/day increase in active leisure and transport. The breakdown of this came from a significant
7 reduction of 12 min/day of screen sedentary leisure (8 min (median) of which was sedentary
8 electronic game exposure), a non significant reduction of 3 min/day in non screen sedentary
9 leisure and a non significant reduction in non-game computer use by 1 min/day. Television
10 viewing was reported to increase by 3 min/day, though this was not significant.

11
12 Again, when looking at the after school period, replacing traditional electronic games with active
13 electronic games resulted in an overall decrease of 21 min/day in sedentary leisure and a
14 corresponding non significant increase of 3 min/day in active leisure and transport along with
15 8min/day (median) of active input game time: i.e. an overall increase of activity time of about 11
16 min/day. The reduced sedentary time was achieved through a significant decrease of 14 min/day
17 in sedentary screen leisure and a 7 min/day non significant reduction in non-screen sedentary
18 leisure. No significant changes in television viewing (0 min/day), or non-game computer use (-1
19 min/day) were reported when active input games were introduced. The diary reported changes in
20 both the removal and replacement of traditional electronic games conditions provide the context
21 to the accelerometer measured activity differences during the after school period (see text within
22 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 physical activity 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 physical activity⁴⁶ 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 minutes more activity and 5 minutes less sedentary time, is similar to improvements observed in other home based studies. Maddison et al¹⁴ found a self reported 10 minute increase in active games use and a self reported reduction in sedentary electronic game use when children were provided with active electronic games in addition to traditional electronic games in a 6 month study. Whilst Baranowski et al¹⁶ 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. Whilst time spent viewing television appears to be stable,⁶ leisure time exposure to console based electronic games and computing is increasing

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2
3 rapidly,⁶ as is the increase in mobile smart phones and touch screen tablets that are used for
4
5 electronic gaming, social networking, video viewing, and internet surfing.⁴⁷ Therefore small
6
7 changes across a variety of these platforms could result in a more substantial clinical impact.
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9

10 Whilst our study focussed on the home-setting, school offers another opportunity for more active
11
12 technologies.⁴⁸ Children sit for a long time at school and there is potential to further reduce
13
14 sedentariness by engaging with technologies such as sit-stand desks, or active-input electronic
15
16 media as part of lessons.³⁵
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20 The strengths of the study include the strong within subjects randomised controlled trial design
21
22 with staggered starts and counterbalanced orders to control for extraneous factors. The
23
24 participants were representative of a general population of 10-12 year old children in terms of
25
26 sex, weight, motor coordination, electronic game experience and socio-economic status,
27
28 informing the likely broad impact of replacement as a public health intervention. The study was
29
30 also grounded in the naturalistic setting of the family home. Whilst active-input technologies have
31
32 been tested by children in the laboratory and found to increase energy expenditure, this does not
33
34 account for what happens in practice when the active games are amongst a milieu of other
35
36 distractions.¹⁷ Furthermore, this is the first study to examine the effects of fully removing
37
38 electronic games from the home. The study also used active electronic game technology with a
39
40 known capacity to increase whole body movement and energy expenditure, rather than the Wii®
41
42 which children can play with only hand movement. Some Wii® based games have been found to
43
44 be little different to traditional sedentary electronic games.⁴⁹ The study also provided a
45
46 substantial range and variation in game offerings, addressing the known issue of active games
47
48 being less engaging,⁴⁹ although it was difficult at times to keep participants engaged as the most
49
50 popular game genre – killing – was excluded from the study on ethical grounds. The other key
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1
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3 strength of the study is that it used an objective measure of physical activity and sedentary time
4
5 and supplemented this with self-reported diary measures to aid understanding and interpretation
6
7 of results.
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10
11 The main weakness was the need to curtail the study one year early due to electronic game
12
13 technology changes, specifically the widespread introduction during late 2010 of new active
14
15 electronic game devices Xbox Kinect® and PlayStation Move®. These new technologies and the
16
17 active games available on these devices were qualitatively different and could not simply replace
18
19 the older devices in the same protocol. This meant children were unwilling to agree to the original
20
21 protocol and thus recruitment ceased. The inability to recruit participants for the final planned
22
23 year resulted in a reduced sample size which was partly compensated for by using data from 9
24
25 subjects who participated in the protocol in 2007. The reduced numbers meant we were unable to
26
27 determine whether the 10-15 minute change in sedentary and light intensity activity on weekends
28
29 was real. The withdrawal of participants and the lack of adequate accelerometry data on some
30
31 participants are other obvious limitations. A further limitation was that whilst the diaries
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33 suggested compliance to both conditions was good, we did not have a way of measuring precisely
34
35 how much the active games were used.¹⁷
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42 The accelerometer data presented here showed small improvements in whole body movement,
43
44 which may be useful for a range of physiological effects, one of which is energy expenditure.
45
46 However the actual energy expenditure, and thus the likely impact on obesity, should also be
47
48 determined. The small improvements seen at a group level may mask varied changes for
49
50 individuals, with the potential for the exposure of some individuals to be markedly effected. Thus
51
52 the effect modification of factors such as sex, age, electronic game experience, attitudes to
53
54 technology and physical activity, motor competence and weight status should also be examined.
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3 Given the strong evidence for detrimental effects of too little physical activity and too much
4
5 sedentary time,^{50, 51} in particular too much screen time³ and the potential interaction between
6
7 these in children,²¹ there is a mounting need to understand childhood behaviours and intervene.
8
9 Children in this study were sedentary for just over 8 hours per day and reported spending
10
11 approximately three hours per day on screen based leisure, on the low side but comparable with
12
13 international findings.^{6, 47} Given this high sedentary exposure, health care practitioners should use
14
15 all available opportunities to encourage children (and their parents) to be more active and less
16
17 sedentary. Sigman³ has recently called for the medical community to take a more proactive
18
19 approach to reducing children's screen time exposure. With the increasingly electronic media
20
21 enmeshed world of youth, it is unrealistic for parents to remove access to screen based leisure
22
23 completely and therefore parents and health professionals alike need to work with technology to
24
25 assist its development in ways which are health enhancing rather than health reducing. It was
26
27 encouraging in this study that the replacing option resulted in at least as good an outcome as
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29 removing, and this may potentially result in more successful long term outcomes due to better
30
31 sustained compliance.
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39 **CONCLUSION**

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42 Screen based leisure is a major component of sedentary behaviour and interventions should be
43
44 targeted to television, computer and electronic game use. This study has shown that replacing
45
46 sedentary with active electronic games will provide at least as good an activity outcome and
47
48 perhaps be easier for parent and child to sustain than removing electronic game technology from
49
50 the home.
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3 *Acknowledgements:* We thank all the children and their families for their dedication. We thank D
4
5 Metcalf, A Campbell, R Collins, J Coleman, D Gill and J Chua for help with data collection and
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7 processing.
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11 *Contributors:* All authors had full access to the data and can take responsibility for the integrity of
12
13 the data and accuracy of the data analyses. LS conceived and managed the study; LS, RA and AS
14
15 designed the study; AS analysed the data; LS and RA drafted the manuscript; LS, RA and AS edited,
16
17 critically revised and approved the manuscript.
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20
21 *Funding:* The study was funded by a National Health and Medical Research Council of Australia
22
23 project grant (533526). LS was on a fellowship funded by the National Health and Medical
24
25 Research Council of Australia. The funding body had no influence on the analysis and reporting of
26
27 the study.
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31 *Competing interests:* none declared. All authors have completed the Unified Competing Interest
32
33 form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author)
34
35 and declare: LS had financial support from an NHMRC senior research fellowship for the
36
37 submitted work, no financial support for RA or AS; no financial relationships with any
38
39 organisations that might have an interest in the submitted work in the previous 3 years; no other
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41 relationships or activities that could appear to have influenced the submitted work.
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46 *Ethical approval:* The study had ethical approval from the Human Research Ethics Committee of
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48 Curtin University (approval number HR131/2006). All participating children and their parents gave
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50 informed assent/consent.
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54 *Data sharing:* no additional data available
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ARTICLE SUMMARY

Article Focus:

- Physical activity 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 home, 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 to 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 physical activity and sedentary behaviour supplemented with self-report measures.
- Longer term studies are needed to assess whether the small effects observed over eight weeks are sustained.

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3 **Figure Legends:**
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6 Figure 1. CONSORT diagram of flow of participants. Order of conditions is shown with
7 T=traditional electronic games, A=active electronic games and X= not electronic games.
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11 Figure 2. Summary of impact of removing or replacing traditional electronic games in terms of
12 objectively measured activity time (MVPA and light) and sedentary time during the after school
13 period along with diary determined changes in activities.
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To remove or to replace traditional electronic games? A ~~within subject~~cross-over randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children.

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Word count: [4467](#)

Abstract word count: [299](#)

Number of tables: 2

Number of figures: 2

Number of references: [51](#)

Keywords children, physical activity, sedentary behaviour, accelerometry, screentime

ABSTRACT

Objective To evaluate the impact of a) the removal of home access to traditional electronic games, or b) their replacement, with active input electronic games, on daily physical activity and sedentary behaviour in children aged 10-12 years.

Design ~~Within-subjects~~Cross-over randomised controlled trial, over 6 months.

Setting Family homes in metropolitan Perth, Australia ~~from (2007- to~~ 2010).

Participants 10-12 year old children were recruited through school and community media. From 210 children who were eligible, 75-74 met inclusion criteria, 10-8 withdrew, and 9-10 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 outcomes ~~were~~ was accelerometer assessed moderate/vigorous physical activity- (MVPA)~~and sedentary time~~. 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. Compared-However, compared with home access to traditional electronic games, removal of all electronic games resulted in a significant increase in MVPA (mean 3.8min/day, 95% ~~confidence interval~~CI 1.5- to 6.1) and a decrease in sedentary time (4.7min/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 (3.2min/day, 0.9- to 5.5) and a decrease in sedentary time (6.2min/day, 1.4- to 11.4) in the after school period. Diary

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7 reports supported an increase in physical activity and decrease in screen based sedentary
8 behaviours with both interventions.
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11 **Conclusion** Removal of sedentary electronic games from the child's home and replacing
12 these with active electronic games both resulted in ~~both~~ small objectively measured
13 improvements in after school activity and sedentary time. Parents can be advised that
14 replacing sedentary games with active electronic games is likely to have the same effect as
15 removing all electronic games.
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22 **Trial Registration** Australia and New Zealand Clinical Trials Registry (ACTRN
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INTRODUCTION

It is well recognised that physical activity 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 physical activity and increase in sedentary time.^{3,4} Electronic games are played on various devices including dedicated consoles (e.g. Microsoft Xbox®, Sony PlayStation 3®, Nintendo Wii®) and hand held players (e.g. Nintendo DS®, PlayStationPSP®) as well as non-dedicated technologies such as computers, tablets and smart phones. International evidence shows the majority of children in affluent countries now have substantial daily exposure to electronic games. For example in the UK, approximately half of children spend over an hour per day on using computer games alone.⁵ In the United States, children's use of video games has tripled in the past 10 years ~~to a~~ current average of 73 minutes per day.⁶ Indeed, ~~screen based media as a whole has been~~ estimated to occupy up to 5 hours per day for British children.⁷ estimates of the daily exposure of children to electronic games in countries such as UK, USA and Australia range from 38min/day to 90min/day.⁶⁻⁸

Whilst 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 physical activity (i.e. 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 physical activity level, with a similar relationship for obesity.¹¹ However, to date, no study has removed electronic game access entirely from the home and examined the effect on

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7 activity. More recently, the new generation 'active' electronic games, such as Sony
8 PlayStation EyeToy® and Move®, dance mats, ~~Nintendo Wii~~ and Microsoft Xbox Kinect®
9
10 have added to the controversy. Laboratory studies have shown that some of these active
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12 games can result in meaningful increases in muscle activity, movement and energy
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14 expenditure whilst others ~~are result in~~ less activeactivity.^{12,13} Findings from the few available
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16 home-based interventions comparing access to traditional electronic games alone with
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18 supplemental access to active electronic games have been mixed: with some evidence for
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20 improvements in body fatness,¹⁴ and fitness in overweight children,¹⁵ though no effect on
21
22 objectively measured physical activity for a sample including both overweight and normal
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24 weight children.¹⁶ The long term efficacy of active games in promoting physical activity
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26 remains questionable,^{13,17} but with potential promise.¹⁸
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30 With no clear evidence either way, the public health response to date has been to develop
31
32 recommendations to restrict all children's screen based leisure (~~TVtelevision~~, computers and
33
34 all electronic games), typically to maximum of 2hrs a day.^{19,20} Compliance with these
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36 guidelines has been poor,^{21,22} ~~suggesting which may be due to~~ difficulties ~~for experienced~~
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38 ~~by~~ parents ~~when trying to implement the guidelines~~. Options for parents include removing
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40 electronic games from the family home or replacing traditional electronic games with active
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42 electronic games. To date there has been no study evaluating the ~~efficacy effect~~ of both
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44 these approaches. Therefore this study sought to explore, through a ~~within-subjectscross-~~
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46 ~~over~~ randomised controlled trial, the effect of either removing electronic games from the
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48 children's home environment or replacing traditional sedentary electronic games with
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50 active input electronic games on children's physical activity and sedentary behaviour.
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53 METHODS

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Study design methods and participants

This study used a within subjects [cross-over](#) randomised controlled trial design and was conducted in Perth, West[ern](#) Australia in 2007-~~2011~~[2010](#). The detailed design of the study protocol has been previously described.²³ In summary, 10-12 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 diary and questionnaires²⁴, have a high use of electronic games⁶ and are developing activity [and sedentary behaviour](#) patterns pre-adolescence,⁷ which may track into adulthood.^{25, 26} Recruitment was staggered over three years to account for seasonal variation and targeted to enable participation of equal numbers of males and females, and children representative of a spread of socio-economic 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 [significant-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 Curtin University Human Research Ethics Committee.](#)

Intervention

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7 There were three levels of electronic game access. 'No games' involved all dedicated
8 electronic game devices being removed from the family home with a contract by each child
9 that electronic games were to be avoided where possible on other devices and at other
10 locations. 'Traditional games' involved the provision of a Sony PlayStation 2[®] with a range of
11 non-violent games requiring game pad input. 'Active games' involved the provision of a Sony
12 PlayStation 2[®] with EyeToy[®] and dance mat input devices and a range of non-violent games.
13
14 For each condition children selected 6 games and were allowed to change games mid
15 intervention. A condition period of 8 weeks was chosen for each intervention as it has been
16 found to be sufficient to show physical and psychological changes. Eight weeks also allows
17 for children to accommodate to each condition and is not so long to adversely affect
18 recruitment and compliance in the 'no games' condition. From our pilot study and
19 discussions with children, the removal of all electronic games was acceptable as a way of
20 getting access to a range of new games and equipment for four months. This is why a within
21 subjects design was chosen.
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36 Sample size

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38 For power calculations, daily moderate/vigorous physical activity (MVPA) was estimated at
39 115+30 min with a minimum effect size of 15 min considered important based on effects in
40 prior studies.²⁷ If the variation in the physical activity level between repeated time points in
41 each individual is normally distributed with standard deviation 30 min, and the true effect of
42 game condition is 15 min, a study with 72 subjects would reject the null hypothesis that this
43 response difference is zero with probability (power) 0.986. The Type I error probability
44 associated with this test of this null hypothesis is 0.05. If the Type I error is lowered to 0.01
45 to account for 'repeated' contrasts between conditions, the power is 0.943.²⁸ We allowed
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7 for a 10% attrition in data. The study was curtailed earlier than planned as new electronic
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9 game technologies ([Sony PlayStation 3® and Microsoft Xbox Kinect®](#)) became popular in late
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11 2010 [in Perth](#) making it unfeasible to recruit children to the older game technology. [Data](#)
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13 [from 9 children who participated in the 2007 pilot study using the same activity and](#)
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15 [condition protocol were included to provide the best estimate of intervention effects.](#)
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17 **Recruitment and study procedure**

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20 Following screening, participants were randomly allocated to an order of conditions by
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22 selection of an opaque sealed envelope. A balance of orders across the year was achieved
23
24 by having sets of the 6 possible order permutations in each year cohort. After informed
25
26 consent/assent from parent and child, a research officer visited the home and instructed the
27
28 parent and child in baseline assessments. The baseline visit included an explanation of the
29
30 accelerometer along with a physical activity recall diary (see outcomes measures for detail).
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32 At baseline data ~~was~~ were also collected on the child's height, weight, socioeconomic status,
33
34 motor coordination and electronic game experience. The research officer returned after 10
35
36 days to collect baseline assessments and set up the electronic game condition. This involved
37
38 either removal of all electronic games or setting up electronic game equipment and
39
40 instructing parent and child in its use. Follow-up phone calls were made the next day and
41
42 after 6 days to ensure game equipment was working correctly. Towards the end of the 6th
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44 week in each condition, the research officer visited again to set up the physical activity
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46 assessments (accelerometer and diary). After 8 weeks in each condition the research officer
47
48 returned, collected the completed activity diary and accelerometer and set up the next
49
50 condition. Assessments were scheduled to avoid school and public holidays where possible.
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52 Individualised reports were provided to participants on study completion. The research
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7 officers involved with the setting up each condition were not involved in the subsequent
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9 analyses of the primary and secondary outcomes.

10 11 **Outcome measures**

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14 ~~Primary~~—Physical activity and sedentary time by accelerometry

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17 The primary outcome was the mean daily minutes of MVPA over the whole week. Time

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19 spent in moderate to vigorous, light and sedentary intensity physical activity was assessed

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21 over 7 days using Actical accelerometers worn on the hip. Actical is a widely used and

22
23 validated accelerometer in studies of children and adolescents.²⁹⁻³¹ The accelerometers

24
25 were set to record at 15 second epoch intervals.³² As per established standard practices

26
27 with accelerometry, a minimum of 4 days (at least one weekend day) was regarded as a

28
29 valid recording.³³ The minimum recording time required for a day to be considered valid was

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31 500 minutes.⁷ Data were individually visually checked for missing values. Non-wear time,

32
33 regarded as 120 minutes of consecutive zero's (based on pilot data showing children could

34
35 accumulate more than 60 minutes of consecutive zero counts when watching television),

36
37 was removed prior to analyses. Activity intensity thresholds based on Colley *et al.*³⁴ were

38
39 used to convert the raw counts into minutes of sedentary, light, moderate and vigorous

40
41 intensity physical activity ~~(MVPA)~~. Minutes spent in each of these intensity categories were

42
43 calculated for an average day over the whole week. As there are known to be variations

44
45 depending on the type of day³⁵ and time of the day³⁶ which may be masked in whole week

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47 analysis, analysis was also conducted on school days, weekend days, and the afterschool

48
49 period (from 3.30 to 6.00pm). The after school period was chosen as this has been

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51 suggested to be an important time in the child's day for both discretionary physical activity

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53 and sedentary leisure time.³⁷ Measures of the pattern of sedentary, light and moderate-to-

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vigorous activity were also calculated for the same time periods.³⁸ A custom LabView program was used to process the data.

Secondary—Physical activity 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 minute 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, BMI and electronic game experience were considered for potential modification of condition effects. Prior physical activity 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 versus traditional e-[lectronic](#) games, and active e-[lectronic](#) games versus traditional e-[lectronic](#) 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. [Statistical significance for a carryover effect \(treatment by period interaction\) was set at \$p < 0.1\$.](#) 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 10.1 for Windows (StataCorp LP, College Station TX, USA). All statistical tests were 2-tailed with $\alpha = 0.05$. 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 \(6 male, mean age 10.5 years, height 1.48m, weight 48.3kg, socioeconomic status range 5th to 9th centile, 4 condition orders\).](#) Ten participants [completed the study but had insufficient accelerometer data after all three conditions \(5 male, mean age 11.4 years, height 1.48m, weight 43.8kg, socioeconomic status range 3rd to](#)

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7 10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female)
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9 who completed the study and had sufficient accelerometry data for planned analyses had a
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11 mean (sd) age of 11.3 (0.8) years. Participant height (1.50 (0.08) m), weight (41.3 (10.3) kg)
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13 and zBMI (-0.1 (1.2)) were similar to the national distribution for this age.³⁹ Nearly all
14
15 children had home access to electronic games (91%) and reported playing electronic games
16
17 in the last month (95%), with 61% reporting playing at least 2-3 times a week. Duration of
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19 playing sessions was most commonly <30min (41%), though 31% usually played for 30-
20
21 60min and 24% usually played for 1-2hrs. Participant socioeconomic status based on
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23 location of family home⁴⁰ ranged from the second to tenth Australian centile. Participant
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25 motor coordination status ranged from poor to excellent (MAND⁴¹ 2007:NDI 62-125; MABC-
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27 2⁴² 2009-10: 9-98%), approximating a general population.

Accelerometry

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32 Daily accelerometer wear time was around 827.8 min over the week, and was somewhat
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34 shorter on weekend days than school days (788.9 vs 827.8min). With home access to
35
36 traditional games, regarded as the norm for most families at the start of this study, daily
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38 MVPA was less than one hour (mean 54.1 min, 95% confidence intervalCI 47.5- to 60.7)
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40 whereas daily sedentary time was around eight and a half hours (522.7 min, 509.4- to
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42 535.9).

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45 Table 1 shows that in comparison to traditional games, removal of all electronic games
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47 resulted in no significant change in daily MVPA over the whole week. However it did result
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49 in a 3.8 min/day (1.5- to 6.1, p=0.001) increase in MVPA in the after school period. Similar
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51 similar, though non-significant, increases-increase in MVPA were-was observed over the
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53 whole week-and-on-school days. The removal of all electronic games resulted in a small non-
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7 significant increase in light activity over the whole week, with a larger though still non-
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9 significant increase on weekend days. Removal of all electronic games also resulted in a
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11 significant decrease of 4.7 min/day (0.0- to 9.5, p=0.05) in sedentary time in the after school
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13 period, which was matched with a small non-significant decrease in sedentary time over the
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15 whole week and a larger non-significant decrease on weekend days. Replacing traditional
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17 games with active input games had similar findings (Table 1). This exchange resulted in no
18
19 significant change in MVPA over the whole week but a 3.2 min/day (0.9- to 5.5, p=0.007)
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21 increase in MVPA in the after school period, with a similar though non-significant pattern of
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23 MVPA over the whole ~~week and on~~ school days. Replacing electronic games with active
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25 input games also resulted in a small non-significant increase in light activity over the whole
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27 week, with a larger though still non-significant increase on weekend days. Furthermore,
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29 replacement of traditional games with active input games resulted in a significant decrease
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31 in sedentary time in the after school period (6.2 min/day (1.4- to 11.1, p=0.012)). A small
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33 non-significant decrease in sedentary time over the whole week and a larger non-significant
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35 decrease on weekend days were also observed.
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Table 1: Accelerometer determined daily minutes of MVPA, light activity and sedentary time over the whole week, weekend days, school days and 3.30-6pm 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 (49.2,62.3)	54.1 (47.5,60.7)	56.1 (49.5,62.8)	1.7 (-3.2,6.6) 0.493	2.0 (-3.0,7.1) 0.428
School day	60.9 (53.9,67.8)	58.2 (51.2,65.2)	61.5 (54.4,68.5)	2.6 (-2.4,7.7) 0.306	3.2 (-2.0,8.4) 0.228
Weekend day	43.2 (34.3,52.2)	42.8 (33.7,51.9)	43.0 (33.9,52.2)	0.4 (-9.1,9.9) 0.933	0.2 (-9.5,10.0) 0.966
3.30-6pm school day	12.9 (10.3,15.5)	9.1 (6.4,11.7)	12.3 (9.6,14.9)	3.8 (1.5,6.1) 0.001	3.2 (0.9,5.5) 0.007
LIGHT PA					
Week	242.5 (230.8,254.2)	240.3 (228.5,252.2)	245.6 (233.7,257.5)	2.2 (-9.4,13.7) 0.712	5.3 (-6.6,17.2) 0.385
School day	241.3 (229.9,252.7)	242.3 (230.7,253.9)	243.8 (232.1,255.4)	-1.0 (-11.8, 9.8) 0.854	1.5 (-9.6, 12.6) 0.794
Weekend day	245.5 (228.7,262.3)	235.3 (218.3,252.4)	250.2 (233.0,267.4)	10.2 (-9.1,29.5) 0.302	14.9 (-4.9,34.6) 0.140
3.30-6pm school day	48.8 (45.3,52.4)	48.0 (44.4,51.5)	50.9 (47.2,54.5)	0.9 (-2.9,4.6) 0.649	2.9 (-1.0,6.8) 0.142
SEDENTARY					
Week	518.7 (505.6,531.7)	522.7 (509.4,535.9)	515.4 (502.1,528.7)	-4.0 (-16.8,8.8) 0.540	-7.2 (-20.4,5.9) 0.282
School day	531.1 (518.3,543.9)	532.7 (519.7,545.7)	528.3 (515.2,541.3)	-1.6 (-13.7,10.4) 0.790	-4.5 (-16.9, 8.0) 0.483
Weekend day	487.6 (468.3,507.0)	498.5 (478.8, 518.2)	483.1 (463.3,503.0)	-10.8 (-32.9,11.3) 0.336	-15.3 (-37.9,7.3) 0.184
3.30-6pm school day	88.0 (83.3,92.7)	92.7 (88.0,97.5)	86.5 (81.7,91.2)	-4.7 (-9.5,0.0) 0.050	-6.2 (-11.1,-1.4) 0.012

Formatted Table

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7 Removing or replacing traditional electronic games had no significant effect on exposures to
8 bouts of MVPA lasting at least 10min, bouts of sustained sedentary time lasting at least
9 30min, or brief bursts at any intensity lasting less than 5 min and breaks in sedentary time
10 (data not shown).
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15 Figure 2 provides a visual summary of the key daily differences in accelerometer determined
16 activity and sedentary time, for the after school period.
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19 Diary

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22 According to diary records, in the traditional games condition, children spent on average,
23 one and a half hours per day on active leisure and transport (mean 78min, 95% ~~confidence~~
24 ~~intervals~~CI 63- to 93) and four and a half hours per day on all sedentary leisure (non-screen
25 and screen: 267min, 243- to 292). Leisure time spent on screen-based media made up more
26 than half of reported sedentary leisure (163min, 139- to 187). ~~TV-Television~~ viewing was the
27 largest contributor (107min, 85- to 129), followed by sedentary electronic games (44min,
28 37- to 50) and ~~non-non~~ gaming computer use (24min, 15- to 32).
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37 ~~Reported non-exposure to sedentary electronic games during the 'no games' (median 0 min)~~
38 ~~and 'active games' (0min) conditions and to active electronic games during the 'no~~
39 ~~games'(0min) and 'traditional games' (0min) conditions confirmed compliance with avoiding~~
40 ~~non-protocol games. Reported-Participants reported~~ exposure to active electronic games
41 during the 'active games' condition ~~was of~~ 19 min/day, suggesting reasonable compliance
42 with this condition. Similarly, ~~participants~~ reported exposure to traditional electronic games
43 during the 'traditional games' condition ~~was of~~ 34 min/day.
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52 Participant median exposure to sedentary electronic games was zero minutes during the
53 'no games' and 'active games' conditions. Similarly, participant median exposure to active
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7 electronic games was zero minutes during the 'no games' and 'traditional games'
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9 conditions, suggesting compliance with avoiding non protocol games.
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Table 2: Diary reported daily minutes of active leisure, sedentary leisure, and components of sedentary leisure in the 3.30-6pm after school period, adjusted for condition order.

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

¹median (95%CI for median), Wilcoxon sign-rank test for condition differences

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8 The diary records also provide context to the changes observed in accelerometry in the after
9 school period (Table 2). When looking at the after school period alone, the removal of electronic
10 games resulted in a significant decrease of 14 min/day in sedentary leisure and a corresponding
11 12 min/day increase in active leisure and transport. The breakdown of this came from a significant
12 reduction of 12 min/day of screen sedentary leisure (8 min (median) of which was sedentary
13 electronic game exposure), a non significant reduction of 3 min/day in non screen sedentary
14 leisure and a non significant reduction in non-game computer use by 1 min/day. ~~TV~~ Television
15 viewing was reported to increase by 3 min/day, though this was not significant.
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23 Again, when looking at the after school period, replacing traditional electronic games with active
24 electronic games resulted in an overall decrease of 21 min/day in sedentary leisure and a
25 corresponding non significant increase of 3 min/day in active leisure and transport along with
26 8min/day (median) of active input game time: ie an overall increase of activity time of about 11
27 min/day. The reduced sedentary time was achieved through a significant decrease of 14 min/day
28 in sedentary screen leisure and a 7 min/day non significant reduction in non-screen sedentary
29 leisure. No significant changes in ~~TV~~ television viewing (0 min/day), or non-game computer use (-1
30 min/day) were reported when active input games were introduced. The diary reported changes in
31 both the removal and replacement of traditional electronic games conditions provide the context
32 to the accelerometer measured activity differences during the after school period (see text within
33 Figure 2).
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48 DISCUSSION

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50 This randomised controlled study showed that removing access to sedentary electronic games in
51 children's homes, or replacing them with active electronic games, resulted in small but significant
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8 increases in physical activity and reductions in sedentary time ~~in~~during after school time. No
9 significant effects on overall daily or weekly activity or sedentary time were observed.
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12 This is the first randomised controlled study, in the real world setting of the home, to assess the
13 two alternatives parents have for reducing the time their children spend on sedentary electronic
14 games: removal or replacement with something more active. The study findings suggest that
15 parents choosing either option may see a small improvement, more activity and less
16 sedentariness, in the after school period. Our study corroborates previous research that has
17 shown this time to be a 'critical window' for intervening with physical activity ⁴⁶ and supports
18 more recent qualitative findings that suggest it is also an important time in the day to reduce
19 children's screen viewing.³⁷ The magnitude of effect, approximately 5 minutes more activity and 5
20 minutes less sedentary time, is similar to improvements observed in other home based studies.
21

22
23 Maddison et al ¹⁴ found a self reported 10 minute increase in active games use and a self reported
24 reduction in sedentary electronic game use when they were provided in active electronic games in
25 addition to traditional electronic games in a 6 month study. Whilst Baranowski et al ¹⁶ observed no
26 objectively measured increase in daily MVPA or decrease in daily sedentary time in their home
27 based study, day type or specific day periods were not studied.
28

29
30 On its own the magnitude of the change observed is unlikely to be of clinical importance, however
31 it needs to be seen in the context of electronic games being part of the rapidly growing exposure
32 that children have to screen based media. Whilst ~~traditional time spent viewing~~ television ~~viewing~~
33 appears to be stable,⁶ leisure time exposure to console based electronic games and computing is
34 increasing rapidly,⁶ as is the increase in mobile smart phones and touch screen tablets that are
35 used for e-lectronic gaming, social networking, video viewing, and internet surfing.⁴⁷ Therefore
36 small changes across a variety of these platforms could result in a more significant-substantial
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8 clinical impact. Whilst our study focussed on the home-setting, school offers another opportunity
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10 for more active technologies.⁴⁸ Children sit for a long time at school and there is potential to
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12 further reduce sedentariness by engaging with technologies such as sit-stand desks, or active-
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14 input electronic media as part of lessons.³⁵

15
16 The strengths of the study include the strong within subjects randomised controlled trial design
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18 with staggered starts and counterbalanced orders to control for extraneous factors. The
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20 participants were representative of a general population of 10-12 year old children in terms of
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22 sex, weight, motor coordination, electronic game experience and socio-economic status,
23
24 informing the likely broad impact of replacement as a public health intervention. The study was
25
26 also grounded in the naturalistic setting of the family home. Whilst active-input technologies have
27
28 been tested by children in the laboratory and found to increase energy expenditure, this does not
29
30 account for what happens in practice when the active games are amongst a milieu of other
31
32 distractions.¹⁷ Furthermore, this is the first study to examine the effects of fully removing
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34 electronic games from the home. The study also used active electronic game technology with a
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36 known capacity to increase whole body movement and energy expenditure, rather than the Wii[®]
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38 which children can play with only hand movement. Some Wii[®] based games have been found to
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40 be little different to traditional sedentary electronic games.⁴⁹ The study also provided a
41
42 substantial range and variation in game offerings, addressing the known issue of active games
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44 being less engaging,⁴⁹ although it was difficult at times to keep participants engaged as the most
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46 popular game genre – killing – was excluded from the study on ethical grounds. The other key
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48 strength of the study is that it used an objective measure of physical activity and sedentary time
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50 and supplemented this with self-reported diary measures to aid understanding and interpretation
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52 of results.

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8 The main weakness was the need to curtail the study one year early due to [electronic game](#)
9 technology changes, [specifically the widespread introduction during late 2010 of new active](#)
10 [electronic game devices Xbox Kinect® and PlayStation Move®](#). These new technologies and the
11 [active games available on these devices were qualitatively different and could not simply replace](#)
12 [the older devices in the same protocol](#). This meant children were unwilling to agree to the original
13 [protocol and thus recruitment ceased](#). The inability to recruit participants for the final planned
14 [year resulted in a reduced sample size which was partly compensated for by using data from 9](#)
15 [subjects who participated in the protocol in 2007](#). The reduced numbers ~~which~~ meant we were
16 unable to determine whether the 10-15 minute change in sedentary and light intensity activity on
17 weekends was real. [The withdrawal of participants and the lack of adequate accelerometry data](#)
18 [on some participants are other obvious limitations](#). ~~Further~~A further limitation was that, whilst the
19 diaries suggested compliance to both conditions was good, we did not have a way of measuring
20 precisely how much the active games were used.¹⁷

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

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48 Given the strong evidence for detrimental effects of too little physical activity and too much
49 sedentary time,^{50,51} in particular too much screen time³ and the potential interaction between
50 these in children,²¹ there is a mounting need to understand childhood behaviours and intervene.

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8 Children in this study were sedentary for just over 8 hours per day and reported spending
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10 approximately three hours per day on screen based leisure, on the low side but comparable with
11 international findings.^{6,47} Given this high sedentary exposure, health care practitioners should use
12
13 all available opportunities to encourage children (and their parents) to be more active and less
14
15 sedentary. Sigman³ has recently called for the medical community to take a more proactive
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17 approach to reducing children's screen time exposure. With the increasingly electronic media
18
19 enmeshed world of youth, it is unrealistic for parents to remove access to screen based media
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21 completely and therefore parents and health professionals alike need to work with technology to
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23 assist its development in ways which are health enhancing rather than health reducing. It was
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25 encouraging in this study that the replacing option resulted in at least as good an outcome as
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27 removing, and this may potentially result in more successful long term outcomes due to better
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29 sustained compliance.
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31 32 CONCLUSION

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34 Screen based [media-sedentary leisure](#) is a major component of [leisure](#)-sedentary behaviour and
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36 interventions should be targeted to ~~TV~~[television](#), computer and electronic game use. This study
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38 has shown that replacing sedentary with active electronic games will provide at least as good an
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40 activity outcome and perhaps be easier for parent and child to sustain than removing [electronic](#)
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42 [game](#) technology from the home.
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47 *Acknowledgements:* We thank all the children and their families for their dedication. We thank D
48
49 Metcalf, A Campbell, R Collins, J Coleman, D Gill and J Chua for help with data collection and
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51 processing.
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8 *Contributors:* All authors had full access to the data and can take responsibility for the integrity of
9 the data and accuracy of the data analyses. LS conceived and managed the study; LS, RA and AS
10 designed the study; AS analysed the data; LS and RA drafted the manuscript; LS, RA and AS edited,
11 critically revised and approved the manuscript.
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15
16 *Funding:* The study was funded by a National Health and Medical Research Council of Australia
17 project grant (533526). LS ~~is~~ was on a fellowship funded by the National Health and Medical
18 Research Council of Australia. The funding body had no influence on the analysis and reporting of
19 the study.
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24 *Competing interests:* none declared. All authors have completed the Unified Competing Interest
25 form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author)
26 and declare: LS had financial support from an NHMRC senior research fellowship for the
27 submitted work, no financial support for RA or AS; no financial relationships with any
28 organisations that might have an interest in the submitted work in the previous 3 years; no other
29 relationships or activities that could appear to have influenced the submitted work.
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37 *Ethical approval:* The study had ethical approval from the Human Research Ethics Committee of
38 Curtin University (approval number HR131/2006). All participating children and their parents gave
39 informed assent/consent.
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43 *Data sharing:* no additional data available
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ARTICLE SUMMARY

Article Focus:

- Physical activity 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 home, 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 to 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 physical activity and sedentary behaviour supplemented with self-report measures.
- Longer term studies are needed to assess whether the small effects observed over eight weeks are sustained.

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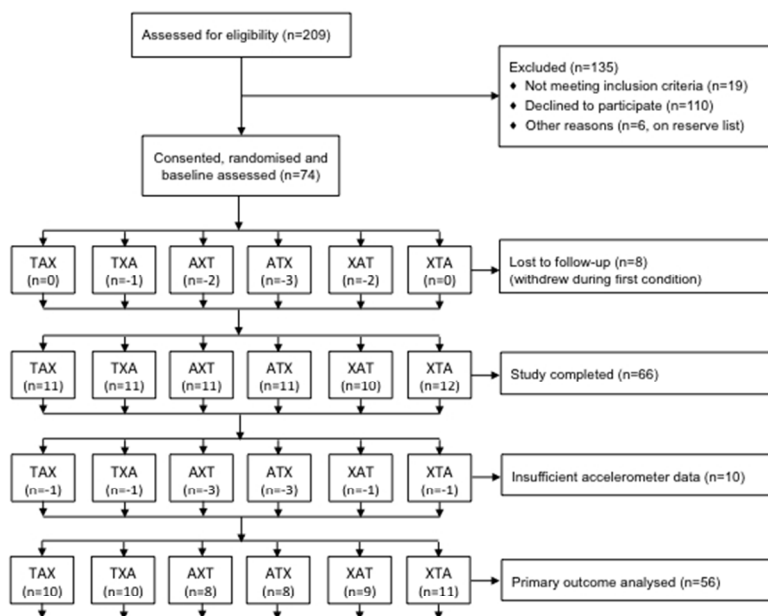
Figure Legends:

[Figure 1. CONSORT diagram of flow of participants. Order of conditions is shown with T=traditional electronic games, A=active electronic games and X= not electronic games.](#)

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

For peer review only

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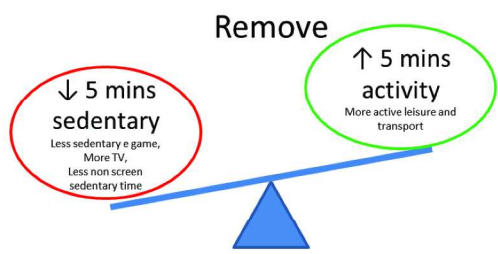


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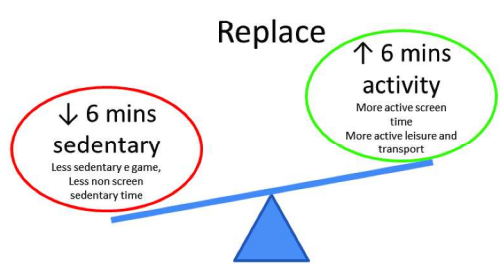
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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2,3
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	5
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	5
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	na
Participants	4a	Eligibility criteria for participants	6
	4b	Settings and locations where the data were collected	6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	8-9
	6b	Any changes to trial outcomes after the trial commenced, with reasons	na
Sample size	7a	How sample size was determined	7
	7b	When applicable, explanation of any interim analyses and stopping guidelines	na
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	7
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	7
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	7
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	na
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	8

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2		assessing outcomes) and how	
3			
4		11b If relevant, description of the similarity of interventions	na
5	Statistical methods	12a Statistical methods used to compare groups for primary and secondary outcomes	10-11
6		12b Methods for additional analyses, such as subgroup analyses and adjusted analyses	10-11
7			
8	Results		
9	Participant flow (a	13a For each group, the numbers of participants who were randomly assigned, received intended treatment, and	Fig 1
10	diagram is strongly	were analysed for the primary outcome	
11	recommended)	13b For each group, losses and exclusions after randomisation, together with reasons	Fig 1
12	Recruitment	14a Dates defining the periods of recruitment and follow-up	5
13		14b Why the trial ended or was stopped	na
14			
15	Baseline data	15 A table showing baseline demographic and clinical characteristics for each group	In text, 11
16	Numbers analysed	16 For each group, number of participants (denominator) included in each analysis and whether the analysis was	NA
17		by original assigned groups	(crossover)
18			
19	Outcomes and	17a For each primary and secondary outcome, results for each group, and the estimated effect size and its	
20	estimation	precision (such as 95% confidence interval)	Table 1
21		17b For binary outcomes, presentation of both absolute and relative effect sizes is recommended	na
22	Ancillary analyses	18 Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing	na
23		pre-specified from exploratory	
24			
25	Harms	19 All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	na
26			
27	Discussion		
28	Limitations	20 Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	16-17
29	Generalisability	21 Generalisability (external validity, applicability) of the trial findings	15-17
30	Interpretation	22 Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	15-17
31			
32	Other information		
33	Registration	23 Registration number and name of trial registry	3
34	Protocol	24 Where the full trial protocol can be accessed, if available	5
35	Funding	25 Sources of funding and other support (such as supply of drugs), role of funders	18
36			

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

Manuscript ID bmjopen-2013-002629

"To remove or to replace traditional electronic games? A within subject randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children."

Straker, Abbott, Smith

Author Response to Review

2nd May 2013

- The authors thank the editor and reviewers for their thoughtful comments and provide our responses in bullet points following.

From BMJ Open editors:

We are a little concerned by the retrospective registration. The registry gives an intended enrolment date of 29/04/09 and registration date of 15/05/09. Can you explain the reason for the late registration and clarify when the first participant was enrolled?

- The trial registration information was first submitted on 09/03/2009 (as shown on trial registry history). ANZCTR required clarification on a number of issues and these clarifications were accepted by ANZCTR and the trial registered on 15/05/2009.
- The first 2009 participant wearing the accelerometer/completing the diary on 02/05/2009 and the accelerometer and activity diary was collected on 20/05/2009.
- 22 participants completed the study between May and December 2009 and a further 32 between January and December 2010. This was funded by a National Health and Medical Research Council of Australia grant which also covered doubly labelled water data collection and analysis which is not included in this paper. In 2007 12 participants had completed the same protocol without the doubly labelled water, as reported in the BMC Public Health protocol paper cited in the trial registration. In the activity analysis reported in this paper, data from 9 of these participants who had adequate accelerometer data were also included, to partly compensate for the early trial termination due to electronic game technology changes in the Australian marketplace in late 2010, and thus provide the best estimate of the intervention effect. We have also conducted the primary analyses without these 9 participants from 2007 and the conclusions remain the same with very similar results.
- The manuscript has been modified to make this clearer.

A few other points: do you have any info on the drop outs that can be included?

- Descriptive details on the sex, age, height, weight, socioeconomic status and allocated order of conditions of the 8 participants who provided baseline data but did not complete the study has now been provided.
- Further, similar details on the 10 participants who completed the study but did not have adequate activity data has also been provided.

MVPA (moderate and vigorous intensity physical activity) needs to be spelled out in the abstract.

- Changed as requested.

Reviewer: Robin Christensen

Copenhagen University Hospital, Frederiksberg, The Parker Institute: MSU

This is a good paper. The authors follow their hypothesis and objective in their statistical analysis.

- We thank the reviewer for their comment.

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2
3 My only worry is - well known for Cross-Over studies - the inadequate reporting due to difficulties
4 defining the ITT population.

- 5 • Please see detailed discussion below under the 1st and 3rd points by other reviewer (RM).
6 Briefly, the primary analysis conducted assumed participants received the treatment they
7 were allocated to, and included non-biased imputation of outcomes for those participants
8 missing data for one condition, and is thus faithful to the concept of ITT in the context of
9 cross-over trials.

10
11 I would ask the authors to provide a detailed flow diagram for each of the three Intervention-
12 periods; potentially a different attrition pattern appears across interventions; this could appear
13 valuable.

- 14 • We have added the specific condition orders that each child was randomised to in the text
15 under Participants and shown this in the revised flow diagram. The eight withdrawing
16 participants did so in their first condition, and the 10 without adequate accelerometer data
17 completed all conditions but had inadequate data for all conditions. On detailed checking of
18 each participant and reasons and timing for exclusion from final analysis three errors were
19 found which have now been corrected. One participant was found to have been listed as lost
20 to followup as they had provided verbal consent, but they had actually 'withdrawn' prior to
21 written consent and baseline assessment. A second participant had been counted in both
22 lost to followup and insufficient accelerometer data rather than just the later. A third
23 participant had been listed as lost to followup as they had no accelerometer data, but they
24 had completed other aspects of the study and should have been counted in insufficient
25 accelerometer data group.
26
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29 I would strongly suggest the authors to ALSO report a "conservative" estimate for those participant
30 who didn't complete the study. Ie, please use a non-responder imputation (keep baseline) as
31 secondary analysis plan. Please submit all these as supplementary files supporting the existing
32 tables.

- 33 • Please see detailed discussion below under the 1st and 3rd points by other reviewer. 'Non-
34 responder' imputation was performed where possible and appropriate.

35
36 Well done; and a nice protocol manuscript as well.

- 37 • We thank the reviewer for their kind comment.

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40 **Reviewer: Ralph Maddison**

41 Associate Professor, National Institute for Health Innovation University of Auckland New Zealand

42
43 Overall comments:

44
45 This paper presents an interesting topic, which is to determine the effect of removing or replacing
46 electronic games on physical activity levels in children aged 10-12 years. Overall, the findings should
47 a small effect for removing electronic games on after-school physical activity, which seem to come
48 from a displacement of time being sedentary. These findings in themselves are important and
49 potentially add to the literature. Notwithstanding these comments I have some concerns regarding
50 the study design, primary outcome and analysis, which impact on the interpretation of the findings.
51 Specific comments are highlighted below.

- 52 • Please see our responses to specific issues below.

53
54
55 Specific comments

1
2
3 1. Study design: This study used a randomised cross over-trial design, whereby participants
4 were randomised to the order that they were exposed to the condition. On page 8, the authors
5 describe some of the reasons why a within subject design was used. However I am not convinced
6 that this was the best design to use for this trial and has several limitations. Specifically, some of the
7 considerations for using a cross-over trial include, they are restricted to treatments that produce
8 rapid effects with rapid returns to baseline, treatments must be reversible, and the need for a
9 washout period to minimise carryover effect. While other conditions exist, these are the most salient
10 to this study (Friedman LM, Furberg CD, DeMets DL. Fundamentals of Clinical Trials. 3rd edn. New
11 York: Springer-Verlag. 1998). It is my opinion that the interventions used were not reversible. They
12 were behavioural change approaches, the effect of which may have carried over into the subsequent
13 treatment. The authors do not indicate whether values returned to baseline following removal of a
14 specific condition and there was no washout period in-between conditions to account for this.
15 While clearly it is too late to change the design, the following issues need to be addressed
16 thoroughly and a stronger rationale needs to be made.
17

- 18 • We disagree with the reviewer that this was not the best design for this trial. Rather, we
19 believe it was the *only* design feasible for the trial.
- 20 • This trial is the only study to test whether the removal of electronic games actually enhances
21 children's activity profile. To test this hypothesis we required children to agree to avoid
22 playing electronic games for two months. If we had tried to use a standard parallel arms
23 RCT, the only children who would have agreed to participate would have been children not
24 interested in playing electronic games, and therefore the sample would have been highly
25 biased and any conclusions drawn invalid for the general population. We discussed the study
26 with several groups of children when planning the study to ascertain what they were willing
27 to agree to. The only reason they would consider going without electronic games for 2
28 months was if they could have access to a large number of games for the other conditions.
29 Therefore a repeated measures/cross over trial was the only design viable. We clearly state
30 this reason in the Intervention section of the Methods.
- 31 • We agree that behavioural changes made during one condition may have carried over into
32 later conditions. Thus a washout period between conditions would not have been
33 particularly useful and would have extended the study period to an onerous extent.
34 Similarly, repeated assessments at the end of conditions to determine whether behaviour
35 had returned to baseline levels would have added to an already extensive participant
36 burden. Therefore we dealt with the potential carry over effects in the design and analysis
37 by balancing the order of conditions and adjusting for period to account for any time-related
38 effects. Although contentious (Mills, 2009), we also tested for carry-over by testing the
39 period*condition interaction and found no evidence at the more liberal $p < .100$. We are
40 therefore confident that the differences seen were the result of the specified condition, and
41 not due to any period or carry-over effects.
42
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44

45 2. The second issue relates to the primary outcome. The primary outcome is not specific
46 enough. What was the a priori outcome? Was this total daily MVPA levels? The sample size
47 calculation was based on daily MVPA, with an estimate of 15 min difference (but this is not clear).
48 Thus it seems the primary should be daily MVPA, but in the abstract and in the results there is a
49 tendency to report after school after, which was not the primary outcome. Can this be clarified in
50 the paper and ensure that the primary outcome results are presented first. In addition, sedentary
51 time is also included as a primary outcome but was not powered accordingly and should be
52 presented as a secondary outcome.
53

- 54 • Whilst we were fundamentally concerned with different intensities of activity and time
55 periods, we have clarified in the Outcome measures that mean daily MVPA over the whole
56 week was considered the primary outcome.
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- We have edited the text to report mean daily MVPA over the whole week as the primary outcome variable as requested.

3. Third, ITT analysis was stated in the manuscript but the results presented are not ITT, but reflect observed data. According to Figure 1, 75 participants were randomised, thus data for 75 participants should be analysed, not the 56 presented in this study. It is acknowledged that 19 participants, did not provide follow-up data, therefore the authors should have looked at imputation techniques to manage these data. Using an ITT analysis it is likely that the main effect will be diluted, which has implications when interpreting these data. The results of the 56 participants should be presented as sensitivity analysis only.

- Intention to treat analysis in the context of randomized parallel group trials refers to comparing study groups in terms of the treatment they were allocated regardless of the treatment they actually received (The Cochrane Collaboration Glossary of Terms (<http://www.cochrane.org/glossary>), thus avoiding bias resulting from disruption of baseline equivalence established by randomisation. In crossover trials, the intention is that all participants receive all treatments, thus acting as their own controls, and treatment efficacy estimates are based upon within-subject rather than between-subject comparisons. However, participants may 'cross-over' to another condition that is not the condition they were intended to receive in a particular block, or drop-out during the study with the result that outcomes are available for only those conditions which they completed. Our primary analysis was performed using all available data (see below) including 11 subjects who had valid accelerometry data for only two conditions (4 subjects missed traditional, 2 missed no games and 5 missed active games) and assuming that participants were receiving the condition they were allocated for a particular block. The linear mixed model used is a likelihood-based estimation procedure resulting in non-biased estimates by imputation of missing responses based upon the surrounding responses and modelled covariance structure, provided data are missing at random (MAR) or completely at random (MCAR) (Cnaan 1997). Therefore, we contend that our analysis of the 56 participants with available data for two or more conditions represents an ITT analysis, and our 'per protocol' analysis was a sensitivity analysis for those participants truly participating in the active electronic games condition, rather than including those participants who 'crossed over' to the no games condition by not playing the active electronic games (they did not 'cross over' to the traditional games condition as these had been removed from the household).
- There were 10 participants who completed the study that had no valid accelerometry data for any of the 3 conditions, or at baseline. Therefore, imputation of post-condition accelerometry data based upon baseline values is not possible. There were 8 participants who withdrew from the study prior to completion of the first condition. Imputation of values for both these groups of participants using observed values such as the mean from those participants with data is statistically invalid, can lead to bias, and can cause standard errors to be too small (Sterne 2009).

4. Abstract: The objective of this study needs to be much clearer. The authors need to say something like "to evaluate the impact of the removal of home access electronic screen-based media on daily physical activity levels in children aged 10-12 years.

- Additional detail added as suggested

5. Abstract: It would be good to use the terminology cross-over randomised controlled design.

- Terminology has been changed as suggested

6. P.3, l 24, number of participants does not reflect ITT (see above)

- See detailed response to Point 3

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7. Abstract results: The results should reflect the primary outcome first before presenting secondary results. Should also present data using 95% CI convention
- We have added a sentence about daily MVPA over the whole week as suggested.
 - 95% confidence interval data were presented. The presentation style has been changed to replace full text with CI abbreviation and hyphen with 'to'.
8. Abstract conclusion: remove the words both and objectively from line 6.
- 'both' was in the wrong place in the sentence and this has been corrected
 - We believe 'objectively' should be retained to clarify this relates to the accelerometer determined activity rather than just self-report activity measures.
9. Page 5. It is important to define the terminology used such as electronic games as this is pivotal to the study. This relates also to the intervention, because it is not clear when electronic games were removed, did this include games only or all electronic devices? Does this include TV, smart phones, ipods?
- We have added a sentence to clarify the platforms that electronic games are commonly played on.
 - We have also edited the Intervention section to clarify that dedicated electronic game devices only were removed, but that the children committed to avoiding electronic games on other devices and other locations.
10. Page 5, lines 7-28 there are some quiet wide sweeping statements that need to refined somewhat to improve the clarity of this introduction section.
- The international evidence sentence is followed by examples of studies which support the proposition and provide detail.
 - The concept of traditional electronic game body movement and energy expenditure is referenced.
 - The cross-sectional relationships for traditional electronic games are referenced.
 - The laboratory studies on active game movement are referenced.
 - The field studies on electronic game use impacts are also referenced.
 - Therefore we believe the statements made are adequately supported by evidence and that the evidence is cited.
11. P.5. l 16 affluent....does this mean developed?
- We prefer not to use the term 'developed' as this is a Western/capitalist perspective seen as condescending. 'Affluent' is accurate as it relates to the ability to purchase the electronic equipment.
12. P.5. l 17, daily exposure....does this also include play or do the authors mean play
- We have replaced "on" with "using".
13. P.5. l 25, the term screen-based media....what does this include?
- We have deleted mention here of screen-based media to avoid reader confusion.
14. P.5. l 49 correct convention required for games such as EyeToy®
- Registered trademark symbol added as suggested.
15. P.5. l 57 it is stated that some active games are less active...does this refer to PA or EE, or both?

- The sentence has been edited to more accurately state muscle activity, movement and energy expenditure, as discussed in the cited papers.

16. P.6, l 25 the comment that compliance with guidelines has been poor suggests difficulties for parents is not necessarily supported by evidence. To the best of my knowledge I have not seen causal data linking these. Low compliance may be due to a myriad of factors such as poor dissemination, personal and situational factors. I think this rationale needs to be tempered to reflect this.

- The sentence has been edited as requested.

17. P.6, l 30, the authors state that now studies have examined the efficacy of this approach. Does this mean the presented study is an efficacy trial? This was not clearly stated in the MS.

- The word 'efficacy' has been replaced by 'effect' to avoid terminology confusion.

18. P.6, l 49, it would be more accurate to include the terminology cross-over trial

- We have changed the terminology as requested

19. P.6, l 56 – How has mass media used to recruit participants? Was this TV, radio advertising

- The specific type of mass media used has been clarified as requested.

20. P.7, l 2-7, references or citations are needed for these statements

- We have provided references as requested.

21. Page 7, a statement of ethical approval needs to be included in the MS

- Included as requested.

22. P.7, inclusion criteria, this comment really refers back to the issue of defining electronic games, because it is stated that kids should be able to access electronic games but it is not clear what this means. Does this refer to ownership or access through a friend? Can more details be provided? Also, how many days were defined as "most days of the week" (e.g., 5 or more)? How was a diagnosed disorder determined and what disorders were considered to exclude participants (e.g., asthma)?

- Access to electronic games has been clarified to indicate it refers to the equipment provided in the study.
- "most" was not specified in the protocol, but in effect meant 5 or more as this criteria was to ensure children would be physically able to access the equipment to achieve per protocol use and not be regularly in after-school care etc without time to use the equipment.
- Impact of a disorder on study participation was determined by discussion between the parent and research physiotherapist.
- Diagnosed disorder was determined by parent report and this has been clarified in the manuscript as suggested.

23. P.9, l 10, data are plural therefore the text should read asAt baseline data were....

- Thank you for picking this up error, we have corrected the text.

24. How were the demographic and SES measures used for randomization as this was a within subjects design and all participants received the intervention

- We stated in Study design methods and participants that we targeted recruitment to ensure the children were a reasonably representative sample in terms of males and females, SES and electronic game experience. We stated in Covariates that age, sex and electronic game experience were considered in analysis for potential effects. Under Recruitment and study

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3 procedure we stated that participants were randomly allocated to an order of conditions.
4 We did not state that 'demographic and SES measures' were used for randomisation, as this
5 was not the case.
6

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8 25. P.10, l 3-13. The decision making for processing accelerometer data needs to be stronger.
9 Other data reduction approaches recommend 600 minutes of wear time (10 h) (Masse et al 2005
10 Med Sci Sports Exerc. 2005 Nov;37(11 S544-54.). Also the decision for 120 minutes consecutive
11 zeroes is quite long given this young population where 60 minutes of consecutive zeroes would
12 indicate lack of movement (and non-wear time). Why was 120 minutes used?

- 13 • We agree that 600 minutes is more commonly used as a minimum daily wear time. However
14 a 500 minute minimum is also used. We cited Jago et al (2010) in the paper for this, but
15 other examples are evident, including the SPEEDY study in the UK (Steele et al 2010 and
16 Corder et al 2010), and more recently Ekelund et al (2012) reporting from the international
17 children's accelerometry database. Moreover, 500 minutes enabled a larger number of
18 participants to remain in the analysis and thus provide a better estimate of effect.
- 19 • Non-wear time has been classified based on 20, 30, 60 and 120 minutes of consecutive
20 zeros. The early accelerometer research was focussed on MVPA and thus was not so
21 concerned with sedentary time being miss-classified as non-wear time. In pilot studies we
22 identified that children can accumulate over 60 minutes of consecutive zeros when involved
23 in sedentary activities such as watching TV. Given we were particularly interested in the
24 potential shift from sedentary to light or MVPA we wanted to ensure we did not miss-
25 classify sedentary time as non-wear time. The rationale for 120mins has been added to the
26 text.
27

28
29 26. P.10, l 39, abbreviation of electronic games (e-games) was used at this point but not earlier.
30 This needs to be rectified throughout for consistency

- 31 • Thank you for picking up this error. Electronic has been spelt in full throughout now.
32

33 27. P.12, l 7. As stated above ITT was not used (56 were analysed, which is not the number
34 randomised). Per protocol analysis was presented. The additional analysis with those who adhered
35 to the intervention is a sensitivity analysis, but these data are not present in the MS (I may have
36 missed this).
37

- 38 • Please see response to point 3
39

40 28. P.12, l 29, 91% of children had access to electronic games; however this number should be
41 100% as this was part of the inclusion criteria. Can this be explained?

- 42 • The clarification provided above, that the inclusion referred to participants being able to
43 access the games provided in the study, explains the perceived inconsistency. The data are
44 correct and no changes were made here, only to clarify the inclusion criteria.
45

46 29. P.12-14 results. It is important to present the primary outcome data first. Everything else is
47 secondary as the study was not powered to detect these effects. The term significant is misleading. If
48 used this should refer to statistical significance. However many of the findings suggest a trend in a
49 particular direction and the term non-significant is misleading.
50

- 51 • We have edited the text to report the mean daily MVPA over the whole week first as
52 requested.
- 53 • On pages 6 and 18 we used 'significant' in the lay sense rather than the statistical sense and
54 this was a mistake. We have replaced these instances with 'substantial'. Now all use of the
55 term is in the statistical sense to avoid confusion.
- 56 • We have used the term 'non-significant' trend to highlight the consistency of direction but
57 be clear about the lack of statistical significance.
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4 30. Page 16, final paragraph is confusing. Can this be restructured to reflect its true meaning?
5 • The paragraph has been edited to improve clarity as suggested.
6
7
8 31. P. 19, line 3, should this be sedentary time during after school time?
9 • Have replaced 'in' with 'during' as suggested.
10
11 32. P. 19, line 19, the Maddison study also should a reduction in sedentary time, which reflected
12 the time gained in PA. This should be mentioned as the findings of the present study suggest a
13 similar compensation. Thus displacement in sedentary behaviour may be compensated with
14 increases in PA time.
15 • Additional detail from Maddison study included as requested.
16
17 33. P. 19, line 45, should this read...Whilst time spent viewing TV appears.....
18 • Sentence edited as suggested
19
20 34. P. 20 The weakness outlined in this needs to be expanded on. Why was the study terminated
21 early? What were the technology changes and how did this impact the study (low recruitment,
22 power etc). Was this a protocol violation? Other weakness need to be considered (loss to follow-up,
23 lack of imputation of missing data).
24 • We have provided details of the new electronic game technology released late 2010 in
25 Australia and that this resulted in no children being willing to commit to the original study
26 protocol. The new devices, and the games available on them, were qualitatively different to
27 those in the original protocol so we could not simply replace the equipment and continue
28 with the study.
29 • We have included mention of the withdrawal of participants and lack of adequate
30 accelerometer data limitations. We have not listed lack of imputation of missing data as a
31 limitation, as we have explained above that the analysis approach taken was appropriate for
32 the design.
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References for Response:

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4 Ridley R et al. 2006 The Multimedia activity recall for children and adolescents (MARCA): development and
5 evaluation Int J Behav Nutr Phys Act. 2006; 3: 10. doi: 10.1186/1479-5868-3-10
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8 SPEEDY Study. Int J Behav Nut Phys Act, 7:88 doi:10.1186/1479-5868-7-88
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For peer review only



To remove or to replace traditional electronic games? A cross-over 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.

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2013-002629.R2
Article Type:	Research
Date Submitted by the Author:	17-May-2013
Complete List of Authors:	Straker, Leon; Curtin University, Department of Physiotherapy Abbott, Rebecca; University of Exeter, Medical School Smith, Anne; Curtin University, School of Physiotherapy
Primary Subject Heading:	Public health
Secondary Subject Heading:	Sports and exercise medicine, Epidemiology, Paediatrics, Public health
Keywords:	child, physical activity, sedentary behaviour, accelerometry, screentime

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To remove or to replace traditional electronic games? A cross-over 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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Word count: 4631

Abstract word count: 300

Number of tables: 2

Number of figures: 2

Number of references: 51

Keywords children, physical activity, sedentary behaviour, accelerometry, screentime

ABSTRACT

Objective To evaluate the impact of a) the removal of home access to traditional electronic games, or b) their replacement with active input electronic games, on daily physical activity and sedentary behaviour in children aged 10-12 years.

Design Cross-over randomised controlled trial, over 6 months.

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

Participants 10-12 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 3.8min/day, 95% CI 1.5 to 6.1) and a decrease in sedentary time (4.7min/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 (3.2min/day, 0.9 to 5.5) and a decrease in sedentary time (6.2min/day, 1.4 to 11.4) in the after school period. Diary reports supported an increase in

1
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3 physical activity and decrease in screen based sedentary behaviours with both
4
5 interventions.
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8 **Conclusion** Removal of sedentary electronic games from the child's home and replacing
9
10 these with active electronic games both resulted in small objectively measured
11
12 improvements in after school activity and sedentary time. Parents can be advised that
13
14 replacing sedentary electronic games with active electronic games is likely to have the same
15
16 effect as removing all electronic games.
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20 **Trial Registration** Australia and New Zealand Clinical Trials Registry (ACTRN
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22 12609000279224)
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ARTICLE SUMMARY

Article Focus:

- Physical activity 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 home, 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 to 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 physical activity and sedentary behaviour supplemented with self-report measures.
- Longer term studies are needed to assess whether the small effects observed over eight weeks are sustained.

INTRODUCTION

It is well recognised that physical activity 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 physical activity and increase in sedentary time.^{3,4} Electronic games are played on various devices including dedicated consoles (e.g. Microsoft Xbox®, Sony PlayStation 3®, Nintendo Wii®) and hand held players (e.g. Nintendo DS®, PlayStationPSP®) as well as non-dedicated technologies such as computers, tablets and smart phones. International evidence shows the majority of children in affluent countries now have substantial daily exposure to electronic games. For example in the United Kingdom (UK), approximately half of children spend over an hour per day using computer games alone.⁵ In the United States of America (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 UK, USA and Australia range from 38min/day to 90min/day.⁶⁻⁸

Whilst 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 physical activity (i.e. 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 physical activity level, with a similar relationship for obesity.¹¹ However, to date, 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

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3 PlayStation EyeToy® and Move®, dance mats and Microsoft Xbox Kinect® have added to the
4
5 controversy. Laboratory studies have shown that some of these active games can result in
6
7 meaningful increases in muscle activity, movement and energy expenditure whilst others
8
9 result in less activity.^{12, 13} Findings from the few available home-based interventions
10
11 comparing access to traditional electronic games alone with supplemental access to active
12
13 electronic games have been mixed: with some evidence for improvements in body fatness,
14
15 ¹⁴ and fitness in overweight children, ¹⁵ though no effect on objectively measured physical
16
17 activity for a sample including both overweight and normal weight children.¹⁶ The long term
18
19 efficacy of active games in promoting physical activity remains questionable,^{13, 17} but with
20
21 potential promise.¹⁸

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27 With no clear evidence either way, the public health response to date has been to develop
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29 recommendations to restrict all children's screen based leisure (television, computers and
30
31 all electronic games), typically to maximum of 2hrs a day.^{19, 20} Compliance with these
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33 guidelines has been poor,^{21, 22} which may be due to difficulties experienced by parents when
34
35 trying to implement the guidelines. Options for parents include removing electronic games
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37 from the family home or replacing traditional electronic games with active electronic games.
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39 To date there has been no study evaluating the effect of both these approaches. Therefore
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41 this study sought to explore, through a cross-over randomised controlled trial, the effect of
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43 either removing electronic games from the children's home environment or replacing
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45 traditional sedentary electronic games with active input electronic games on children's
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47 physical activity and sedentary behaviour.
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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, 10-12 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 diary and questionnaires,²⁴ have a high use of electronic games⁶ and are developing activity and sedentary behaviour patterns pre-adolescence which may track into adulthood.^{25, 26} Recruitment was staggered as well as being spread over three 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 socio-economic 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 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 6 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. 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 cross-over design was chosen (see Figure 1).

Sample size

1
2
3 For power calculations, daily moderate/vigorous physical activity (MVPA) was estimated at
4
5 115+30 min with a minimum effect size of 15 min considered important based on effects in
6
7 prior studies.²⁷ If the variation in the physical activity level between repeated time points in
8
9 each individual is normally distributed with standard deviation 30 min, and the true effect of
10
11 game condition is 15 min, a study with 72 subjects would reject the null hypothesis that this
12
13 response difference is zero with probability (power) 0.986. The Type I error probability
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15 associated with this test of this null hypothesis is 0.05. If the Type I error is lowered to 0.01
16
17 to account for 'repeated' contrasts between conditions, the power is 0.943.²⁸ We allowed
18
19 for a 10% attrition in data. The study was curtailed earlier than planned as new electronic
20
21 game technologies (Sony PlayStation 3® and Microsoft Xbox Kinect®) became popular in late
22
23 2010 in Perth making it unfeasible to recruit children to the older game technology. Data
24
25 from 9 children who participated in the 2007 pilot study using the same activity and
26
27 condition protocol were included to provide the best estimate of intervention effects.
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34 **Recruitment and study procedure**

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36
37 Following screening, participants were randomly allocated to an order of conditions by
38
39 selection of an opaque sealed envelope. A balance of orders across the year was achieved
40
41 by having sets of the 6 possible order permutations in each year cohort. After informed
42
43 consent/assent from parent and child, a research officer visited the home and instructed the
44
45 parent and child in baseline assessments. The baseline visit included an explanation of the
46
47 accelerometer along with a physical activity recall diary (see outcomes measures for detail).
48
49 At baseline data were also collected on the child's height, weight, socioeconomic status,
50
51 motor coordination and electronic game experience. The research officer returned after 10
52
53 days to collect baseline assessments and set up the electronic game condition. This involved
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3 either removal of all electronic games or setting up electronic game equipment and
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5 instructing parent and child in its use. Follow-up phone calls were made the next day and
6
7 after 6 days to ensure game equipment was working correctly. Towards the end of the 6th
8
9 week in each condition, the research officer visited again to set up the physical activity
10
11 assessments (accelerometer and diary). After 8 weeks in each condition the research officer
12
13 returned, collected the completed activity diary and accelerometer and set up the next
14
15 condition. Assessments were scheduled to avoid school and public holidays where possible.
16
17 Individualised reports were provided to participants on study completion. The research
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19 officers involved with the setting up each condition were not involved in the subsequent
20
21 analyses of the primary and secondary outcomes.
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27 **Outcome measures**

28 *Physical activity and sedentary time by accelerometry*

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33 The primary outcome was the mean daily minutes of MVPA over the whole week. Time
34
35 spent in moderate to vigorous, light and sedentary intensity physical activity was assessed
36
37 over 7 days using Actical accelerometers worn on the hip. Actical is a widely used and
38
39 validated accelerometer in studies of children and adolescents.²⁹⁻³¹ The accelerometers
40
41 were set to record at 15 second epoch intervals.³² As per established standard practices
42
43 with accelerometry, a minimum of 4 days (at least one weekend day) was regarded as a
44
45 valid recording.³³ The minimum recording time required for a day to be considered valid was
46
47 500 minutes.⁷ Data were individually visually checked for missing values. Non-wear time,
48
49 regarded as 120 minutes of consecutive zero's (based on pilot data showing children could
50
51 accumulate more than 60 minutes of consecutive zero counts when watching television),
52
53 was removed prior to analyses. Activity intensity thresholds based on Colley *et al.*³⁴ were
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1
2
3 used to convert the raw counts into minutes of sedentary, light, moderate and vigorous
4
5 intensity physical activity. Minutes spent in each of these intensity categories were
6
7 calculated for an average day over the whole week. As there are known to be variations
8
9 depending on the type of day³⁵ and time of the day³⁶ which may be masked in whole week
10
11 analysis, analysis was also conducted on school days, weekend days, and the afterschool
12
13 period (from 3.30 to 6.00pm). The after school period was chosen as this has been
14
15 suggested to be an important time in the child's day for both discretionary physical activity
16
17 and sedentary leisure time.³⁷ Measures of the pattern of sedentary, light and moderate-to-
18
19 vigorous activity were also calculated for the same time periods.³⁸ custom LabView
20
21 program was used to process the data.
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27 *Physical activity and sedentary behaviours by diary*

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30 To provide descriptive information on the type of activities performed and understand any
31
32 changes in accelerometer determined exposure, participants used a modified version of the
33
34 previous-day physical activity recall (PDPAR) in the form of a diary for 7 days.³⁹ The
35
36 predominant activity was recorded for each 30 minute block during waking hours. Use of
37
38 the PDPAR over several consecutive days, in the form of a diary has also been shown to be
39
40 valid, against measures of accelerometry, and feasible.⁴⁰ The participants also used this
41
42 diary to make a note of whether and why the accelerometer was removed for any period
43
44 during the day. Active leisure, sedentary leisure and various components of sedentary
45
46 leisure were assessed across the whole week, school days, weekend days and during the
47
48 after school period using custom macros in Excel.
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54 *Covariates*

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3 Age, sex, BMI and electronic game experience were considered for potential modification of
4
5 condition effects. Prior physical activity research has identified significant differences
6
7 between summer and winter seasons and interactions with sex (more reduction in PA in
8
9 winter in girls).⁴¹ The potential seasonal effect was allowed for in the design by having a
10
11 balanced ordering of game conditions and a staggered start to cover the whole school year.
12
13 Previous electronic game experience which could confound the effect of the game condition
14
15 was measured using a questionnaire based on our prior studies and a large USA study and
16
17 used in analysis.⁴²
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22 **Statistical Analyses**

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24
25 Data were analysed using mixed-model repeated measures analyses to estimate the
26
27 magnitude of two condition contrasts for each outcome (no games versus traditional
28
29 electronic games, and active electronic games versus traditional electronic games) using
30
31 measures from participants with valid data from at least two of the three conditions,
32
33 adjusting for period and, in the case of accelerometry data, accelerometer wear time.
34
35
36 Eleven participants were missing valid accelerometry data for one condition (4 traditional, 2
37
38 no games and 5 active games), and there were no participants missing data for more than
39
40 one condition These missing values were accounted for in the linear mixed model, which
41
42 uses a likelihood-based estimation procedure resulting in non-biased estimates by imputation of
43
44 missing responses based upon the surrounding responses and modelled covariance structure.
45
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47 Testing for a treatment by period interaction with statistical significance set at $p < 0.1$ was
48
49 used to determine whether a carryover effect existed. To verify the absence of influential
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51 outliers, initial screening was performed by graphical examination of condition differences
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3 plotted against averages, and standardised residuals from each model were plotted against
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5 fitted values.
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9 Statistical analysis was performed using Stata/IC 10.1 for Windows (StataCorp LP, College
10
11 Station TX, USA). All statistical tests were 2-tailed with $\alpha=0.05$. Analysis was by intention-to-
12
13 treat, though per protocol analysis was also conducted, with the 33 participants who used
14
15 active games for more than 15 min/day during the active e-game condition.
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17

18 19 RESULTS

20 21 Participants

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23
24 Figure 1 shows the participant flow chart. Eight participants provided baseline data but
25
26 withdrew during their first condition (6 male, mean age 10.5 years, height 1.48m , weight
27
28 48.3kg , socioeconomic status range 5th to 9th centile, 4 condition orders). Ten participants
29
30 completed the study but had insufficient accelerometer data after all three conditions (5
31
32 male, mean age 11.4 years, height 1.48m, weight 43.8kg, socioeconomic status range 3rd to
33
34 10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female)
35
36 who completed the study and had sufficient accelerometry data for planned analyses had a
37
38 mean (sd) age of 11.3 (0.8) years. Participant height (1.50 (0.08) m), weight (41.3 (10.3) kg)
39
40 and zBMI (-0.1 (1.2)) were similar to the national distribution for this age.⁸ Nearly all
41
42 children had home access to electronic games (91%) and reported playing electronic games
43
44 in the last month (95%), with 61% reporting playing at least 2-3 times a week. Duration of
45
46 playing sessions was most commonly <30min (41%), though 31% usually played for 30-
47
48 60min and 24% usually played for 1-2hrs. Participant socioeconomic status based on
49
50 location of family home⁴³ ranged from the second to tenth Australian centile. Participant
51
52 motor coordination status ranged from poor to excellent (MAND⁴⁴ 2007:NDI 62-125; MABC-
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3 2⁴⁵ 2009-10: 9-98%), approximating a general population. There were no deviations from
4
5 randomised allocation.
6
7

8 **Accelerometry**

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11 Daily accelerometer wear time was around 827.8 min over the week, and was somewhat
12
13 shorter on weekend days than school days (788.9 vs 827.8min). With home access to
14
15 traditional games, regarded as the norm for most families at the start of this study, daily
16
17 MVPA was less than one hour (mean 54.1 min, 95% CI 47.5 to 60.7) whereas daily sedentary
18
19 time was around eight and a half hours (522.7 min, 509.4 to 535.9).
20
21

22
23 Table 1 shows that in comparison to traditional games, removal of all electronic games
24
25 resulted in no significant change in daily MVPA over the whole week. However it did result
26
27 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
28
29 similar, though non-significant, increase in MVPA was observed over the whole school day.
30
31 The removal of all electronic games resulted in a small non-significant increase in light
32
33 activity over the whole week, with a larger though still non-significant increase on weekend
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35 days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day
36
37 (0.0 to 9.5, p=0.05) in sedentary time in the after school period, which was matched with a
38
39 small non-significant decrease in sedentary time over the whole week and a larger non-
40
41 significant decrease on weekend days. Replacing traditional games with active input games
42
43 had similar findings (Table 1). This exchange resulted in no significant change in MVPA over
44
45 the whole week but a 3.2 min/day (0.9 to 5.5, p=0.007) increase in MVPA in the after school
46
47 period, with a similar though non-significant pattern of MVPA over the whole school day.
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49 Replacing electronic games with active input games also resulted in a small non-significant
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51 increase in light activity over the whole week, with a larger though still non-significant
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3 increase on weekend days. Furthermore, replacement of traditional games with active input
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5 games resulted in a significant decrease in sedentary time in the after school period of 6.2
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7 min/day (1.4 to 11.1, $p=0.012$). A small non-significant decrease in sedentary time over the
8
9 whole week and a larger non-significant decrease on weekend days were also observed.
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Table 1: Accelerometer determined daily minutes of MVPA, light activity and sedentary time over the whole week, weekend days, school days and 3.30-6pm 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 (49.2,62.3)	54.1 (47.5,60.7)	56.1 (49.5,62.8)	1.7 (-3.2,6.6) 0.493	2.0 (-3.0,7.1) 0.428
School day	60.9 (53.9,67.8)	58.2 (51.2,65.2)	61.5 (54.4,68.5)	2.6 (-2.4,7.7) 0.306	3.2 (-2.0,8.4) 0.228
Weekend day	43.2 (34.3,52.2)	42.8 (33.7,51.9)	43.0 (33.9,52.2)	0.4 (-9.1,9.9) 0.933	0.2 (-9.5,10.0) 0.966
3.30-6pm school day	12.9 (10.3,15.5)	9.1 (6.4,11.7)	12.3 (9.6,14.9)	3.8 (1.5,6.1) 0.001	3.2 (0.9,5.5) 0.007
LIGHT PA					
Week	242.5 (230.8,254.2)	240.3 (228.5,252.2)	245.6 (233.7,257.5)	2.2 (-9.4,13.7) 0.712	5.3 (-6.6,17.2) 0.385
School day	241.3 (229.9,252.7)	242.3 (230.7,253.9)	243.8 (232.1,255.4)	-1.0 (-11.8, 9.8) 0.854	1.5 (-9.6, 12.6) 0.794
Weekend day	245.5 (228.7,262.3)	235.3 (218.3,252.4)	250.2 (233.0,267.4)	10.2 (-9.1,29.5) 0.302	14.9 (-4.9,34.6) 0.140
3.30-6pm school day	48.8 (45.3,52.4)	48.0 (44.4,51.5)	50.9 (47.2,54.5)	0.9 (-2.9,4.6) 0.649	2.9 (-1.0,6.8) 0.142
SEDENTARY					
Week	518.7 (505.6,531.7)	522.7 (509.4,535.9)	515.4 (502.1,528.7)	-4.0 (-16.8,8.8) 0.540	-7.2 (-20.4,5.9) 0.282
School day	531.1 (518.3,543.9)	532.7 (519.7,545.7)	528.3 (515.2,541.3)	-1.6 (-13.7,10.4) 0.790	-4.5 (-16.9, 8.0) 0.483
Weekend day	487.6 (468.3,507.0)	498.5 (478.8, 518.2)	483.1 (463.3,503.0)	-10.8 (-32.9,11.3) 0.336	-15.3 (-37.9,7.3) 0.184
3.30-6pm school day	88.0 (83.3,92.7)	92.7 (88.0,97.5)	86.5 (81.7,91.2)	-4.7 (-9.5,0.0) 0.050	-6.2 (-11.1,-1.4) 0.012

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3 Removing or replacing traditional electronic games had no significant effect on exposures to
4
5 bouts of MVPA lasting at least 10min, bouts of sustained sedentary time lasting at least
6
7 30min, or brief bursts at any intensity lasting less than 5 min and breaks in sedentary time
8
9 (data not shown).
10

11
12 Figure 2 provides a visual summary of the key daily differences in accelerometer determined
13
14 activity and sedentary time, for the after school period.
15
16

17 18 **Diary**

19
20 According to diary records, in the traditional games condition, children spent on average,
21
22 one and a half hours per day on active leisure and transport (mean 78min, 95% CI 63 to 93)
23
24 and four and a half hours per day on all sedentary leisure (non-screen and screen: 267min,
25
26 243 to 292). Leisure time spent on screen-based activities made up more than half of
27
28 reported sedentary leisure (163min, 139 to 187). Television viewing was the largest
29
30 contributor (107min, 85 to 129), followed by sedentary electronic games (44min, 37 to 50)
31
32 and non-gaming computer use (24min, 15 to 32).
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38 Participants reported exposure to active electronic games during the 'active games'
39
40 condition of 19 min/day, suggesting reasonable compliance with this condition. Similarly,
41
42 participants reported exposure to traditional electronic games during the 'traditional games'
43
44 condition of 34 min/day. Participant median exposure to sedentary electronic games was
45
46 zero minutes during the 'no games' and 'active games' conditions. Similarly, participant
47
48 median exposure to active electronic games was zero minutes during the 'no games' and
49
50 'traditional games' conditions, suggesting compliance with avoiding non protocol games.
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Table 2: Diary reported daily minutes of active leisure, sedentary leisure, and components of sedentary leisure in the 3.30-6pm after school period, adjusted for condition order.

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

¹median (95%CI for median), Wilcoxon sign-rank test for condition differences

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3 The diary records also provide context to the changes observed in accelerometry in the after
4 school period (Table 2). When looking at the after school period alone, the removal of electronic
5 games resulted in a significant decrease of 14 min/day in sedentary leisure and a corresponding
6
7 12 min/day increase in active leisure and transport. The breakdown of this came from a significant
8 reduction of 12 min/day of screen sedentary leisure (8 min (median) of which was sedentary
9 electronic game exposure), a non significant reduction of 3 min/day in non screen sedentary
10 leisure and a non significant reduction in non-game computer use by 1 min/day. Television
11 viewing was reported to increase by 3 min/day, though this was not significant.
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22 Again, when looking at the after school period, replacing traditional electronic games with active
23 electronic games resulted in an overall decrease of 21 min/day in sedentary leisure and a
24 corresponding non significant increase of 3 min/day in active leisure and transport along with
25 8min/day (median) of active input game time: i.e. an overall increase of activity time of about 11
26 min/day. The reduced sedentary time was achieved through a significant decrease of 14 min/day
27 in sedentary screen leisure and a 7 min/day non significant reduction in non-screen sedentary
28 leisure. No significant changes in television viewing (0 min/day), or non-game computer use (-1
29 min/day) were reported when active input games were introduced. The diary reported changes in
30 both the removal and replacement of traditional electronic games conditions provide the context
31 to the accelerometer measured activity differences during the after school period (see text within
32 Figure 2).
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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 physical activity 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 physical activity⁴⁶ 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 minutes more activity and 5 minutes less sedentary time, is similar to improvements observed in other home based studies. Maddison et al¹⁴ found a self reported 10 minute increase in active games use and a self reported reduction in sedentary electronic game use when children were provided with active electronic games in addition to traditional electronic games in a 6 month study. Whilst Baranowski et al¹⁶ 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. Whilst time spent viewing television appears to be stable,⁶ leisure time exposure to console based electronic games and computing is increasing

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2
3 rapidly,⁶ as is the increase in mobile smart phones and touch screen tablets that are used for
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5 electronic gaming, social networking, video viewing, and internet surfing.⁴⁷ Therefore small
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7 changes across a variety of these platforms could result in a more substantial clinical impact.
8
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10 Whilst our study focussed on the home-setting, school offers another opportunity for more active
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12 technologies.⁴⁸ Children sit for a long time at school and there is potential to further reduce
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14 sedentariness by engaging with technologies such as sit-stand desks, or active-input electronic
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16 media as part of lessons.³⁵
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20 The strengths of the study include the strong within subjects randomised controlled trial design
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22 with staggered starts and counterbalanced orders to control for extraneous factors. The
23
24 participants were representative of a general population of 10-12 year old children in terms of
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26 sex, weight, motor coordination, electronic game experience and socio-economic status,
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28 informing the likely broad impact of replacement as a public health intervention. The study was
29
30 also grounded in the naturalistic setting of the family home. Whilst active-input technologies have
31
32 been tested by children in the laboratory and found to increase energy expenditure, this does not
33
34 account for what happens in practice when the active games are amongst a milieu of other
35
36 distractions.¹⁷ Furthermore, this is the first study to examine the effects of fully removing
37
38 electronic games from the home. The study also used active electronic game technology with a
39
40 known capacity to increase whole body movement and energy expenditure, rather than the Wii®
41
42 which children can play with only hand movement. Some Wii® based games have been found to
43
44 be little different to traditional sedentary electronic games.⁴⁹ The study also provided a
45
46 substantial range and variation in game offerings, addressing the known issue of active games
47
48 being less engaging,⁴⁹ although it was difficult at times to keep participants engaged as the most
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50 popular game genre – killing – was excluded from the study on ethical grounds. The other key
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3 strength of the study is that it used an objective measure of physical activity and sedentary time
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5 and supplemented this with self-reported diary measures to aid understanding and interpretation
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7 of results.
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11 The main weakness was the need to curtail the study one year early due to electronic game
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13 technology changes, specifically the widespread introduction during late 2010 of new active
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15 electronic game devices Xbox Kinect® and PlayStation Move®. These new technologies and the
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17 active games available on these devices were qualitatively different and could not simply replace
18
19 the older devices in the same protocol. This meant children were unwilling to agree to the original
20
21 protocol and thus recruitment ceased. The inability to recruit participants for the final planned
22
23 year resulted in a reduced sample size which was partly compensated for by using data from 9
24
25 subjects who participated in the protocol in 2007. The reduced numbers meant we were unable to
26
27 determine whether the 10-15 minute change in sedentary and light intensity activity on weekends
28
29 was real. The withdrawal of participants and the lack of adequate accelerometry data on some
30
31 participants are other obvious limitations. A further limitation was that whilst the diaries
32
33 suggested compliance to both conditions was good, we did not have a way of measuring precisely
34
35 how much the active games were used.¹⁷
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42 The accelerometer data presented here showed small improvements in whole body movement,
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44 which may be useful for a range of physiological effects, one of which is energy expenditure.
45
46 However the actual energy expenditure, and thus the likely impact on obesity, should also be
47
48 determined. The small improvements seen at a group level may mask varied changes for
49
50 individuals, with the potential for the exposure of some individuals to be markedly effected. Thus
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52 the effect modification of factors such as sex, age, electronic game experience, attitudes to
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54 technology and physical activity, motor competence and weight status should also be examined.
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3 Given the strong evidence for detrimental effects of too little physical activity and too much
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5 sedentary time,^{50, 51} in particular too much screen time³ and the potential interaction between
6
7 these in children,²¹ there is a mounting need to understand childhood behaviours and intervene.
8
9 Children in this study were sedentary for just over 8 hours per day and reported spending
10
11 approximately three hours per day on screen based leisure, on the low side but comparable with
12
13 international findings.^{6, 47} Given this high sedentary exposure, health care practitioners should use
14
15 all available opportunities to encourage children (and their parents) to be more active and less
16
17 sedentary. Sigman³ has recently called for the medical community to take a more proactive
18
19 approach to reducing children's screen time exposure. With the increasingly electronic media
20
21 enmeshed world of youth, it is unrealistic for parents to remove access to screen based leisure
22
23 completely and therefore parents and health professionals alike need to work with technology to
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25 assist its development in ways which are health enhancing rather than health reducing. It was
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27 encouraging in this study that the replacing option resulted in at least as good an outcome as
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29 removing, and this may potentially result in more successful long term outcomes due to better
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31 sustained compliance.
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39 **CONCLUSION**

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42 Screen based leisure is a major component of sedentary behaviour and interventions should be
43
44 targeted to television, computer and electronic game use. This study has shown that replacing
45
46 sedentary with active electronic games will provide at least as good an activity outcome and
47
48 perhaps be easier for parent and child to sustain than removing electronic game technology from
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50 the home.
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3 *Acknowledgements:* We thank all the children and their families for their dedication. We thank D
4
5 Metcalf, A Campbell, R Collins, J Coleman, D Gill and J Chua for help with data collection and
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7 processing.
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11 *Contributors:* All authors had full access to the data and can take responsibility for the integrity of
12
13 the data and accuracy of the data analyses. LS conceived and managed the study; LS, RA and AS
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15 designed the study; AS analysed the data; LS and RA drafted the manuscript; LS, RA and AS edited,
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17 critically revised and approved the manuscript.
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19

20
21 *Funding:* The study was funded by a National Health and Medical Research Council of Australia
22
23 project grant (533526). LS was on a fellowship funded by the National Health and Medical
24
25 Research Council of Australia. The funding body had no influence on the analysis and reporting of
26
27 the study.
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30
31 *Competing interests:* none declared. All authors have completed the Unified Competing Interest
32
33 form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author)
34
35 and declare: LS had financial support from an NHMRC senior research fellowship for the
36
37 submitted work, no financial support for RA or AS; no financial relationships with any
38
39 organisations that might have an interest in the submitted work in the previous 3 years; no other
40
41 relationships or activities that could appear to have influenced the submitted work.
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46 *Ethical approval:* The study had ethical approval from the Human Research Ethics Committee of
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48 Curtin University (approval number HR131/2006). All participating children and their parents gave
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50 informed assent/consent.
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54 *Data sharing:* no additional data available
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3 **Figure Legends:**
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6 Figure 1. CONSORT diagram of flow of participants. Order of conditions is shown with
7 T=traditional electronic games, A=active electronic games and X= not electronic games.
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11 Figure 2. Summary of impact of removing or replacing traditional electronic games in terms of
12 objectively measured activity time (MVPA and light) and sedentary time during the after school
13 period along with diary determined changes in activities.
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To remove or to replace traditional electronic games? A cross-over randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children.

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Word count: **44674631**

Abstract word count: 300

Number of tables: 2

Number of figures: 2

Number of references: 51

Keywords children, physical activity, sedentary behaviour, accelerometry, screentime

ABSTRACT

Objective To evaluate the impact of a) the removal of home access to traditional electronic games, or b) their replacement with active input electronic games, on daily physical activity and sedentary behaviour in children aged 10-12 years.

Design Cross-over randomised controlled trial, over 6 months.

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

Participants 10-12 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 3.8min/day, 95% CI 1.5 to 6.1) and a decrease in sedentary time (4.7min/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 (3.2min/day, 0.9 to 5.5) and a decrease in sedentary time (6.2min/day, 1.4 to 11.4) in the after school period. Diary reports supported an increase in

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7 physical activity and decrease in screen based sedentary behaviours with both
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9 interventions.

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11 **Conclusion** Removal of sedentary electronic games from the child's home and replacing
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13 these with active electronic games both resulted in small objectively measured
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15 improvements in after school activity and sedentary time. Parents can be advised that
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17 replacing sedentary electronic games with active electronic games is likely to have the same
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19 effect as removing all electronic games.

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22 **Trial Registration** Australia and New Zealand Clinical Trials Registry (ACTRN
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24 12609000279224)

INTRODUCTION

It is well recognised that physical activity 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 physical activity and increase in sedentary time.^{3,4} Electronic games are played on various devices including dedicated consoles (e.g. Microsoft Xbox®, Sony PlayStation 3®, Nintendo Wii®) and hand held players (e.g. Nintendo DS®, PlayStationPSP®) as well as non-dedicated technologies such as computers, tablets and smart phones. International evidence shows the majority of children in affluent countries now have substantial daily exposure to electronic games. For example in the United Kingdom (UK), approximately half of children spend over an hour per day using computer games alone.⁵ In the United States of America (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 UK, USA and Australia range from 38min/day to 90min/day.⁶⁻⁸

Whilst 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 physical activity (i.e. 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 physical activity level, with a similar relationship for obesity.¹¹ However, to date, 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

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7 PlayStation EyeToy® and Move®, dance mats and Microsoft Xbox Kinect® have added to the
8 controversy. Laboratory studies have shown that some of these active games can result in
9 meaningful increases in muscle activity, movement and energy expenditure whilst others
10 result in less activity.^{12, 13} Findings from the few available home-based interventions
11 comparing access to traditional electronic games alone with supplemental access to active
12 electronic games have been mixed: with some evidence for improvements in body fatness,
13 ¹⁴ and fitness in overweight children, ¹⁵ though no effect on objectively measured physical
14 activity for a sample including both overweight and normal weight children.¹⁶ The long term
15 efficacy of active games in promoting physical activity remains questionable,^{13, 17} but with
16 potential promise.¹⁸

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28 With no clear evidence either way, the public health response to date has been to develop
29 recommendations to restrict all children's screen based leisure (television, computers and
30 all electronic games), typically to maximum of 2hrs a day.^{19, 20} Compliance with these
31 guidelines has been poor,^{21, 22} which may be due to difficulties experienced by parents when
32 trying to implement the guidelines. Options for parents include removing electronic games
33 from the family home or replacing traditional electronic games with active electronic games.
34 To date there has been no study evaluating the effect of both these approaches. Therefore
35 this study sought to explore, through a cross-over randomised controlled trial, the effect of
36 either removing electronic games from the children's home environment or replacing
37 traditional sedentary electronic games with active input electronic games on children's
38 physical activity and sedentary behaviour.

METHODS

Study ~~design methods and~~ participants

~~This study used a within subjects cross-over randomised controlled trial design and was conducted in Perth, Western Australia in 2007-2010. Th~~[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 design of the study protocol has been previously described published.](#)²³ In summary, 10-12 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 diary and questionnaires,²⁴ have a high use of electronic games⁶ and are developing activity and sedentary behaviour patterns pre-adolescence which may track into adulthood.^{25, 26}

Recruitment was staggered [as well as being spread](#) over three 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 socio-economic 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

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7 maintain game condition access, or lived remote to the University campus. Ethical approval
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9 was provided by Curtin University Human Research Ethics Committee.

10 11 **Intervention**

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14 There were three levels of electronic game access. 'No games' involved all dedicated
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16 electronic game devices being removed from the family home with a contract by each child
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18 that electronic games were to be avoided where possible on other devices and locations.
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20 'Traditional games' involved the provision of a Sony PlayStation 2® with a range of non-
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22 violent games requiring game pad input. 'Active games' involved the provision of a Sony
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24 PlayStation 2® with EyeToy® and dance mat input devices and a range of non-violent games.
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26 For each condition children selected 6 games and were allowed to change games mid
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28 intervention. A condition period of 8 weeks was chosen for each intervention as it has been
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30 found to be sufficient to show physical and psychological changes. Eight weeks also allows
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32 for children to accommodate to each condition and is not so long to adversely affect
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35 recruitment and compliance in the 'no games' condition. ~~From our pilot study and~~
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37 ~~discussions with children, the removal of all electronic games was acceptable as a way of~~
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39 ~~getting access to a range of new games and equipment for four months. This is why a within~~
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41 ~~subjects design was chosen.~~

42 43 **Study Design**

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46 ~~This study used a within subjects cross over randomised controlled trial design and was~~
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48 ~~conducted in Perth, Western Australia in 2007-2010. A challenge for the design of this study~~
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50 ~~was to select a design which provided a 'no games' condition with high internal and external~~
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52 ~~validity. A traditional parallel arms randomised and controlled trial would have had low~~
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7 external validity as the children volunteering would not have been representative. From our
8 our pilot study and discussions with children, the removal of all electronic games was only
9 acceptable to the majority of children if the same children could get as a way of getting
10 access to a range of new games and equipment for four months. This is why a within
11 subjects design was chosen. To control for an order effect, children were randomised to a
12 balanced ordering of the three electronic game conditions. This is why a cross-over design
13 was chosen (see Figure 1).
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21 **Sample size**

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24 For power calculations, daily moderate/vigorous physical activity (MVPA) was estimated at
25 115+30 min with a minimum effect size of 15 min considered important based on effects in
26 prior studies.²⁷ If the variation in the physical activity level between repeated time points in
27 each individual is normally distributed with standard deviation 30 min, and the true effect of
28 game condition is 15 min, a study with 72 subjects would reject the null hypothesis that this
29 response difference is zero with probability (power) 0.986. The Type I error probability
30 associated with this test of this null hypothesis is 0.05. If the Type I error is lowered to 0.01
31 to account for 'repeated' contrasts between conditions, the power is 0.943.²⁸ We allowed
32 for a 10% attrition in data. The study was curtailed earlier than planned as new electronic
33 game technologies (Sony PlayStation 3® and Microsoft Xbox Kinect®) became popular in late
34 2010 in Perth making it unfeasible to recruit children to the older game technology. Data
35 from 9 children who participated in the 2007 pilot study using the same activity and
36 condition protocol were included to provide the best estimate of intervention effects.
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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 6 possible order permutations in each year cohort. After informed consent/assent from 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 physical activity recall diary (see outcomes measures for detail). At 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 parent and child in its use. Follow-up phone calls were made the next day and after 6 days to ensure game equipment was working correctly. Towards the end of the 6th week in each condition, the research officer visited again to set up the physical activity 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 each condition were not involved in the subsequent analyses of the primary and secondary outcomes.

Outcome measures

Physical activity 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 physical activity 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 second epoch intervals.³² As per established standard practices with accelerometry, a minimum of 4 days (at least one weekend day) was regarded as a valid recording.³³ The minimum recording time required for a day to be considered valid was 500 minutes.⁷ Data were individually visually checked for missing values. Non-wear time, regarded as 120 minutes of consecutive zero's (based on pilot data showing children could accumulate more than 60 minutes of consecutive zero counts when watching television), was removed prior to analyses. Activity intensity thresholds based on Colley *et al.*³⁴ were used to convert the raw counts into minutes of sedentary, light, moderate and vigorous intensity physical activity. 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 day³⁵ and time of the day³⁶ which may be masked in whole week analysis, analysis was also conducted on school days, weekend days, and the afterschool period (from 3.30 to 6.00pm). The after school period was chosen as this has been suggested to be an important time in the child's day for both discretionary physical activity 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 custom LabView program was used to process the data.

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7 *Physical activity and sedentary behaviours by diary*
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10 To provide descriptive information on the type of activities performed and understand any
11 changes in accelerometer determined exposure, participants used a modified version of the
12 previous-day physical activity recall (PDPAR) in the form of a diary for 7 days.³⁹ The
13 predominant activity was recorded for each 30 minute block during waking hours. Use of
14 the PDPAR over several consecutive days, in the form of a diary has also been shown to be
15 valid, against measures of accelerometry, and feasible.⁴⁰ The participants also used this
16 diary to make a note of whether and why the accelerometer was removed for any period
17 during the day. Active leisure, sedentary leisure and various components of sedentary
18 leisure were assessed across the whole week, school days, weekend days and during the
19 after school period using custom macros in Excel.
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30 *Covariates*
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33 Age, sex, BMI and electronic game experience were considered for potential modification of
34 condition effects. Prior physical activity research has identified significant differences
35 between summer and winter seasons and interactions with sex (more reduction in PA in
36 winter in girls).⁴¹ The potential seasonal effect was allowed for in the design by having a
37 balanced ordering of game conditions and a staggered start to cover the whole school year.
38
39 Previous electronic game experience which could confound the effect of the game condition
40 was measured using a questionnaire based on our prior studies and a large USA study and
41 used in analysis.⁴²
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Statistical Analyses

Data were analysed using mixed-model repeated measures analyses to estimate the magnitude of two condition contrasts for each outcome (no games versus traditional electronic games, and active electronic games versus 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 upon the surrounding responses and modelled covariance structure.

Testing for a treatment by period interaction. Statistical with statistical significance set at $p < 0.1$ was used to determine whether a carryover effect (treatment by period interaction) existed at $p < 0.1$. 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 10.1 for Windows (StataCorp LP, College Station TX, USA). All statistical tests were 2-tailed with $\alpha = 0.05$. 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

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7 Figure 1 shows the participant flow chart. Eight participants provided baseline data but
8 withdrew during their first condition (6 male, mean age 10.5 years, height 1.48m , weight
9 48.3kg , socioeconomic status range 5th to 9th centile, 4 condition orders). Ten participants
10 completed the study but had insufficient accelerometer data after all three conditions (5
11 male, mean age 11.4 years, height 1.48m, weight 43.8kg, socioeconomic status range 3rd to
12 10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female)
13 who completed the study and had sufficient accelerometry data for planned analyses ([valid
14 data for at least two conditions](#)) had a mean (sd) age of 11.3 (0.8) years. Participant height
15 (1.50 (0.08) m), weight (41.3 (10.3) kg) and zBMI (-0.1 (1.2)) were similar to the national
16 distribution for this age.⁸ Nearly all children had home access to electronic games (91%) and
17 reported playing electronic games in the last month (95%), with 61% reporting playing at
18 least 2-3 times a week. Duration of playing sessions was most commonly <30min (41%),
19 though 31% usually played for 30-60min and 24% usually played for 1-2hrs. Participant
20 socioeconomic status based on location of family home⁴³ ranged from the second to tenth
21 Australian centile. Participant motor coordination status ranged from poor to excellent
22 (MAND⁴⁴ 2007:NDI 62-125; MABC-2⁴⁵ 2009-10: 9-98%), approximating a general population.
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39 [There were no deviations from randomised allocation.](#)
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42 Accelerometry

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44 Daily accelerometer wear time was around 827.8 min over the week, and was somewhat
45 shorter on weekend days than school days (788.9 vs 827.8min). With home access to
46 traditional games, regarded as the norm for most families at the start of this study, daily
47 MVPA was less than one hour (mean 54.1 min, 95% CI 47.5 to 60.7) whereas daily sedentary
48 time was around eight and a half hours (522.7 min, 509.4 to 535.9).
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7 Table 1 shows that in comparison to traditional games, removal of all electronic games
8 resulted in no significant change in daily MVPA over the whole week. However it did result
9 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
10 similar, though non-significant, increase in MVPA was observed over the whole school day.
11
12 The removal of all electronic games resulted in a small non-significant increase in light
13 activity over the whole week, with a larger though still non-significant increase on weekend
14 days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day
15 (0.0 to 9.5, $p=0.05$) in sedentary time in the after school period, which was matched with a
16 small non-significant decrease in sedentary time over the whole week and a larger non-
17 significant decrease on weekend days. Replacing traditional games with active input games
18 had similar findings (Table 1). This exchange resulted in no significant change in MVPA over
19 the whole week but a 3.2 min/day (0.9 to 5.5, $p=0.007$) increase in MVPA in the after school
20 period, with a similar though non-significant pattern of MVPA over the whole school day.
21
22 Replacing electronic games with active input games also resulted in a small non-significant
23 increase in light activity over the whole week, with a larger though still non-significant
24 increase on weekend days. Furthermore, replacement of traditional games with active input
25 games resulted in a significant decrease in sedentary time in the after school period of 6.2
26 min/day (1.4 to 11.1, $p=0.012$). A small non-significant decrease in sedentary time over the
27 whole week and a larger non-significant decrease on weekend days were also observed.
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Table 1: Accelerometer determined daily minutes of MVPA, light activity and sedentary time over the whole week, weekend days, school days and 3.30-6pm 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 (49.2,62.3)	54.1 (47.5,60.7)	56.1 (49.5,62.8)	1.7 (-3.2,6.6) 0.493	2.0 (-3.0,7.1) 0.428
School day	60.9 (53.9,67.8)	58.2 (51.2,65.2)	61.5 (54.4,68.5)	2.6 (-2.4,7.7) 0.306	3.2 (-2.0,8.4) 0.228
Weekend day	43.2 (34.3,52.2)	42.8 (33.7,51.9)	43.0 (33.9,52.2)	0.4 (-9.1,9.9) 0.933	0.2 (-9.5,10.0) 0.966
3.30-6pm school day	12.9 (10.3,15.5)	9.1 (6.4,11.7)	12.3 (9.6,14.9)	3.8 (1.5,6.1) 0.001	3.2 (0.9,5.5) 0.007
LIGHT PA					
Week	242.5 (230.8,254.2)	240.3 (228.5,252.2)	245.6 (233.7,257.5)	2.2 (-9.4,13.7) 0.712	5.3 (-6.6,17.2) 0.385
School day	241.3 (229.9,252.7)	242.3 (230.7,253.9)	243.8 (232.1,255.4)	-1.0 (-11.8, 9.8) 0.854	1.5 (-9.6, 12.6) 0.794
Weekend day	245.5 (228.7,262.3)	235.3 (218.3,252.4)	250.2 (233.0,267.4)	10.2 (-9.1,29.5) 0.302	14.9 (-4.9,34.6) 0.140
3.30-6pm school day	48.8 (45.3,52.4)	48.0 (44.4,51.5)	50.9 (47.2,54.5)	0.9 (-2.9,4.6) 0.649	2.9 (-1.0,6.8) 0.142
SEDENTARY					
Week	518.7 (505.6,531.7)	522.7 (509.4,535.9)	515.4 (502.1,528.7)	-4.0 (-16.8,8.8) 0.540	-7.2 (-20.4,5.9) 0.282
School day	531.1 (518.3,543.9)	532.7 (519.7,545.7)	528.3 (515.2,541.3)	-1.6 (-13.7,10.4) 0.790	-4.5 (-16.9, 8.0) 0.483
Weekend day	487.6 (468.3,507.0)	498.5 (478.8, 518.2)	483.1 (463.3,503.0)	-10.8 (-32.9,11.3) 0.336	-15.3 (-37.9,7.3) 0.184
3.30-6pm school day	88.0 (83.3,92.7)	92.7 (88.0,97.5)	86.5 (81.7,91.2)	-4.7 (-9.5,0.0) 0.050	-6.2 (-11.1,-1.4) 0.012

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7 Removing or replacing traditional electronic games had no significant effect on exposures to
8 bouts of MVPA lasting at least 10min, bouts of sustained sedentary time lasting at least
9 30min, or brief bursts at any intensity lasting less than 5 min and breaks in sedentary time
10 (data not shown).
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15 Figure 2 provides a visual summary of the key daily differences in accelerometer determined
16 activity and sedentary time, for the after school period.
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19 **Diary**

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22 According to diary records, in the traditional games condition, children spent on average,
23 one and a half hours per day on active leisure and transport (mean 78min, 95% CI 63 to 93)
24 and four and a half hours per day on all sedentary leisure (non-screen and screen: 267min,
25 243 to 292). Leisure time spent on screen-based activities made up more than half of
26 reported sedentary leisure (163min, 139 to 187). Television viewing was the largest
27 contributor (107min, 85 to 129), followed by sedentary electronic games (44min, 37 to 50)
28 and non-gaming computer use (24min, 15 to 32).
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37 Participants reported exposure to active electronic games during the 'active games'
38 condition of 19 min/day, suggesting reasonable compliance with this condition. Similarly,
39 participants reported exposure to traditional electronic games during the 'traditional games'
40 condition of 34 min/day. Participant median exposure to sedentary electronic games was
41 zero minutes during the 'no games' and 'active games' conditions. Similarly, participant
42 median exposure to active electronic games was zero minutes during the 'no games' and
43 'traditional games' conditions, suggesting compliance with avoiding non protocol games.
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Table 2: Diary reported daily minutes of active leisure, sedentary leisure, and components of sedentary leisure in the 3.30-6pm after school period, adjusted for condition order.

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

¹median (95%CI for median), Wilcoxon sign-rank test for condition differences

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8 The diary records also provide context to the changes observed in accelerometry in the after
9 school period (Table 2). When looking at the after school period alone, the removal of electronic
10 games resulted in a significant decrease of 14 min/day in sedentary leisure and a corresponding
11 12 min/day increase in active leisure and transport. The breakdown of this came from a significant
12 reduction of 12 min/day of screen sedentary leisure (8 min (median) of which was sedentary
13 electronic game exposure), a non significant reduction of 3 min/day in non screen sedentary
14 leisure and a non significant reduction in non-game computer use by 1 min/day. Television
15 viewing was reported to increase by 3 min/day, though this was not significant.
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24 Again, when looking at the after school period, replacing traditional electronic games with active
25 electronic games resulted in an overall decrease of 21 min/day in sedentary leisure and a
26 corresponding non significant increase of 3 min/day in active leisure and transport along with
27 8min/day (median) of active input game time: i.e. an overall increase of activity time of about 11
28 min/day. The reduced sedentary time was achieved through a significant decrease of 14 min/day
29 in sedentary screen leisure and a 7 min/day non significant reduction in non-screen sedentary
30 leisure. No significant changes in television viewing (0 min/day), or non-game computer use (-1
31 min/day) were reported when active input games were introduced. The diary reported changes in
32 both the removal and replacement of traditional electronic games conditions provide the context
33 to the accelerometer measured activity differences during the after school period (see text within
34 Figure 2).
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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 physical activity 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 physical activity⁴⁶ 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 minutes more activity and 5 minutes less sedentary time, is similar to improvements observed in other home based studies. Maddison et al¹⁴ found a self reported 10 minute increase in active games use and a self reported reduction in sedentary electronic game use when children were provided with active electronic games in addition to traditional electronic games in a 6 month study. Whilst Baranowski et al¹⁶ 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. Whilst time spent viewing television appears to be stable,⁶ leisure time exposure to console based electronic games and computing is increasing

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7 rapidly,⁶ as is the increase in mobile smart phones and touch screen tablets that are used for
8 electronic gaming, social networking, video viewing, and internet surfing.⁴⁷ Therefore small
9 changes across a variety of these platforms could result in a more substantial clinical impact.
10
11 Whilst our study focussed on the home-setting, school offers another opportunity for more active
12 technologies.⁴⁸ Children sit for a long time at school and there is potential to further reduce
13 sedentariness by engaging with technologies such as sit-stand desks, or active-input electronic
14 media as part of lessons.³⁵
15
16 The strengths of the study include the strong within subjects randomised controlled trial design
17 with staggered starts and counterbalanced orders to control for extraneous factors. The
18 participants were representative of a general population of 10-12 year old children in terms of
19 sex, weight, motor coordination, electronic game experience and socio-economic status,
20 informing the likely broad impact of replacement as a public health intervention. The study was
21 also grounded in the naturalistic setting of the family home. Whilst active-input technologies have
22 been tested by children in the laboratory and found to increase energy expenditure, this does not
23 account for what happens in practice when the active games are amongst a milieu of other
24 distractions.¹⁷ Furthermore, this is the first study to examine the effects of fully removing
25 electronic games from the home. The study also used active electronic game technology with a
26 known capacity to increase whole body movement and energy expenditure, rather than the Wii®
27 which children can play with only hand movement. Some Wii® based games have been found to
28 be little different to traditional sedentary electronic games.⁴⁹ The study also provided a
29 substantial range and variation in game offerings, addressing the known issue of active games
30 being less engaging,⁴⁹ although it was difficult at times to keep participants engaged as the most
31 popular game genre – killing – was excluded from the study on ethical grounds. The other key
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8 strength of the study is that it used an objective measure of physical activity and sedentary time
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10 and supplemented this with self-reported diary measures to aid understanding and interpretation
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12 of results.
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14 The main weakness was the need to curtail the study one year early due to electronic game
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16 technology changes, specifically the widespread introduction during late 2010 of new active
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18 electronic game devices Xbox Kinect® and PlayStation Move®. These new technologies and the
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20 active games available on these devices were qualitatively different and could not simply replace
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22 the older devices in the same protocol. This meant children were unwilling to agree to the original
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24 protocol and thus recruitment ceased. The inability to recruit participants for the final planned
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26 year resulted in a reduced sample size which was partly compensated for by using data from 9
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28 subjects who participated in the protocol in 2007. The reduced numbers meant we were unable to
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30 determine whether the 10-15 minute change in sedentary and light intensity activity on weekends
31
32 was real. The withdrawal of participants and the lack of adequate accelerometry data on some
33
34 participants are other obvious limitations. A further limitation was that whilst the diaries
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36 suggested compliance to both conditions was good, we did not have a way of measuring precisely
37
38 how much the active games were used.¹⁷
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40 The accelerometer data presented here showed small improvements in whole body movement,
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42 which may be useful for a range of physiological effects, one of which is energy expenditure.
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44 However the actual energy expenditure, and thus the likely impact on obesity, should also be
45
46 determined. The small improvements seen at a group level may mask varied changes for
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48 individuals, with the potential for the exposure of some individuals to be markedly effected. Thus
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50 the effect modification of factors such as sex, age, electronic game experience, attitudes to
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52 technology and physical activity, motor competence and weight status should also be examined.
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8 Given the strong evidence for detrimental effects of too little physical activity and too much
9 sedentary time,^{50,51} in particular too much screen time³ and the potential interaction between
10 these in children,²¹ there is a mounting need to understand childhood behaviours and intervene.
11
12 Children in this study were sedentary for just over 8 hours per day and reported spending
13 approximately three hours per day on screen based leisure, on the low side but comparable with
14 international findings.^{6,47} Given this high sedentary exposure, health care practitioners should use
15 all available opportunities to encourage children (and their parents) to be more active and less
16 sedentary. Sigman³ has recently called for the medical community to take a more proactive
17 approach to reducing children's screen time exposure. With the increasingly electronic media
18 enmeshed world of youth, it is unrealistic for parents to remove access to screen based leisure
19 completely and therefore parents and health professionals alike need to work with technology to
20 assist its development in ways which are health enhancing rather than health reducing. It was
21 encouraging in this study that the replacing option resulted in at least as good an outcome as
22 removing, and this may potentially result in more successful long term outcomes due to better
23 sustained compliance.
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37 **CONCLUSION**

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40 Screen based leisure is a major component of sedentary behaviour and interventions should be
41 targeted to television, computer and electronic game use. This study has shown that replacing
42 sedentary with active electronic games will provide at least as good an activity outcome and
43 perhaps be easier for parent and child to sustain than removing electronic game technology from
44 the home.
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8 *Acknowledgements:* We thank all the children and their families for their dedication. We thank D
9 Metcalf, A Campbell, R Collins, J Coleman, D Gill and J Chua for help with data collection and
10 processing.
11

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13
14 *Contributors:* All authors had full access to the data and can take responsibility for the integrity of
15 the data and accuracy of the data analyses. LS conceived and managed the study; LS, RA and AS
16 designed the study; AS analysed the data; LS and RA drafted the manuscript; LS, RA and AS edited,
17 critically revised and approved the manuscript.
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21
22 *Funding:* The study was funded by a National Health and Medical Research Council of Australia
23 project grant (533526). LS was on a fellowship funded by the National Health and Medical
24 Research Council of Australia. The funding body had no influence on the analysis and reporting of
25 the study.
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31 *Competing interests:* none declared. All authors have completed the Unified Competing Interest
32 form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author)
33 and declare: LS had financial support from an NHMRC senior research fellowship for the
34 submitted work, no financial support for RA or AS; no financial relationships with any
35 organisations that might have an interest in the submitted work in the previous 3 years; no other
36 relationships or activities that could appear to have influenced the submitted work.
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43 *Ethical approval:* The study had ethical approval from the Human Research Ethics Committee of
44 Curtin University (approval number HR131/2006). All participating children and their parents gave
45 informed assent/consent.
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50 *Data sharing:* no additional data available
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ARTICLE SUMMARY

Article Focus:

- Physical activity 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 home, 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 to 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 physical activity and sedentary behaviour supplemented with self-report measures.
- Longer term studies are needed to assess whether the small effects observed over eight weeks are sustained.

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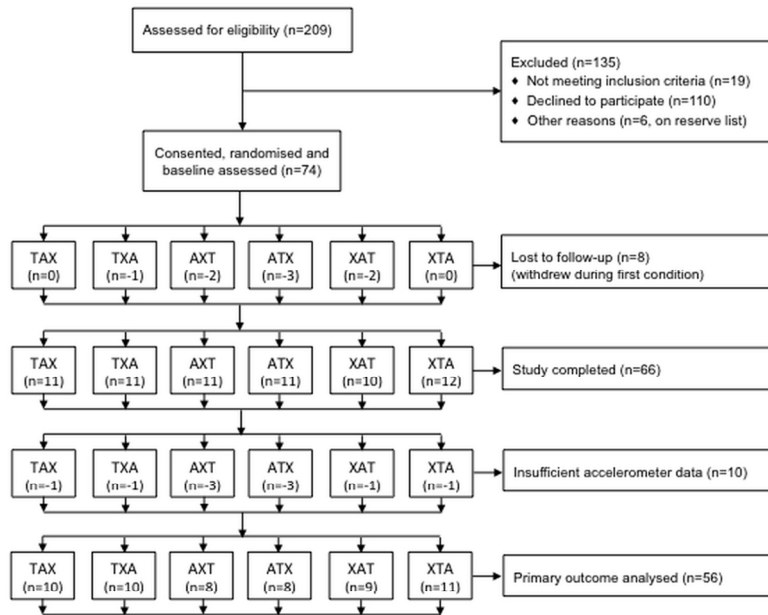
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8 **Figure Legends:**
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10 Figure 1. CONSORT diagram of flow of participants. Order of conditions is shown with
11 T=traditional electronic games, A=active electronic games and X= not electronic games.
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15 Figure 2. Summary of impact of removing or replacing traditional electronic games in terms of
16 objectively measured activity time (MVPA and light) and sedentary time during the after school
17 period along with diary determined changes in activities.
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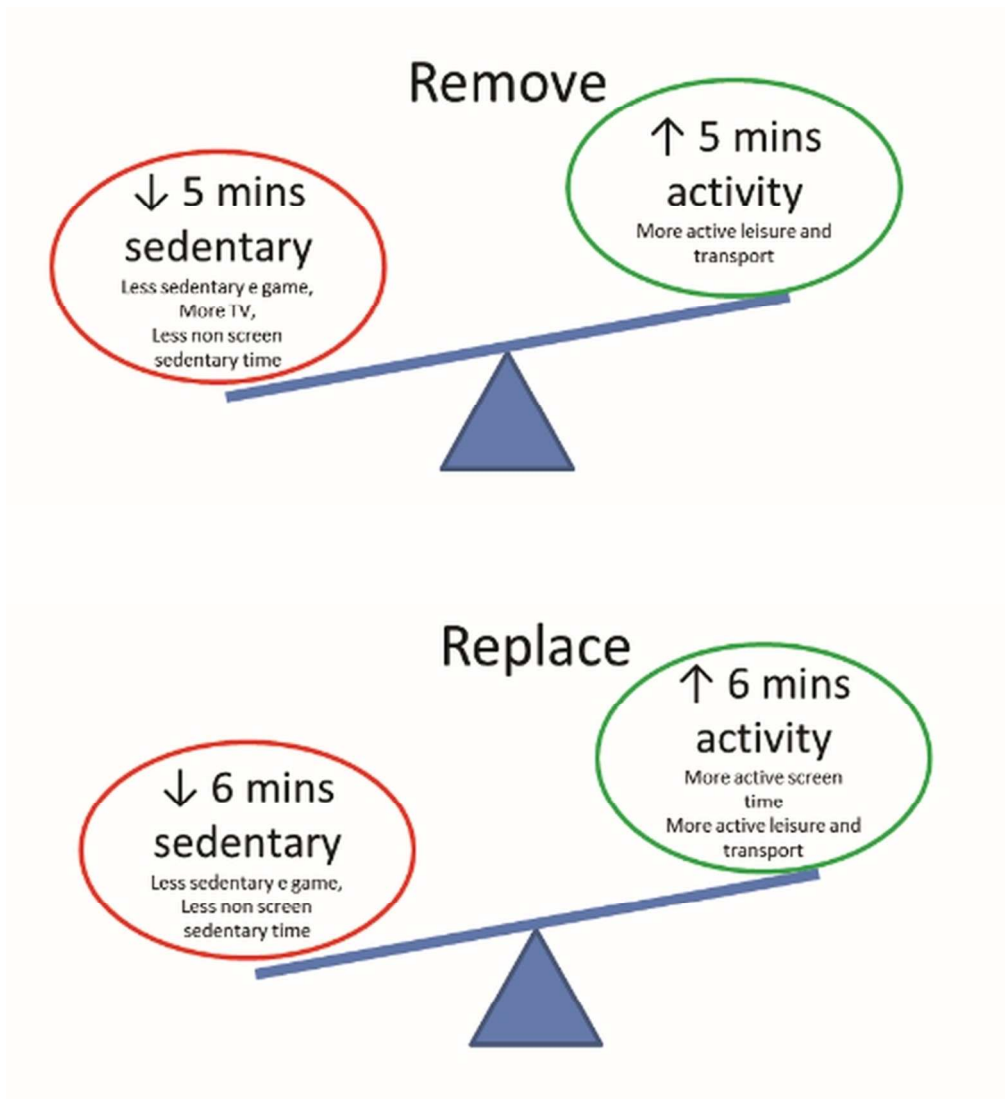
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CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2,3
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	5
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	5
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	na
Participants	4a	Eligibility criteria for participants	6
	4b	Settings and locations where the data were collected	6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	6
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	8-9
	6b	Any changes to trial outcomes after the trial commenced, with reasons	na
Sample size	7a	How sample size was determined	7
	7b	When applicable, explanation of any interim analyses and stopping guidelines	na
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	7
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	7
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	7
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	na
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	8

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	na
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	10-11
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	10-11
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	Fig 1
	13b	For each group, losses and exclusions after randomisation, together with reasons	Fig 1
Recruitment	14a	Dates defining the periods of recruitment and follow-up	5
	14b	Why the trial ended or was stopped	na
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	In text, 11
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	NA (crossover)
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Table 1
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	na
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	na
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	na
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	16-17
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	15-17
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	15-17
Other information			
Registration	23	Registration number and name of trial registry	3
Protocol	24	Where the full trial protocol can be accessed, if available	5
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	18

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.