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Original Article

Active video games as an exercise tool for children with cystic fibrosis

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Abstract

Background: Active video games are used in many hospitals as exercise tools for children with cystic fibrosis. However, the exercise intensity associated with playing these games has not been examined in this population.
Methods: Children with cystic fibrosis [n = 30, aged 12.3 (2.6) years, 17 boys, BMI 17.7 (2.8) kg/m^2] were recruited from outpatient clinics in Dublin hospitals. Age and gender matched control children were recruited from local schools. Oxygen consumption, metabolic equivalents (METs) calculated from resting $\dot{V}O_2$, and heart rate were measured while playing Nintendo Wii™ (Nintendo Co. Ltd., Tokyo, Japan) Sports Boxing and Nintendo Wii Fit Free Jogging using a portable indirect calorimeter (Oxycon Mobile).
Results: Playing Wii Boxing resulted in light intensity activity (2.46 METs) while playing Wii Fit Free Jogging resulted in moderate intensity physical activity (4.44 METs). No significant difference was seen between groups in the energy cost of playing active video games.
Conclusion: Active video games are a useful source of light to moderate intensity physical activity in children with cystic fibrosis.

Keywords: Video game; Physical activity; Metabolic equivalent

1. Introduction

Physical activity is defined as "any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level [1]". Exercise is a subcategory of physical activity and is characterised by being "planned, structured, repetitive and purposive in the sense that the improvement or maintenance of one or more components of physical fitness is the objective". Physical activity has been shown to have many beneficial effects among children including improved muscle strength [2], cardiorespiratory fitness [3], cardiovascular health [4], and bone health [5]. Physical activity has also been shown to reduce symptoms of depression [6] and enhance self esteem in children [7]. Current guidelines from the Centres for Disease Control and Prevention (CDC) recommend that all children engage in at least 60 min of moderate to vigorous physical activity daily [8].

Cystic fibrosis (CF) is the most common lethal inherited disease in Caucasians [9]. CF is often characterised by recurrent respiratory infection, progressive airflow obstruction, hypoxemia, malnutrition and reduced muscle mass, factors which can adversely affect physical activity levels [10], and long-term prognosis [11]. Since peak aerobic capacity and peak oxygen consumption have been associated with improved prognosis in CF [12], physical activity and exercise are of central importance in the treatment of children with CF. Physical activity in children with CF has proven beneficial effects on pulmonary function and peak oxygen consumption, and can result in enhanced sputum clearance, reduction of breathlessness, increased exercise capacity, improved body image and improvements in quality of life [13]. Studies have shown that adherence to exercise programs among those with CF can be poor and that exercise which is "pleasant and enjoyable" can improve adherence to exercise programs [14,15]. Therefore population specific studies into novel child friendly forms of exercise were warranted.

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Active video games (AVGs) can be described as computer games which are designed to be controlled by a players' movement rather than by pressing buttons. Five reviews have been published on the energy cost of video game play among healthy children [16–20]. All reviews concluded that playing AVGs require more energy than playing sedentary games and that playing interactive consoles has the potential to lead to health benefits and the accrual of physical activity in children and youth. Furthermore, reviews stated that certain AVGs are capable of engaging children in moderate intensity physical activity. Therefore playing AVGs could present an effective, novel, and child friendly form of physical activity for children with CF. Many hospitals have a Wii console specifically for children with CF. However, the exercise intensity associated with playing these games has not been examined in this population. Kuys et al. [21] measured the heart rate, estimated energy cost, and rate of perceived exertion of adults with CF playing active video games on the Wii console. Gaming was found to result in moderate to vigorous intensity physical activity, and was comparable to exercise on both treadmill and cycle ergometers [21]. Participants in the study by Kuys et al. also rated the feasibility for including an AVG into exercise regimens as 8 out of 10, indicating that AVG play as a form of exercise appeals to adults with CF [21]. The energy cost of AVG play among children with CF is unknown. As the response to exercise in children may not mirror that in adults [22], there was a need to measure the exercise response of children with CF to AVG play. The aim of this study was to measure the energy cost and exercise intensity of AVG play among children with CF and healthy age and gender matched controls. Exercise intensity is an important consideration since only moderate and vigorous intensity exercise contributes to daily physical activity guidelines. Secondary aims were to compare results with recommended guidelines for moderate intensity activity, and to investigate the relationship between percentage predicted forced expiratory volume in one second (FEV_1% predicted) and the energy expended and exercise intensity reached playing active video games.

2. Patients and methods

Children with CF were recruited from paediatric outpatient cystic fibrosis clinics at two sites in Dublin. Age and gender matched children with no health concerns were recruited from schools in the Dublin locality. All participants completed a physical activity readiness questionnaire [23] and provided written informed assent and parental/guardian written informed consent before any testing took place. Diagnosis of CF was established according to standard published guidelines [24]. Children with CF were excluded if they were clinically unstable (defined as changes in symptoms or treatment in the four weeks preceding testing) or required oxygen to exercise at a moderate intensity. Exclusion criteria for both groups were the presence of any neuromuscular, musculoskeletal or rheumatologic condition that could affect exercise. Ethics approval was granted by the Research Ethics Committee of St. James's Hospital/the Adelaide and Meath Hospital Dublin, Incorporating the National Children's Hospital and by the Ethics (Medical Research) Committee Office of Our Lady's Children's Hospital Crumlin, Dublin.

Body mass was measured to the nearest 0.1 kg, and height to the nearest complete 0.001 m using a Seca scales and stadiometer respectively (Seca Mod 220, Germany). Skinfold measurements were taken at the triceps, biceps, subscapular and suprailiac sites to the nearest 0.0001 m according to standardised guidelines [25]. Results were used to estimate body fat percentage using the Durnin Womersley equation [26].

The six-minute walk test (6MWT) was performed as described by the American Thoracic Society [27]. Oxygen consumption ($\dot{V}O_2$), kilocalories expended (kcal), and heart rate (HR) were measured at rest and while playing AVGs using an indirect calorimeter (Oxycon Mobile, Jaeger, Viasys Healthcare, Hoechberg, Germany) and a Polar HR monitor. The Oxycon Mobile is a lightweight portable system, which communicates telemetrically with the Polar HR monitor and laboratory computer to give details on $\dot{V}O_2$, energy expenditure and related cardiorespiratory parameters on a breath-by-breath basis. The Oxycon Mobile has been validated [28], and used in similar studies measuring the energy cost of AVG play [29].

AVGs used were Wii Sports Boxing and Wii Fit Free Jogging (hereafter referred to as Boxing and Jogging respectively). After 15 min of rest in the supine position, participants played each game for 15 min with at least a 5-minute seated rest between games to allow HR to return to resting values. Game order was randomised. Participants wore validated pedometers on each ankle during gaming conditions (Stepwatch, Orthocare Innovations) [30]. Pedometers were worn to determine if there was any difference in the number of steps taken between groups, which in turn could explain differences in the energy cost of gaming [29]. Perceived exertion was rated immediately after each game using the ten point ONMI rate of perceived exertion scale [31]. Among those with CF, oxygen saturation levels were checked at baseline and during all activities using a portable finger probe saturation monitor (Nonin Onyx II, USA).

Metabolic equivalents (METs) were calculated for each individual as gaming $\dot{V}O_2$ divided by resting $\dot{V}O_2$. Age predicted maximal HR was calculated as 208 − (0.7 * age) [32]. Pedometer data from the last 10 min of game play was used in analysis, thus ensuring that participants had become accustomed to the movements required to play the game. To reduce any effect of leg dominance, the average data from pedometers on both legs was calculated for each participant for each game. Mean $\dot{V}O_2$ and HR were calculated from minute 9 to minute 14 to ensure that a steady state was reached. The sum of energy expended in kilocalories for the entire duration of each condition was calculated by the system software of the Oxycon Mobile using $\dot{V}O_2$ and $\dot{V}CO_2$ data, thus giving a realistic measure of the kilocalories expended during an AVG session. For those with CF, spirometry results were recorded within the month before testing took place by trained health care workers (one from each centre) using a calibrated plethysmograph. FEV_1 results were compared with normal age, sex, and height matched standard values (Pan and Cole, 2011, LMS software) and presented as FEV_1 z-scores. Percentage predicted FEV_1 was used to categorise participants into normal, mild or moderate pulmonary disease according to standardised cut points [33].

Data was analysed with the statistical package for social science (SPSS) version 16.0.1. For continuous variables, normal distribution was assessed using the Kolmogorov–Smirnov test. Where data was skewed, natural log transformations were employed. Differences in participant characteristics between groups were assessed using independent t-tests. Single sample t-tests were conducted to compare the energy cost of gaming with the lower recommended cut off value for moderate intensity activity (3 METs and 64%HR_{max}). Differences between conditions and groups were analysed using a mixed-design ANOVA with group as a between-groups factor and condition as the within-groups factor. The difference in rate of perceived exertion between groups was assessed using a Mann–Whitney *U* test. Spearman correlation and linear regression analysis were used to investigate the relationship between lung function and energy expended/exercise intensity during gaming conditions.

Where appropriate, testing was carried out in participants' homes. The choice of location between testing in the research laboratory or in the participant's home was given to the participant and parent/guardian. Where testing took place in participants' homes, children rested supine on a bed or sofa, an area of at least 2 m^2 was cleared in front of the television to allow participants sufficient space for AVG play, and the 6MWT was carried out on a 10 metre flat length of pavement outside.

3. Results

Sixty children took part in this cross-sectional study (30 with CF and 30 controls). The majority of those with CF (24 participants) chose to have testing carried out in the home. Twelve control participants also chose to have testing carried out in the home. There was no significant difference in participant characteristics between participants who choose to undergo testing in their homes and those who did not. Participant characteristics are detailed in Table 1. There was no significant difference in BMI or estimated lean body mass between those with CF and those without CF. Among those with CF mean FEV_1 percentage predicted was 91.38 (22.03)%. Twenty-one participants had an FEV_1 within the normal range (FEV_1 > 80% predicted), four were in the mild category (FEV_1 = 70–79% predicted) and five were considered to have moderate pulmonary disease (FEV_1 = 50–69%) [33]. Those with CF had lower FEV_1 scores than expected for healthy age, sex and height matched children [34]. Boxing $\dot{V}O_2$, and steps taken during Boxing required natural log transformations to be normally distributed and are presented in Table 2 as Ln$\dot{V}O_2$, and LnSteps taken.

Table 2 shows 6MWT results and the energy cost and heart rates reached by participants at rest and during gaming conditions. There was a statistically significant difference between groups for distance covered during the 6MWT with healthy controls covering more distance than those with CF (p = 0.004). Among those with CF mean MET levels reached playing Boxing were statistically significantly lower than the lower recommended guideline for moderate activity of 3 METs (Fig. 1; mean difference = −0.541, CI −0.814 to −0.268). Among healthy controls, mean METs were not statistically significantly higher or lower than 3 METs (Fig. 1; mean difference = −0.229, CI −0.537 to 0.150). Mean %HR_{max} required to play Boxing was not significantly different from the lower guideline for moderate activity among those with CF (mean difference = −0.927, CI −4.91 to 3.05) or healthy controls.

Jogging was consistently and significantly more aerobically demanding than Boxing. The energy cost of Jogging was of a moderate intensity and statistically significantly higher than the guideline lower cut off for moderate activity among those with CF and those without CF (Fig. 1). During Jogging, %HR_{max} reached by both groups was of a moderate intensity on average, and was statistically significantly higher than the recommended lower threshold of moderate activity of 64% (among those with CF mean difference = 13.742, CI 9.145 to 18.342; among healthy controls mean difference = 11.295, CI 6.855 to 15.735).

Repeated measures analysis of variance with METs, %HR_{max}, steps and energy expended in kilocalories as variables

Table 1
Participant characteristics.

	Those with CF N = 30, (17 boys)	Healthy controls N = 30, (17 boys)	Significance (difference between groups)
Age, years	12.3 (2.6)	12.2 (2.7)	0.7
Mass	40.14 (12.93)	43.80 (13.73)	0.3
Height	148.47 (13.12)	151.15 (17.12)	0.5
BMI, $kg.m^{-2}$	17.7 (2.8)	18.6 (2.0)	0.14
Lean body mass, kg	33.5 (10.7)	35.9 (11.9)	0.4
FEV_1, % predicted	91.38 (22.03)	n/a	n/a
FEV1, z score	−1.12 (−3.51)	n/a	n/a

Results are presented as mean (SD); BMI, body mass index; kg, kilograms; FEV_1, forced expiratory volume in 1 s.

Table 2
Participants' HR and VO_2 response to rest and AVG play.

Condition	Variable	Those with CF Mean (SD)	Healthy controls Mean (SD)
6MWT	Distance covered, m *	493.52 (106.15)	579.45 (109.41)
	$\dot{V}O_2$, $ml.min^{-1}.kg^{-1}$	6.44 (1.34)	6.10 (1.64)
	$kcal.15min^{-1}$	18.33 (4.50)	16.87 (5.38)
Boxing	HR_{max}, %	63 (11)	68 (14)
	$\dot{V}O_2$, $ml.min^{-1}.kg^{-1}$	15.47 (4.63)	16.44 (5.29)
	Ln$\dot{V}O_2$, $ml.min^{-1}.kg^{-1}$	2.70 (0.30)	2.75 (0.32)
	METs	2.46 (0.73)	2.77 (0.82)
	$kcal.15min^{-1}$	40.06 (13.00)	44.58 (18.93)
	Steps taken	52.52 (45.42)	91.43 (99.24)
	LnSteps taken	3.58 (0.92)	3.91 (1.26)
Jogging	HR_{max}, %	78 (12)	75 (11)
	$\dot{V}O_2$,	27.65 (6.67)	26.84 (5.69)
	METs	4.44 (1.29)	4.67 (1.30)
	$kcal.15min^{-1}$	82.21 (34.03)	76.79 (36.56)
	Steps taken	505.76 (85.29)	519.78 (58.72)

AVG, active video game; 6MWT, six minute walk test; m, metre; SD, standard deviation; HR, heart rate; bpm, beats per minutes; $\dot{V}O_2$, oxygen consumption; kcal, kilocalories; Ln, natural log; METs, metabolic equivalents.
* Indicates a significant difference between groups where p = 0.004.

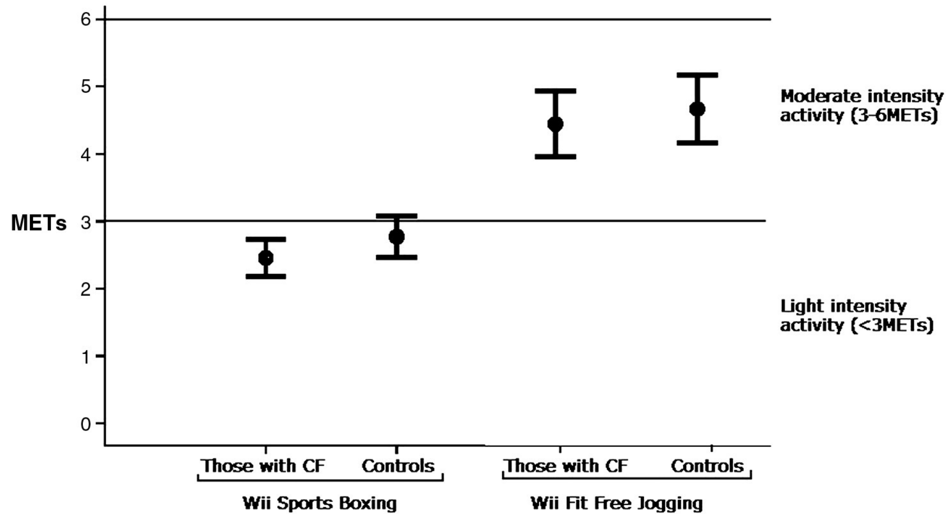

Fig. 1. Graphical representation of METs reached by participants in each group playing Boxing and Jogging with guideline threshold for moderate intensity physical activity (3-6 METs) indicated.

and group as a between subject factor was conducted. The main effects for group, and interaction between group and condition were not significant, indicating that there was no difference in the energy cost or $\dot{V}O_2$ of gaming, or rest, between those with CF and control participants. There was a significant main effect for condition indicating that the energy cost of playing Boxing and Jogging differed significantly ($F = 38.39$, $p < 0.001$). Post-hoc analysis with a Bonferroni correction factor revealed significant differences between conditions for all variables examined (METs, $\%HR_{max}$, and energy expenditure in kilocalories, $p < 0.001$). For all variables, higher values were seen during Jogging than during Boxing, and higher values were seen during Boxing than rest. There was no significant difference between groups in number of steps taken during gaming conditions.

Mann Whitney *U* tests revealed no significant difference between those with CF and healthy controls in rate of perceived exertion immediately after playing either Boxing ($p = 0.445$) or Jogging ($p = 0.548$). Rate of perceived exertion results mirrored HR and MET results obtained in that Jogging consistently resulted in higher levels of perceived exertion than Boxing.

Among participants with CF, there was a significant correlation between $FEV_1\%$ predicted and METs expended playing Jogging ($r = 0.4$, $p = 0.04$). In regression analysis when age and gender were entered as a potential confounders, $FEV_1\%$ predicted remained a significant predictor of METs expended during Jogging ($R^2 = 0.39$, $F(3, 27) = 5.24$, $p = -0.006$. $FEV_1\%$ predicted $\beta = 0.375$, $t = 2.39$, $p = 0.025$). There was no correlation between $FEV_1\%$ predicted and the energy cost of any condition, or the exercise intensity reached playing Boxing.

No adverse events took place during testing. Oxygen saturations did not drop below 4% of resting SpO_2 during exercise.

4. Discussion

The results of this study have demonstrated that for children with CF as well as healthy children, Wii Fit Free Jogging is a suitable form of moderate intensity aerobic activity and Wii Sports Boxing a suitable form of light intensity aerobic activity.

The exercise intensity required to play active video games reported in this study was similar to that reported in previous work carried out on control as well as obese and overweight children [29,35]. On this basis, the exercise intensity required to play Wii Fit Free Jogging could be sufficient to produce cardiovascular health benefits if played on a regular basis. In the CF population, where children may have a reduced capability to take part in other forms of exercise due to deconditioning, or during periods of hospitalisation, AVG play is an attractive option through which to achieve moderate intensity aerobic activity.

The positive correlation between $FEV_1\%$ predicted and the exercise intensity of Jogging is similar to that found in other studies on exercise and lung function in CF [36,37]. Results of linear regression analysis performed suggest that the association is independent of gender and age. These results may indicate that those with lower $FEV_1\%$ predicted were unable to reach as high an exercise intensity playing Jogging as those with higher a $FEV_1\%$ predicted. It is also worth noting that Wii Fit Free Jogging is a self paced game, as such participants were free to slow down or speed up the pace at which they Jogged at their will. Due to the self-paced nature of Jogging, it is possible that participants with CF who had lower $FEV_1\%$ predicted, altered their effort slightly, avoiding desaturation and as a result did not reach as high an exercise intensity as those with higher $FEV_1\%$ predicted. Any differences in rate or perceived exertion or energy cost of gaming between groups however did not reach significance. The fact that $FEV_1\%$ predicted did not correlate with energy expended at rest, or the exercise intensity reached playing Boxing may be due to the relatively high pulmonary function and healthy condition of participants with CF recruited in this study and the fact that Boxing was less physically challenging than Jogging.

Several acute benefits of moderate intensity exercise for those with CF have been demonstrated, including improved sputum expectoration, enhanced mood, and increased self efficacy [38]. These variables were not measured in the current

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study as the primary aim of this study was to determine the exercise intensity of playing AVGs. Further research in this area is warranted to determine whether such acute benefits are also achieved from AVG play.

Results of steps taken during Boxing formed a positive skewed distribution with a large standard deviation. This was likely due to participant's method of play whereby some participants planted their lower limbs while playing Boxing while others took steps throughout the game in an effort to dodge punches. This trait of "stepping or planting" the lower limbs meant that some participants took very few steps during game play, while others took over 200 steps.

It is expected that those with CF would have lower fitness levels than children without CF [10], however the reason for the significant difference in 6MWT between groups in this study could be questioned since those with CF were relatively healthy. One potential explanation is that the testing environment had an effect on results. More children with CF had testing carried out in their homes and as such the 6MWT was carried out outdoors compared to the indoor environment used for most control children. The difference in testing environment could explain the difference in 6MWT results reported.

5. Limitations

Results presented should be interpreted with the caveat that participants in this study with cystic fibrosis were relatively healthy. The CF cohort in this study had high FEV_1 results and did not have a significantly lower BMI than the non-CF participants recruited. Since energy expenditure was the major outcome measure in this study, it was not possible to recruit patients with active infections, nor would it have been appropriate. Finally, since it was necessary to wear a facemask during measurements it was not possible to recruit those who required oxygen to exercise. These methodological criteria favoured the recruitment of children who were well, with relatively high pulmonary function, which may explain the lack of difference between groups. Therefore, a limitation of this study is that results cannot be extrapolated to those with severe CF or those with mild or moderate CF after treatment for an exacerbation, for whom active video games may also be an appropriate form of physical activity.

6. Conclusion

Wii Fit Free Jogging but not Wii Sport Boxing can be recommended as a moderate form of aerobic exercise to children with CF and healthy controls. No significant difference was recorded in the exercise intensity reached by children with CF compared to healthy control children when playing AVGs.

Conflict of interest statement

The authors have no conflicts of interest to disclose.

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References

[1] Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 1985;100:126–31.
[2] Bar-Or O. Role of exercise in the assessment and management of neuromuscular disease in children. Med Sci Sports Exerc 1996;28:421–7.
[3] Ara I, Vicente-Rodriguez G, Perez-Gomez J, et al. Influence of extra-curricular sport activities on body composition and physical fitness in boys: a 3-year longitudinal study. Int J Obes (Lond) 2006;30:1062–71.
[4] Ewart CK, Young DR, Hagberg JM. Effects of school-based aerobic exercise on blood pressure in adolescent girls at risk for hypertension. Am J Public Health 1998;88:949–51.
[5] Specker B, Binkley T. Randomized trial of physical activity and calcium supplementation on bone mineral content in 3- to 5-year-old children. J Bone Miner Res 2003;18:885–92.
[6] Annesi JJ. Correlations of depression and total mood disturbance with physical activity and self-concept in preadolescents enrolled in an after-school exercise program. Psychol Rep 2005;96:891–8.
[7] DeBate RD, Thompson SH. Girls on the Run: improvements in self-esteem, body size satisfaction and eating attitudes/behaviors. Eat Weight Disord 2005;10:25–32.
[8] Centre for disease control and prevention (CDC). How much physical activity do children need? Available at http://www.cdc.gov/physicalactivity/everyone/guidelines/children.html; 2011 . [Accessed July 03rd 2013].
[9] Quinton PM. Cystic fibrosis: a disease in electrolyte transport. FASEB J 1990;4:2709–17.
[10] Marcotte JE, Grisdale R, Levison H, Coates AL, Canny GJ. Multiple factors limit exercise capacity in cystic fibrosis. Pediatr Pulmonol 1986;2:274–81.
[11] Kerem E, Reisman J, Corey M, Canny GJ, Levison H. Prediction of mortality in patients with cystic fibrosis. NEJM 1992;326:1187–91.
[12] Pianosi P, Leblanc J, Almudevar A. Peak oxygen uptake and mortality in children with cystic fibrosis. Thorax 2005;60:50–4.
[13] Bradley JM, Moran FM, Elborn JS. Evidence for physical therapies (airway clearance and physical training) in cystic fibrosis: an overview of five Cochrane systematic reviews. Respir Med 2006;100:191–201.
[14] Stark LJ, Miller ST, Plienes AJ, Drabman RS. Behavioral contracting to increase chest physiotherapy. A study of a young cystic fibrosis patient. Behav Modif 1987;11:75–86.
[15] Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 2011;43:1334–59.
[16] Daley AJ. Can exergaming contribute to improving physical activity levels and health outcomes in children? Pediatrics 2009;124:763–71.
[17] Biddiss E, Irwin J. Active video games to promote physical activity in children and youth: a systematic review. Arch Pediatr Adolesc Med 2010;164:664–72.
[18] Foley L, Maddison R. Use of active video games to increase physical activity in children: a (virtual) reality? Pediatr Exerc Sci 2010;22:7–20.
[19] Barnett A, Cerin E, Baranowski T. Active video games for youth: a systematic review. J Phys Act Health 2011;8:724–37.
[20] Guy S, Ratzki-Leewing A, Gwadry-Sridhar F. Moving beyond the stigma: systematic review of video games and their potential to combat obesity. Int J Hypertens 2011;2011:179124.
[21] Kuys SS, Hall K, Peasey M, Wood M, Cobb R, Bell SC. Gaming console exercise and cycle or treadmill exercise provide similar cardiovascular demand in adults with cystic fibrosis: a randomised cross-over trial. J Physiother(Aust Physiother Assoc) 2011;57:35–40.

[22] Rowland T. Children's exercise physiology. second ed. Champaign, IL: Human Kinetics; 2005.

[23] Thomas S, Reading J, Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Can J Sport Sci 1992;17:338–45.

[24] Farrell PM, Rosenstein BJ, White TB, et al. Guidelines for the diagnosis of CF in newborns through older adults: CF Foundation consensus report. J Pediatr 2008;153:S4–S14.

[25] Ellis L, Gastin P, Lawrence S, et al. Protocols for the physiological assessment of team sport players. In: Gore CJ, editor. Physiological tests for elite athletes. Champaign, IL: Human Kinetics; 2000. p. 128–44.

[26] Durnin JV, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br J Nutr 1974;32:77–97.

[27] American Thoracic Society. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002;166:111–7.

[28] Salier EJ, Rosdahl H, Schantz P. Validity of the Oxycon Mobile metabolic system under field measuring conditions. Eur J Appl Physiol 2012;112:345–55.

[29] O'Donovan C, Roche EF, Hussey J. The energy cost of playing active video games in children with obesity and children of a healthy weight. Pediatr Obes 2013. http://dx.doi.org/10.1111/j.2047-6310.2013.00172.x.

[30] McDonald CM, Widman L, Abresch RT, Walsh SA, Walsh DD. Utility of a step activity monitor for the measurement of daily ambulatory activity in children. Arch Phys Med Rehabil 2005;86:793–801.

[31] Robertson RJ, Goss FL, Aaron DJ, et al. Observation of perceived exertion in children using the OMNI pictorial scale. Med Sci Sports Exerc 2005;38:158–66.

[32] Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. J Am Coll Cardiol 2001;37:153–6.

[33] Siafakas NM, Vermeire P, Pride NB, et al. Optimal assessment and management of chronic obstructive pulmonary disease (COPD). The European Respiratory Society Task Force. Eur Respir J 1995;8:1398–420.

[34] Pan H, Cole T. LMSgrowth, a Microsoft Excel add-in to access growth references based on the LMS method, version 2.74. [online] Available at http://www.healthforallchildren.co.uk; 2011 . [Accessed 2013].

[35] Graf DL, Pratt LV, Hester CN, Short KR. Playing active video games increases energy expenditure in children. Pediatrics 2009;124:534–40.

[36] Lands LC, Heigenhauser GJ, Jones NL. Analysis of factors limiting maximal exercise performance in cystic fibrosis. Clin Sci (Lond) 1992;83:391–7.

[37] Almajed A, Lands LC. The evolution of exercise capacity and its limiting factors in cystic fibrosis. Pediatr Respir Rev 2012;13:195–9.

[38] Yeung RR. The acute effects of exercise on mood state. J Psychosom Res 1996;40:123–41.

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