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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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.

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

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

INTRODUCTION

It is well recognised that physical activity 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 traditional electronic games alone with supplemental access to active electronic games have been mixed: with some evidence for improvements in body fatness, [13] and fitness in overweight children, [14] though no effect on objectively measured physical activity for a sample including both overweight and normal weight children.[15] The long term efficacy of active games in promoting physical activity remains questionable,[12, 16] but with potential promise.[17]

With no clear evidence either way, the public health response to date has been to develop recommendations to restrict all children's screen based leisure (TV, computers and all electronic games), typically to maximum of 2hrs a day.[18, 19] Compliance with these guidelines has been poor,[20, 21] suggesting difficulties for parents. Options for parents include removing electronic games from the family home or replacing traditional electronic games with active electronic games. To date there has been no study evaluating the efficacy of both these approaches. Therefore this study sought to explore, through a within subjects randomised controlled trial, the effect of either removing electronic games from the children's home environment or replacing traditional sedentary electronic games with active input electronic games on children's physical activity and sedentary behaviour.

METHODS

Study design methods and participants

This study used a within subjects randomised controlled trial design and was conducted in Perth, West Australia in 2007-2011. The detailed design of the study protocol has been previously described.[22] In summary, 10-12 year old children were recruited through mass media, community newsletters and local school notices. This age group was selected as they are able to provide detailed information in diary and questionnaires, have a high use of electronic games and are developing activity patterns pre-adolescence, which may track into adulthood. 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 electronic games on most days of the week. Children were excluded if they had a diagnosed disorder 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 amount of time in different houses and was unable to maintain game condition access, or lived remote to the University campus.

Intervention

There were three levels of electronic game access. 'No games' involved all electronic games being removed from the family home with a contract that electronic games were to be avoided where possible at other 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 was estimated at 115+30 min with a minimum effect size of 15 min considered important based on effects in prior studies.[23] 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 to account for 'repeated' contrasts between conditions, the power is 0.943.[24] We allowed for a 10% attrition in data. The study was curtailed earlier than planned as new electronic game technologies became popular in late 2010 making it unfeasible to recruit children to the older game technology.

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 was 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

Primary - Physical activity and sedentary time by accelerometry

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.[25-27] The accelerometers were set to record at 15 second epoch intervals.[28] As per established standard practices with accelerometry, a minimum of 4 days (at least one weekend day) was regarded as a valid recording.[29] The minimum recording time required for a day to be considered valid was 500 minutes.[30] Data were individually visually checked for missing values. Non-wear time, regarded as 120 minutes of consecutive zero's, was removed prior to analyses. Activity intensity thresholds based on Colley *et al*. [31] were used to convert the raw counts into minutes of sedentary, light, moderate and vigorous intensity physical activity (MVPA). Minutes spent in each of these intensity categories were calculated for an average day over the whole week. As there are known to be variations depending on the type of day[32] and time of the day[33] 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 discretional physical activity and sedentary leisure time.[34] Measures of the pattern of sedentary, light and moderate-to-vigorous activity were also calculated for the same time periods.[32] 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.[35] 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.[36] 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).[37] 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.[38]

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-games, and active e-games versus traditional e-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. 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. 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 home[40] ranged from the second to tenth Australian centile. Participant motor coordination status ranged from poor to excellent (MAND[41] 2007:NDI 62-125; MABC-2[42] 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

MVPA was less than one hour (mean 54.1 min, 95% confidence interval 47.5-60.7) whereas daily sedentary time was around eight and a half hours (522.7 min, 509.4-535.9).

Table 1 shows that in comparison to traditional games, removal of all electronic games resulted in a 3.8 min/day (1.5-6.1, p=0.001) increase in MVPA in the after school period. Similar, though non-significant, increases in MVPA were observed over the whole week and on school days. The removal of all electronic games resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day (0.0-9.5, p=0.05) in sedentary time in the after school period, which was matched with a small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days.

Replacing traditional games with active input games had similar findings (Table 1). This exchange resulted in a 3.2 min/day (0.9-5.5, p=0.007) increase in MVPA in the after school period, with a similar though non-significant pattern of MVPA over the whole week and on school days. Replacing electronic games with active input games also resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Furthermore, replacement of traditional games with active input games resulted in a significant decrease in sedentary time in the after school period (6.2 min/day (1.4-11.1, p=0.012)). A small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days were also observed.

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)	Active Games (A)	Remove (X-T)	Replace (A-T)
		Mean (95% CI)		Difference (95% CI), p values	
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**

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

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

Diary

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

Reported non exposure to sedentary electronic games during the 'no games' (median 0 min) and 'active games' (0min) conditions and to active electronic games during the 'no games'(0min) and 'traditional games' (0min) conditions confirmed compliance with avoiding non protocol games. Reported exposure to active electronic games during the 'active games' condition was 19 min/day suggesting reasonable compliance with this condition. Similarly, reported exposure to traditional electronic games during the 'traditional games' condition was 34 min/day

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**

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

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

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

DISCUSSION

This randomised controlled study showed that removing access to sedentary electronic games in children's homes, or replacing them with active electronic games, resulted in small but significant increases in physical activity and reductions in sedentary time in 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 activity [43] and supports more recent qualitative findings that suggest it is also an important time in the day to reduce children's screen viewing.[34] 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 al [13] found a self reported 10 minute increase in active games use when they were provided in addition to traditional games in a 6 month study. Whilst Baranowski et al [15] 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 media. Whilst traditional television viewing appears to be stable,[6] leisure time exposure to console based electronic games and computing is increasing rapidly,[6] as is the increase in mobile smart phones and touch screen tablets that are used for e-gaming, social networking, video viewing, and internet surfing.[7] Therefore small changes across a variety of these platforms could result in a more significant clinical impact. Whilst our study focussed on the home-setting, school offers another opportunity for more active technologies.[47]

Children sit for a long time at school and there is potential to further reduce sedentariness by engaging with technologies such as sit-stand desks, or active-input electronic media as part of lessons.[32]

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

The main weakness was the need to curtail the study one year early due to technology changes, which meant we were unable to determine whether the 10-15 minute change in sedentary and light intensity activity on weekends was real. Further, whilst the diaries suggested compliance to both conditions was good, we did not have a way of measuring precisely how much the active games were used.[16]

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

Given the strong evidence for detrimental effects of too little physical activity and too much sedentary time,[45, 46] in particular too much screen time[3] and the potential interaction between these in children,[20] there is a mounting need to understand childhood behaviours and intervene. Children in this study were sedentary for just over 8 hours per day and reported spending approximately three hours per day on screen based leisure, on the low side but comparable with international findings.[6, 7] Given this high sedentary exposure, health care practitioners should use all available opportunities to encourage children (and their parents) to be more active and less sedentary. Sigman [3] has recently called for the medical community to take a more proactive approach to reducing children's screen time exposure. With the increasingly electronic media enmeshed world of youth, it is unrealistic for parents to remove access to screen based media completely and therefore parents and health professionals alike need to work with technology to assist its development in ways which are health enhancing rather than health reducing. It was encouraging in this study that the replacing option resulted in at least as good an outcome as removing, and this may potentially result in more successful long term outcomes due to better sustained compliance.

CONCLUSION

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

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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.

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Ethical approval: The study had ethical approval from the Human Research Ethics Committee of Curtin University (approval number HR131/2006). All participating children and their parents gave informed assent/consent.

Data sharing: no additional data available

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Figure Legends:

Figure 1. CONSORT Diagram of flow of Participants

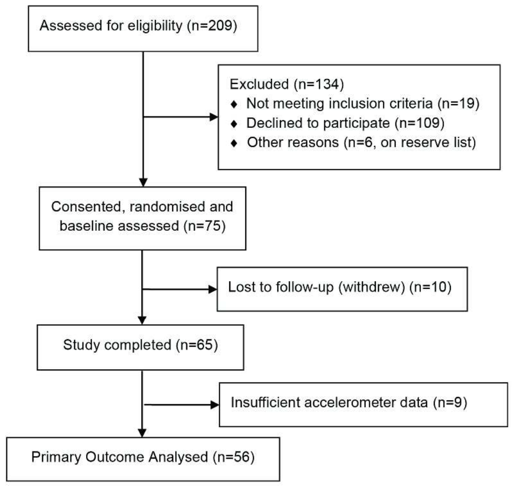
Figure 2. Summary of impact of removing or replacing traditional electronic games in terms of objectively measured activity time (MVPA and light) and sedentary time during the after school period along with diary determined changes in activities.

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.



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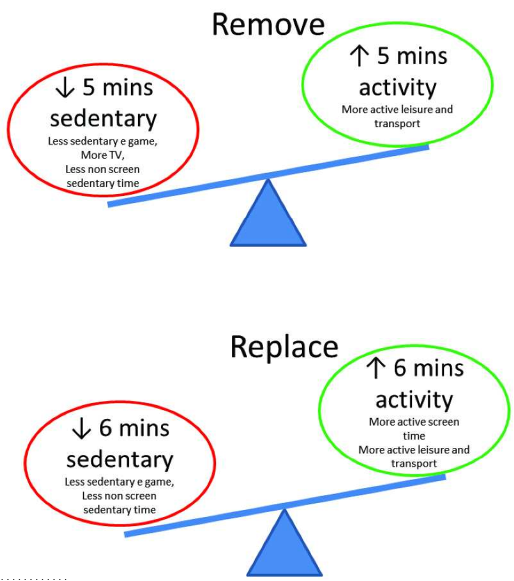

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To remove or to replace traditional electronic games? A cross-over randomised controlled trial on the impact of removing or replacing home access to electronic games on physical activity and sedentary behaviour in children aged 10-12 years.

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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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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

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

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

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

INTRODUCTION

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

With no clear evidence either way, the public health response to date has been to develop recommendations to restrict all children's screen based leisure (television, computers and all electronic games), typically to maximum of 2hrs a day.[19, 20] Compliance with these guidelines has been poor,[21, 22] which may be due to difficulties experienced by parents when trying to implement the guidelines. Options for parents include removing electronic games from the family home or replacing traditional electronic games with active electronic games. To date there has been no study evaluating the effect of both these approaches. Therefore this study sought to explore, through a cross-over randomised controlled trial, the effect of either removing electronic games from the children's home environment or replacing traditional sedentary electronic games with active input electronic games on children's 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. 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 games [6] 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

to account for 'repeated' contrasts between conditions, the power is 0.943.[28] We allowed for a 10% attrition in data. The study was curtailed earlier than planned as new electronic game technologies (Sony PlayStation 3® and Microsoft Xbox Kinect®) became popular in late 2010 in Perth making it unfeasible to recruit children to the older game technology. Data from 9 children who participated in the 2007 pilot study using the same activity and condition protocol were included to provide the best estimate of intervention effects.

Recruitment and study procedure

Following screening, participants were randomly allocated to an order of conditions by selection of an opaque sealed envelope. A balance of orders across the year was achieved by having sets of the 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 day[35] and time of the day[36] which may be masked in whole week analysis, analysis was also conducted on school days, weekend days, and the 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 discretional 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.

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 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. 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 10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female) who completed the study and had sufficient accelerometry data for planned analyses had a mean (sd) age of 11.3 (0.8) years. Participant height (1.50 (0.08) m), weight (41.3 (10.3) kg) and zBMI (-0.1 (1.2)) were similar to the national distribution for this age.[8] Nearly all children had home access to electronic games (91%) and reported playing electronic games in the last month (95%), with 61% reporting playing at least 2-3 times a week. Duration of playing sessions was most commonly <30min (41%), though 31% usually played for 30-60min and 24% usually played for 1-2hrs. Participant socioeconomic status based on location of family home[43] ranged from the second to tenth Australian centile. Participant motor coordination status ranged from poor to excellent (MAND[44] 2007:NDI 62-125; MABC-2[45] 2009-10: 9-98%), approximating a general population.

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 MVPA was less than one hour (mean 54.1 min, 95% CI 47.5 to 60.7) whereas daily sedentary time was around eight and a half hours (522.7 min, 509.4 to 535.9).

Table 1 shows that in comparison to traditional games, removal of all electronic games resulted in no significant change in daily MVPA over the whole week. However it did result in a 3.8 min/day (95% CI 1.5 to 6.1, p=0.001) increase in MVPA in the after school period. A similar, though non-significant, increase in MVPA was observed over the whole school day. The removal of all electronic games resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day (0.0 to 9.5, p=0.05) in sedentary time in the after school period, which was matched with a small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days. Replacing traditional games with active input games had similar findings (Table 1). This exchange resulted in no significant change in MVPA over the whole week but a 3.2 min/day (0.9 to 5.5, p=0.007) increase in MVPA in the after school period, with a similar though non-significant pattern of MVPA over the whole school day. Replacing electronic games with active input games also resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Furthermore, replacement of traditional games with active input games resulted in a significant decrease in sedentary time in the after school period of 6.2 min/day (1.4 to 11.1, p=0.012). A small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days were also observed.

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**

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

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

Diary

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

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

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**

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

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

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

DISCUSSION

This randomised controlled study showed that removing access to sedentary electronic games in children's homes, or replacing them with active electronic games, resulted in small but significant increases in 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 activity [46] and supports more recent qualitative findings that suggest it is also an important time in the day to reduce children's screen viewing.[37] The magnitude of effect, approximately 5 minutes more activity and 5 minutes less sedentary time, is similar to improvements observed in other home based studies. Maddison et al [14] 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 al [16] observed no objectively measured increase in daily MVPA or decrease in daily sedentary time in their home based study, day type or specific day periods were not studied.

On its own the magnitude of the change observed is unlikely to be of clinical importance, however it needs to be seen in the context of electronic games being part of the rapidly growing exposure that children have to screen based leisure. Whilst time spent viewing television appears to be stable,[6] leisure time exposure to console based electronic games and computing is increasing

rapidly,[6] as is the increase in mobile smart phones and touch screen tablets that are used for electronic gaming, social networking, video viewing, and internet surfing.[47] Therefore small changes across a variety of these platforms could result in a more substantial clinical impact. Whilst our study focussed on the home-setting, school offers another opportunity for more active technologies.[48] Children sit for a long time at school and there is potential to further reduce sedentariness by engaging with technologies such as sit-stand desks, or active-input electronic media as part of lessons.[35]

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

strength of the study is that it used an objective measure of physical activity and sedentary time and supplemented this with self-reported diary measures to aid understanding and interpretation of results.

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

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

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

CONCLUSION

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

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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.

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Ethical approval: The study had ethical approval from the Human Research Ethics Committee of Curtin University (approval number HR131/2006). All participating children and their parents gave informed assent/consent.

Data sharing: no additional data available

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.

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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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 outcome~~s 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~~

~~reports supported an increase in physical activity and decrease in screen based sedentary behaviours with both interventions.~~

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

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

INTRODUCTION

It is well recognised that physical activity 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 activity. More recently, the new generation 'active' electronic games, such as Sony PlayStation EyeToy® and Move®, dance mats, Nintendo Wii and Microsoft Xbox Kinect® have added to the controversy. Laboratory studies have shown that some of these active games can result in meaningful increases in muscle activity, movement and energy expenditure whilst others are result in less activeactivity.[12,13] Findings from the few available home-based interventions comparing access to traditional electronic games alone with supplemental access to active electronic games have been mixed: with some evidence for improvements in body fatness, [14] and fitness in overweight children, [15] though no effect on objectively measured physical activity for a sample including both overweight and normal weight children.[16] The long term efficacy of active games in promoting physical activity remains questionable,[13, 17] but with potential promise.[18]

With no clear evidence either way, the public health response to date has been to develop recommendations to restrict all children's screen based leisure (TVtelevision, computers and all electronic games), typically to maximum of 2hrs a day.[19, 20] Compliance with these guidelines has been poor,[21, 22] suggesting which may be due to difficulties for experienced by parents when trying to implement the guidelines. Options for parents include removing electronic games from the family home or replacing traditional electronic games with active electronic games. To date there has been no study evaluating the efficacy effect of both these approaches. Therefore this study sought to explore, through a within subjectscross-over randomised controlled trial, the effect of either removing electronic games from the children's home environment or replacing traditional sedentary electronic games with active input electronic games on children's 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-~~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 questionnaires[24], have a high use of electronic games[6] 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 ~~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

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 andat other 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 to account for 'repeated' contrasts between conditions, the power is 0.943.[28] We allowed for a 10% attrition in data. The study was curtailed earlier than planned as new electronic game technologies (Sony PlayStation 3® and Microsoft Xbox Kinect®) became popular in late 2010 in Perth making it unfeasible to recruit children to the older game technology. Data from 9 children who participated in the 2007 pilot study using the same activity and condition protocol were included to provide the best estimate of intervention effects.

Recruitment and study procedure

Following screening, participants were randomly allocated to an order of conditions by selection of an opaque sealed envelope. A balance of orders across the year was achieved by having sets of the 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 ~~was~~ 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

Primary - 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 (MVPA). Minutes spent in each of these intensity categories were calculated for an average day over the whole week. As there are known to be variations depending on the type of day[35] and time of the day[36] which may be masked in whole week analysis, analysis was also conducted on school days, weekend days, and the 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 discretional 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] 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

10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female) who completed the study and had sufficient accelerometry data for planned analyses had a mean (sd) age of 11.3 (0.8) years. Participant height (1.50 (0.08) m), weight (41.3 (10.3) kg) and zBMI (-0.1 (1.2)) were similar to the national distribution for this age.[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 home[40] ranged from the second to tenth Australian centile. Participant motor coordination status ranged from poor to excellent (MAND[41] 2007:NDI 62-125; MABC-2[42] 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 MVPA was less than one hour (mean 54.1 min, 95% ~~confidence interval~~CI 47.5~~-~~ to 60.7) whereas daily sedentary time was around eight and a half hours (522.7 min, 509.4~~-~~ to 535.9).

Table 1 shows that in comparison to traditional games, removal of all electronic games resulted in no significant change in daily MVPA over the whole week. However it did result in a 3.8 min/day (1.5~~-~~ to 6.1, p=0.001) increase in MVPA in the after school period. ~~Similar~~A similar, though non-significant, ~~increases~~ increase in MVPA ~~were~~ was observed over the whole ~~week and on~~ school day~~s~~. The removal of all electronic games resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day (0.0- to 9.5, p=0.05) in sedentary time in the after school period, which was matched with a small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days. Replacing traditional games with active input games had similar findings (Table 1). This exchange resulted in no significant change in MVPA over the whole week but a 3.2 min/day (0.9- to 5.5, p=0.007) increase in MVPA in the after school period, with a similar though non-significant pattern of MVPA over the whole week and on school days. Replacing electronic games with active input games also resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Furthermore, replacement of traditional games with active input games resulted in a significant decrease in sedentary time in the after school period (6.2 min/day (1.4- to 11.1, p=0.012)). A small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days were also observed.

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)**	**Active Games (A)**	**Remove (X-T)**	**Replace (A-T)**
		Mean (95% CI)		Difference (95% CI), p values	
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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Removing or replacing traditional electronic games had no significant effect on exposures to bouts of MVPA lasting at least 10min, bouts of sustained sedentary time lasting at least 30min, or brief bursts at any intensity lasting less than 5 min and breaks in sedentary time (data not shown).

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

Diary

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

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

Participant median exposure to sedentary electronic games was zero minutes during the 'no games' and 'active games' conditions. Similarly, participant median exposure to active electronic games was zero minutes during the 'no games' and 'traditional games' conditions, suggesting compliance with avoiding non protocol games.

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**

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

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

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

DISCUSSION

This randomised controlled study showed that removing access to sedentary electronic games in children's homes, or replacing them with active electronic games, resulted in small but significant increases in physical activity and reductions in sedentary time in 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 activity [46] and supports more recent qualitative findings that suggest it is also an important time in the day to reduce children's screen viewing.[37] The magnitude of effect, approximately 5 minutes more activity and 5 minutes less sedentary time, is similar to improvements observed in other home based studies. Maddison et al [14] found a self reported 10 minute increase in active games use and a self reported reduction in sedentary electronic game use when they were provided in active electronic games in addition to traditional electronic games in a 6 month study. Whilst Baranowski et al [16] observed no objectively measured increase in daily MVPA or decrease in daily sedentary time in their home based study, day type or specific day periods were not studied.

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

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

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

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

Given the strong evidence for detrimental effects of too little physical activity and too much sedentary time,[50, 51] in particular too much screen time[3] and the potential interaction between these in children,[21] there is a mounting need to understand childhood behaviours and intervene.

Children in this study were sedentary for just over 8 hours per day and reported spending approximately three hours per day on screen based leisure, on the low side but comparable with international findings.[6, 47] Given this high sedentary exposure, health care practitioners should use all available opportunities to encourage children (and their parents) to be more active and less sedentary. Sigman [3] has recently called for the medical community to take a more proactive approach to reducing children's screen time exposure. With the increasingly electronic media enmeshed world of youth, it is unrealistic for parents to remove access to screen based media completely and therefore parents and health professionals alike need to work with technology to assist its development in ways which are health enhancing rather than health reducing. It was encouraging in this study that the replacing option resulted in at least as good an outcome as removing, and this may potentially result in more successful long term outcomes due to better sustained compliance.

CONCLUSION

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

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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.

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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 submitted work, no financial support for RA or AS; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: The study had ethical approval from the Human Research Ethics Committee of Curtin University (approval number HR131/2006). All participating children and their parents gave informed assent/consent.

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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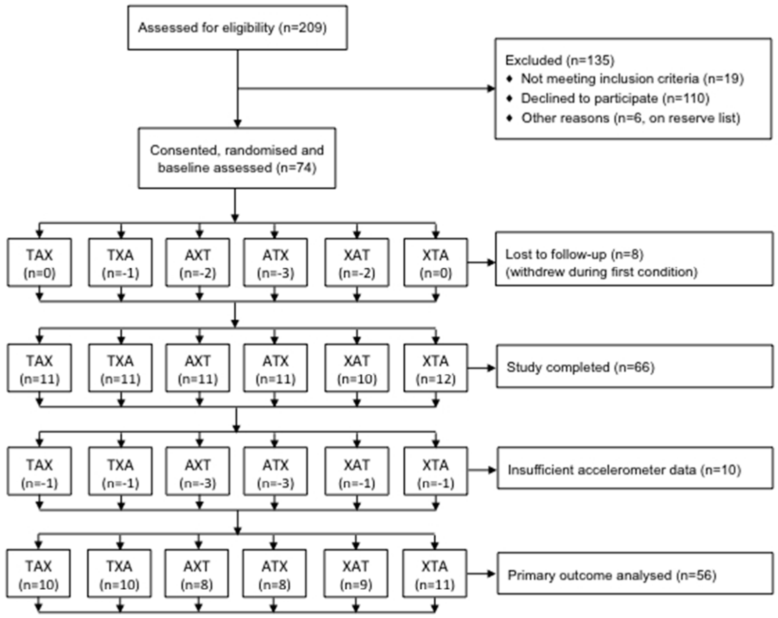
Figure Legends:

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.



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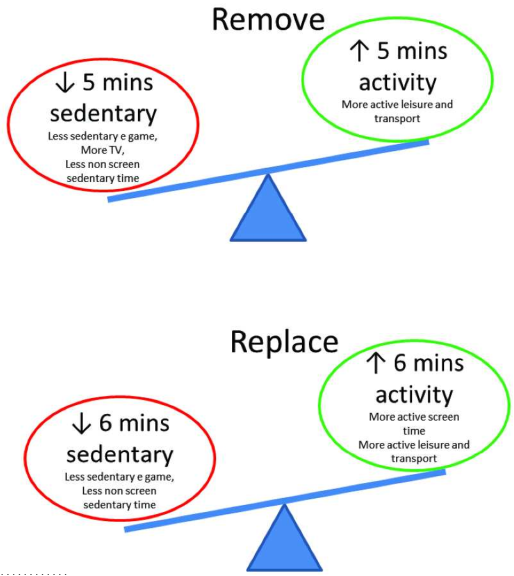

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CONSORT 2010 checklist of information to include when reporting a randomised trial*

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.

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 started 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.

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

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

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

- We have added the specific condition orders that each child was randomised to in the text under Participants and shown this in the revised flow diagram. The eight withdrawing participants did so in their first condition, and the 10 without adequate accelerometer data completed all conditions but had inadequate data for all conditions. On detailed checking of each participant and reasons and timing for exclusion from final analysis three errors were found which have now been corrected. One participant was found to have been listed as lost to followup as they had provided verbal consent, but they had actually 'withdrawn' prior to written consent and baseline assessment. A second participant had been counted in both lost to followup and insufficient accelerometer data rather than just the later. A third participant had been listed as lost to followup as they had no accelerometer data, but they had completed other aspects of the study and should have been counted in insufficient accelerometer data group.

I would strongly suggest the authors to ALSO report a "conservative" estimate for those participant who didn't complete the study. Ie, please use a non-responder imputation (keep baseline) as secondary analysis plan. Please submit all these as supplementary files supporting the existing tables.

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

Well done; and a nice protocol manuscript as well.

- We thank the reviewer for their kind comment.

Reviewer: Ralph Maddison
Associate Professor, National Institute for Health Innovation University of Auckland New Zealand

Overall comments:

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

- Please see our responses to specific issues below.

Specific comments

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

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

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

- Whilst we were fundamentally concerned with different intensities of activity and time periods, we have clarified in the Outcome measures that mean daily MVPA over the whole week was considered the primary outcome.

- 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

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 hypen 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 may 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 pleural therefore the text should read as ....At 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 procedure we stated that participants were randomly allocated to an order of conditions. We did not state that 'demographic and SES measures' were used for randomisation, as this was not the case.

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

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

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

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

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

- Please see response to point 3

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

- The clarification provided above, that the inclusion referred to participants being able to access the games <u>provided in the study</u>, explains the perceived inconsistency. The data are correct and no changes were made here, only to clarify the inclusion criteria.

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

- We have edited the text to report the mean daily MVPA over the whole week first as requested.
- On pages 6 and 18 we used 'significant' in the lay sense rather than the statistical sense and this was a mistake. We have replaced these instances with 'substantial'. Now all use of the term is in the statistical sense to avoid confusion.
- We have used the term 'non-significant' trend to highlight the consistency of direction but be clear about the lack of statistical significance.

30. Page 16, final paragraph is confusing. Can this be restructured to reflect its true meaning?
- The paragraph has been edited to improve clarity as suggested.

31. P. 19, line 3, should this be sedentary time during after school time?
- Have replaced 'in' with 'during' as suggested.

32. P. 19, line 19, the Maddison study also should a reduction in sedentary time, which reflected the time gained in PA. This should be mentioned as the findings of the present study suggest a similar compensation. Thus displacement in sedentary behaviour may be compensated with increases in PA time.
- Additional detail from Maddison study included as requested.

33. P. 19, line 45, should this read…Whilst time spent viewing TV appears…..
- Sentence edited as suggested

34. P. 20 The weakness outlined in this needs to be expanded on. Why was the study terminated early? What were the technology changes and how did this impact the study (low recruitment, power etc). Was this a protocol violation? Other weakness need to be considered (loss to follow-up, lack of imputation of missing data).
- We have provided details of the new electronic game technology released late 2010 in Australia and that this resulted in no children being willing to commit to the original study protocol. The new devices, and the games available on them, were qualitatively different to those in the original protocol so we could not simply replace the equipment and continue with the study.
- We have included mention of the withdrawal of participants and lack of adequate accelerometer data limitations. We have not listed lack of imputation of missing data as a limitation, as we have explained above that the analysis approach taken was appropriate for the design.

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Sterne et al., Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls BMJ 2009;338:b2393

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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Keywords:	child, physical activity, sedentary behaviour, accelerometry, screentime

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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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

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

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

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

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

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

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

METHODS

Study participants

This study was conducted in Perth, Western Australia in 2007-2010, with the trial registered (Australia and New Zealand Clinical Trials Registry (ACTRN 12609000279224)) and the detailed study protocol published.[23] In summary, 10-12 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 games [6] 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

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 to account for 'repeated' contrasts between conditions, the power is 0.943.[28] We allowed for a 10% attrition in data. The study was curtailed earlier than planned as new electronic game technologies (Sony PlayStation 3® and Microsoft Xbox Kinect®) became popular in late 2010 in Perth making it unfeasible to recruit children to the older game technology. Data from 9 children who participated in the 2007 pilot study using the same activity and condition protocol were included to provide the best estimate of intervention effects.

Recruitment and study procedure

Following screening, participants were randomly allocated to an order of conditions by selection of an opaque sealed envelope. A balance of orders across the year was achieved by having sets of the 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 day[35] and time of the day[36] which may be masked in whole week analysis, analysis was also conducted on school days, weekend days, and the 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 discretional 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.

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 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 with statistical significance set at $p<0.1$ was used to determine whether a carryover effectexisted. 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 α=0.05. Analysis was by intention-to-treat, though per protocol analysis was also conducted, with the 33 participants who used active games for more than 15 min/day during the active e-game condition.

RESULTS

Participants

Figure 1 shows the participant flow chart. Eight participants provided baseline data but withdrew during their first condition (6 male, mean age 10.5 years, height 1.48m , 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 10th centile, all 6 condition orders). At baseline, the remaining 56 participants (29 female) who completed the study and had sufficient accelerometry data for planned analyses had a mean (sd) age of 11.3 (0.8) years. Participant height (1.50 (0.08) m), weight (41.3 (10.3) kg) and zBMI (-0.1 (1.2)) were similar to the national distribution for this age.[8] Nearly all children had home access to electronic games (91%) and reported playing electronic games in the last month (95%), with 61% reporting playing at least 2-3 times a week. Duration of playing sessions was most commonly <30min (41%), though 31% usually played for 30-60min and 24% usually played for 1-2hrs. Participant socioeconomic status based on location of family home[43] ranged from the second to tenth Australian centile. Participant motor coordination status ranged from poor to excellent (MAND[44] 2007:NDI 62-125; MABC-

2[45] 2009-10: 9-98%), approximating a general population. There were no deviations from randomised allocation.

Accelerometry

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

Table 1 shows that in comparison to traditional games, removal of all electronic games resulted in no significant change in daily MVPA over the whole week. However it did result in a 3.8 min/day (95% CI 1.5 to 6.1, p=0.001) increase in MVPA in the after school period. A similar, though non-significant, increase in MVPA was observed over the whole school day. The removal of all electronic games resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day (0.0 to 9.5, p=0.05) in sedentary time in the after school period, which was matched with a small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days. Replacing traditional games with active input games had similar findings (Table 1). This exchange resulted in no significant change in MVPA over the whole week but a 3.2 min/day (0.9 to 5.5, p=0.007) increase in MVPA in the after school period, with a similar though non-significant pattern of MVPA over the whole school day. Replacing electronic games with active input games also resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Furthermore, replacement of traditional games with active input games resulted in a significant decrease in sedentary time in the after school period of 6.2 min/day (1.4 to 11.1, p=0.012). A small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days were also observed.

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)**	**Active Games (A)**	**Remove (X-T)**	**Replace (A-T)**
		Mean (95% CI)		Difference (95% CI), p values	
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**

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

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

Diary

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

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

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**

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

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

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

DISCUSSION

This randomised controlled study showed that removing access to sedentary electronic games in children's homes, or replacing them with active electronic games, resulted in small but significant increases in 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 activity [46] and supports more recent qualitative findings that suggest it is also an important time in the day to reduce children's screen viewing.[37] The magnitude of effect, approximately 5 minutes more activity and 5 minutes less sedentary time, is similar to improvements observed in other home based studies. Maddison et al [14] 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 al [16] observed no objectively measured increase in daily MVPA or decrease in daily sedentary time in their home based study, day type or specific day periods were not studied.

On its own the magnitude of the change observed is unlikely to be of clinical importance, however it needs to be seen in the context of electronic games being part of the rapidly growing exposure that children have to screen based leisure. Whilst time spent viewing television appears to be stable,[6] leisure time exposure to console based electronic games and computing is increasing

rapidly,[6] as is the increase in mobile smart phones and touch screen tablets that are used for electronic gaming, social networking, video viewing, and internet surfing.[47] Therefore small changes across a variety of these platforms could result in a more substantial clinical impact. Whilst our study focussed on the home-setting, school offers another opportunity for more active technologies.[48] Children sit for a long time at school and there is potential to further reduce sedentariness by engaging with technologies such as sit-stand desks, or active-input electronic media as part of lessons.[35]

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

strength of the study is that it used an objective measure of physical activity and sedentary time and supplemented this with self-reported diary measures to aid understanding and interpretation of results.

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

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

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

CONCLUSION

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

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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.

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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 submitted work, no financial support for RA or AS; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: The study had ethical approval from the Human Research Ethics Committee of Curtin University (approval number HR131/2006). All participating children and their parents gave informed assent/consent.

Data sharing: no additional data available

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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.

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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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

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

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

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

INTRODUCTION

It is well recognised that physical activity 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

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

With no clear evidence either way, the public health response to date has been to develop recommendations to restrict all children's screen based leisure (television, computers and all electronic games), typically to maximum of 2hrs a day.[19, 20] Compliance with these guidelines has been poor,[21, 22] which may be due to difficulties experienced by parents when trying to implement the guidelines. Options for parents include removing electronic games from the family home or replacing traditional electronic games with active electronic games. To date there has been no study evaluating the effect of both these approaches. Therefore this study sought to explore, through a cross-over randomised controlled trial, the effect of either removing electronic games from the children's home environment or replacing traditional sedentary electronic games with active input electronic games on children's 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. ThThis study was conducted in Perth, Western Australia in 2007-2010, with the trial registered (Australia and New Zealand Clinical Trials Registry (ACTRN 12609000279224)) and thee detailed design of the study protocol has been previously describedpublished.[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 games [6] 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. ~~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.~~

Study Design

~~This study used a within subjects cross-over randomised controlled trial design and was conducted in Perth, Western Australia in 2007-2010.~~ 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 ~~our pilot study and~~ discussions with children, the removal of all electronic games was only acceptable to the majority of children if the same children could get ~~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. 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

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 to account for 'repeated' contrasts between conditions, the power is 0.943.[28] We allowed for a 10% attrition in data. The study was curtailed earlier than planned as new electronic game technologies (Sony PlayStation 3® and Microsoft Xbox Kinect®) became popular in late 2010 in Perth making it unfeasible to recruit children to the older game technology. Data from 9 children who participated in the 2007 pilot study using the same activity and condition protocol were included to provide the best estimate of intervention effects.

Recruitment and study procedure

Following screening, participants were randomly allocated to an order of conditions by selection of an opaque sealed envelope. A balance of orders across the year was achieved by having sets of the 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

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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 day[35] and time of the day[36] which may be masked in whole week analysis, analysis was also conducted on school days, weekend days, and the 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 discretional 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.

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

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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 ~~M~~missing values were accounted for in the linear mixed model, which us~~ing~~es 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~~for a~~ used to determine whether a carryover effect ~~(treatment by period interaction) was s~~existed~~et 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 α=0.05. Analysis was by intention-to-treat, though per protocol analysis was also conducted, with the 33 participants who used active games for more than 15 min/day during the active e-game condition.

RESULTS

Participants

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

Accelerometry

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

Table 1 shows that in comparison to traditional games, removal of all electronic games resulted in no significant change in daily MVPA over the whole week. However it did result in a 3.8 min/day (95% CI 1.5 to 6.1, p=0.001) increase in MVPA in the after school period. A similar, though non-significant, increase in MVPA was observed over the whole school day. The removal of all electronic games resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Removal of all electronic games also resulted in a significant decrease of 4.7 min/day (0.0 to 9.5, p=0.05) in sedentary time in the after school period, which was matched with a small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days. Replacing traditional games with active input games had similar findings (Table 1). This exchange resulted in no significant change in MVPA over the whole week but a 3.2 min/day (0.9 to 5.5, p=0.007) increase in MVPA in the after school period, with a similar though non-significant pattern of MVPA over the whole school day. Replacing electronic games with active input games also resulted in a small non-significant increase in light activity over the whole week, with a larger though still non-significant increase on weekend days. Furthermore, replacement of traditional games with active input games resulted in a significant decrease in sedentary time in the after school period of 6.2 min/day (1.4 to 11.1, p=0.012). A small non-significant decrease in sedentary time over the whole week and a larger non-significant decrease on weekend days were also observed.

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)**	**Active Games (A)**	**Remove (X-T)**	**Replace (A-T)**
	Mean (95% CI)			Difference (95% CI), p values	
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**

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

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

Diary

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

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

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**

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

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

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

DISCUSSION

This randomised controlled study showed that removing access to sedentary electronic games in children's homes, or replacing them with active electronic games, resulted in small but significant increases in 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 activity [46] and supports more recent qualitative findings that suggest it is also an important time in the day to reduce children's screen viewing.[37] The magnitude of effect, approximately 5 minutes more activity and 5 minutes less sedentary time, is similar to improvements observed in other home based studies. Maddison et al [14] 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 al [16] observed no objectively measured increase in daily MVPA or decrease in daily sedentary time in their home based study, day type or specific day periods were not studied.

On its own the magnitude of the change observed is unlikely to be of clinical importance, however it needs to be seen in the context of electronic games being part of the rapidly growing exposure that children have to screen based leisure. Whilst time spent viewing television appears to be stable,[6] leisure time exposure to console based electronic games and computing is increasing

rapidly,[6] as is the increase in mobile smart phones and touch screen tablets that are used for electronic gaming, social networking, video viewing, and internet surfing.[47] Therefore small changes across a variety of these platforms could result in a more substantial clinical impact. Whilst our study focussed on the home-setting, school offers another opportunity for more active technologies.[48] Children sit for a long time at school and there is potential to further reduce sedentariness by engaging with technologies such as sit-stand desks, or active-input electronic media as part of lessons.[35]

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

strength of the study is that it used an objective measure of physical activity and sedentary time and supplemented this with self-reported diary measures to aid understanding and interpretation of results.

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

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

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

CONCLUSION

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

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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.

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Ethical approval: The study had ethical approval from the Human Research Ethics Committee of Curtin University (approval number HR131/2006). All participating children and their parents gave informed assent/consent.

Data sharing: no additional data available

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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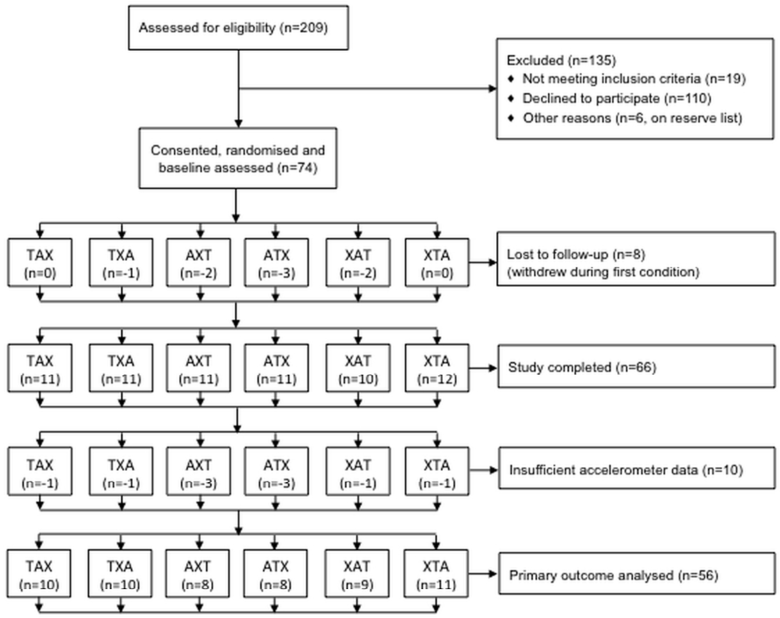
Figure Legends:

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.



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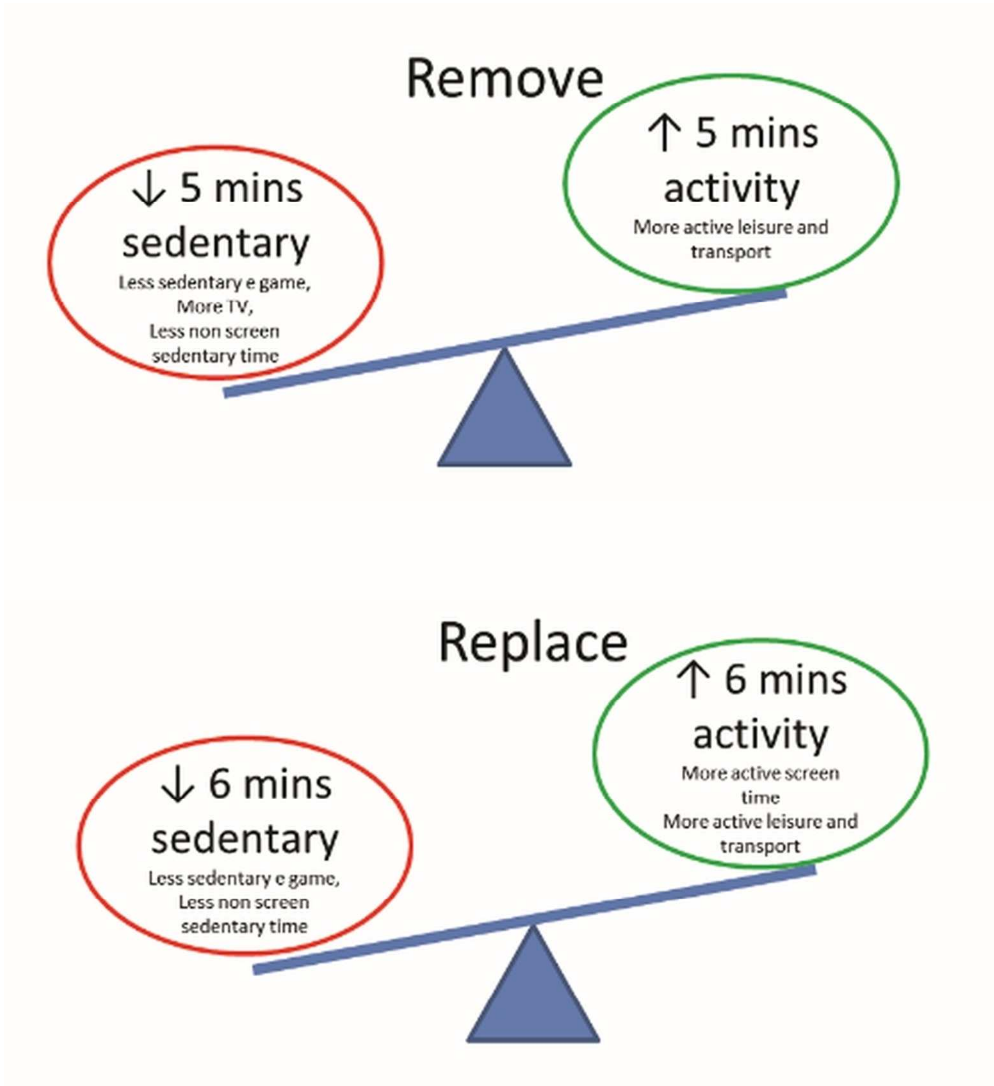

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CONSORT 2010 checklist of information to include when reporting a randomised trial*

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.