J SPORTS MED PHYS FITNESS 2007;47:217-22

# Habitual physical activity levels in childhood and adolescence assessed with accelerometry

V. P. LOPES [1], C. M. S. VASQUES [1], J. A. R. MAIA [2], J. C. V. FERREIRA [3]

***Aim.*** **The purposes of this study were: 1) to evaluate age and gender differences in physical activity (PA) of children and adolescents; 2) to find out if children and adolescents fulfill the PA recommendations of 60 min*day$^{-1}$ of moderate (MPA) to vigorous PA (VPA).**

***Methods.*** **PA was assessed in 265 female and 238 male subjects, ranging from 6 to 18 years of age, grouped in 4 age groups, with MTI ActiGraph model 7164, during 7 consecutive days. The MTI actigraph data was reduced to bouts (30-, 20-, 10-, and 5-min) and minutes spent in MPA, VPA, and very VPA (VVPA).**

***Results.*** **The oldest boys and girls revealed a lower number of PA bouts than the younger ones. Significant gender differences were found in daily VPA, $F(1, 492)=37.67$, $P<0.001$; and VVPA $F(1, 494)=24.11$, $P<0.001$. Boys were more active than girls. Significant age group differences were also found in MPA, $F(3, 494)=87.4$, $P<0.001$; VPA, $F(3, 492)=78.15$, $P<0.001$; and VVPA, $F(3, 454)=54.89$, $P<0.001$. In both genders MPA, VPA and VVPA decreased with age. Till the age of 14, children had means between 79.6±30.6 and 144.1±76.9 min*day$^{-1}$ of PA. After this age, there was a decrease to 44.1±19.9 min*day$^{-1}$ in girls and to 56.3±31.9 min*day$^{-1}$ in boys.**

***Conclusion.*** **Boys had more minutes a day of VPA and VVPA than girls. PA decreased with age. The subjects of this study, aged 6 to 15, fulfilled the recommendations of 60 min*day$^{-1}$ of MPA to VPA.**

KEY WORDS: Physical Fitness - Child - Adolescence - Accelerometry.

Received on May 17, 2006.
Accepted for publication on December 22, 2006.

Address reprint requests to: V. P. Lopes, Rua Almada Negreiros 74, 5300-171 Bragança, Portugal. E-mail: vplopes@ipb.pt

*[1]School of Education, Polytechnic Institute of Bragança, Portugal*
*[2]Laboratory of Kinanthropometry, Faculty of Sports University of Porto, Porto, Portugal*
*[3]School of Education, Polytechnic Institute of Viseu, Portugal*

There is a strong agreement in the scientific community that physical activity (PA) positively influences individual health status, both in children[1] and adults.[2, 3] Regular PA is an important factor to promote a healthy lifestyle along the whole life cycle, although some studies have shown that children and adolescents spend a large part of their free leisure time in sedentary activities.[4, 5]

PA duration, *i.e.*, total energy expenditure, is relevant in obesity problems: several studies have demonstrated a negative relationship between PA and body fat.[6-8] But PA intensity is also important to improve physical fitness components, namely cardiovascular fitness. Therefore, it is important in habitual PA assessment to consider not only the duration, but also the intensity and frequency of PA.

Most of the epidemiological studies done with youth samples indicate that boys are more active than girls.[9, 10] Longitudinal studies report that PA declines with age, mainly between childhood and adolescence and during adult age, namely between 9 and 27 years.[11-13]

The importance of evaluating PA in any population is due to the need of establishing the current level of PA of that population and to determine if that level is appropriate for good health. The PA guidelines for children and

adolescents from various organizations vary in PA intensity, duration and frequency prescribed.[14] The most recent PA recommendation for American students aged 6 to18 calls for 60 min or more per day of moderate (MPA) to vigorous PA (VPA).[1] Other recommendations[15-17] call for 30 to 60 min of daily MPA to VPA. In Portugal, there are very few large sample studies carried out with youth, and most of them use self-report methods to assess PA. Although these studies contain important information about the PA of Portuguese children and adolescents, a large sample has never been assessed with an objective instrument in order to have a more precise understanding of the PA characteristics of Portuguese children and adolescents. Therefore, the purposes of this study were: 1) to evaluate age and gender differences in PA of children and adolescents, using accelerometry as an objective method of PA evaluation; and 2) to find out if children and adolescents fulfill the PA recommendations.

## Materials and methods

### *Sample*

The sample size comprised 503 individuals from 6 to 18 years of age (265 female, 238 male) grouped as follows: group 1, aged 6 to 8, n=156 (76 boys and 80 girls); group 2, aged 9 to 11, n=149 (79 boys and 70 girls); group 3, aged 12 to 14, n=100 (42 boys and 58 girls); and group 4, aged 15 to 18, n=98 (41 boys and 57 girls).

The subjects were recruited from public elementary and secondary school system from two towns in the North of Portugal (Bragança and Viseu). All the subjects lived in the urban area. In elementary schools, there is no weekly physical education or sports program. However, they have occasionally organized PA activities. In secondary schools, there are 3 h a week of physical education and students could choose to participate in extra-curricular school sport programs. Previous informed consent was obtained from children, their parents, and school directors.

### *Physical activity measurement*

PA was evaluated during 7 consecutive days with the MTI ActiGraph model 7164 (Manufacturing Technology, Inc., Fort Walton Beach, FL, USA), former CSA. The MTI actigraph is a uniaxial accelerometer designed to detect vertical acceleration ranging in magnitude from 0.05 to 2 Gs with frequency of 0.25-2.5 Hz. These parameter values allow the detection of human motion and will reject high frequency vibrations from other sources, such as riding in a car. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified time interval. At the end of each interval, the summed value or activity count is stored in memory, and the integrator is reset. For this study, a 1-min time interval was used. All activity monitors used were previously calibrated according to manufacturer parameters.

The validity of the MTI actigraph has been established with indirect calorimetry[18] (r=0.86) and doubly labeled water[19] (r=0.39 to r=0.58) as criterion measures.

Subjects were instructed to wear the MTI actigraph during waking hours. Monitors were attached to an elastic belt worn firmly over the waist. Subjects were instructed not to remove the device, except for bathing, swimming or sleeping. Each subject had to register the time they wore the monitor.

### *Accelerometer counts analysis*

The stored activity counts were downloaded to a computer for subsequent data reduction and analysis. With a specific computer software, the MTI actigraph data of each day was reduced to bouts (30-, 20-, 10-, and 5-min) of sustained MPA (3-5.9 METs), VPA (6-8.9 METs), and very VPA (VVPA) (≥9 METs), as well as to minutes spent in MPA, VPA, and VVPA. The software converted the MTI ActiGraph counts into units of relative energy expenditure (METs), using the regression equation developed by Freedson *et al.*[20] for children from 6 to 18 years of age: METs= 2.757+(0.0015 x counts/min)–(0.0896 x age[years]) –(0.000038 x counts/min x age), with $r^2$=0.9 and SEE=1.08 METs.

To prevent eventual instrument malfunction, all the counts that were constant for more than 10 min were excluded from the analyses.

The interest in quantifying the number of sustained bouts of activity resides in the fact that such variables provide information regarding compliance with existing PA guidelines which call for sustained bouts of PA, and because of the importance of sustained PA to the development of physical fitness, namely cardiovascular fitness. Bouts can be operationalized in many different ways. In the strictest definition of a bout, for

TABLE I.—*Measured number of weekly 30-, 20-, 10-, and 5-min bouts of moderate physical activity by gender and age groups, and P values for J.*

| Group | 30-min bouts | | 20-min bouts | | 10-min bouts | | 5-min bouts | |
|---|---|---|---|---|---|---|---|---|
| | Girls | Boys | Girls | Boys | Girls | Boys | Girls | Boys |
| 1 | 0.4±0.8 | 0.6±1.4 | 1.1±1.2 | 1±1.2 | 7.1±5.2 | 7±5.1 | 27.1±13.4 | 27±15.3 |
| 2 | 0.1±0.4 | 0.4±0.7* | 0.6±1.1 | 1±1.1* | 5.2±4.5 | 6.1±3.8* | 20.9±10.8 | 22.9±10.5 |
| 3 | 0.1±0.5 | 0.4±0.9* | 0.6±1 | 0.6±1.1 | 3.7±2.9 | 4.6±3.9 | 12±6.3 | 14±9.4 |
| 4 | 0.1±0.4 | 0.1±0.2 | 0.6±1 | 0.5±1.6 | 2.8±2.6 | 2.6±2.1 | 6.6±4.7 | 8.8±6.3 |
| P | 0.001 | 0.001 | 0.031 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

*Significant gender difference (P≤0.05).

TABLE II.—*Measured number of weekly 30-, 20-, 10-, and 5-min bouts of vigorous physical activity by gender and age groups, and P values for J.*

| Group | 30-min bouts | | 20-min bouts | | 10-min bouts | | 5-min bouts | |
|---|---|---|---|---|---|---|---|---|
| | Girls | Boys | Girls | Boys | Girls | Boys | Girls | Boys |
| 1 | 0.01±0.1 | 0±0 | 0±0 | 0.01±0.1 | 0.1±0.4 | 0.5±0.9* | 1.2±1.8 | 2.7±3.2* |
| 2 | 0±0 | 0±0 | 0±0 | 0.03±0.2 | 0.1±0.4 | 0.1±0.7* | 1±1.6 | 2.1±2.8* |
| 3 | 0.02±0.1 | 0±0 | 0.03±0.2 | 0±0 | 0.2±0.5 | 0.4±0.7 | 1.1±1.3 | 1.9±2.3 |
| 4 | 0±0 | 0±0 | 0.1±0.3 | 0±0 | 0.1±0.2 | 0.2±0.5* | 0.3±0.6 | 1.3±1.7* |
| P | — | — | 0.121 | 1 | 0.003 | 0.137 | 0.003 | 0.036 |

—: values not calculated. *Significant gender difference (P≤0.05).

instance, a 30-min bout of MPA is recorded when the software encounters 30 consecutive counts between 3 and 5.9 MET; a bout is considered over when the program encounters the first recorded count outside the limits of 3 and 5.9 MET. Instead of using the strictest definition of a bout, we allowed a brief interruption interval of 1 min. This strategy is justified by the fact that, in children, PA patterns are characterized by short bursts of activity, with interruptions.[21]

### *Statistical analysis*

The first step of the analysis was the calculation of the weekly average of minutes spent in MPA, VPA and VVPA, and also the total of 30-, 20-, 10-, and 5-min bouts of MPA, VPA and VVPA per week.

Since the bouts of different time duration of MPA, VPA and VVPA showed no normal distribution, a non-parametric statistic was used. The Mann-Whitney U-test was used to analyze the difference between boys and girls in bouts of different time duration of MPA, VPA and VVPA. The Jonckheere-Terpstra test was used to analyze the decrease or increase with age of the number of bouts of different time duration of MPA, VPA and VVPA. The result of a Jonckheere-Terpstra test is a J-statistic, which is distributed as a normal z-statistic. Therefore, all Jonckheere-Terpstra results are presented as z-statistics with their corresponding P values. This analysis was only conducted in variables with a mean different from 0.

Factorial ANOVA (gender·age group) was used to test gender and age group differences in the weekly averages of the minutes spent in MPA, VPA and VVPA. The LSD test was run as a *post-hoc* test. Before running the ANOVA, the VPA and VVPA were log-transformed because they did not show normal distributions. Statistical significance was set at P≤0.05.

## Results

Means and standard deviations for the weekly number of 30-, 20-, 10-, and 5-min bouts of MPA, VPA, and VVPA are shown in Tables I-III.

In all age groups, there was a mean of 0 or close to 0 in 30- and 20-min bouts in both VPA and VVPA in both boys and girls. Girls of group 4 had no bouts of 30-, 20-, and 10-min in either VPA or VVPA. Boys of

TABLE III.—*Measured number of weekly 30-, 20-, 10-, and 5-min bouts of very vigorous physical activity by gender and age groups, and P values for J.*

| Group | 30-min bouts | | 20-min bouts | | 10-min bouts | | 5-min bouts | |
|---|---|---|---|---|---|---|---|---|
| | Girls | Boys | Girls | Boys | Girls | Boys | Girls | Boys |
| 1 | 0.01±0.1 | 0.1±0.3 | 0.01±0.1 | 0.1±0.3* | 0.1±0.3 | 0.3±0.6* | 0.4±1.1 | 1.26±1.9* |
| 2 | 0±0 | 0±0 | 0±0 | 0±0 | 0.1±0.2 | 0.1±0.4 | 0.2±0.6 | 0.8±1.7 |
| 3 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0.1±0.2 | 0.1±0.3 | 0.2±0.5 |
| 4 | 0±0 | 0±0 | 0±0 | 0±0 | 0±0 | 0.1±0.2 | 0.1±0.2 | 0.1±0.3 |
| P | — | — | — | — | 0.01 | 0.006 | 0.002 | <0.001 |

—: values not calculated. *Significant gender difference (P≤0.05).

TABLE IV.—*Average minutes of daily moderate, vigorous and very vigorous physical activity, by age group and gender.*

| | Group 1 | | Group 2 | | Group 3 | | Group 4 | |
|---|---|---|---|---|---|---|---|---|
| | Girls | Boys | Girls | Boys | Girls | Boys | Girls | Boys |
| MPA* | 133.6±54.1 | 122.6±62 | 107.2±42.2 | 113.5±40.3 | 70.7±25.8 | 77±39.4 | 41.3±18.7 | 48.4±27.3 |
| VPA*° | 14.6±9.9 | 22.6±13.6 | 13.4±7.8 | 18.8±11.5 | 7.9±6.3 | 12.4±9.4 | 2.4±2.6 | 7±6.4 |
| VVPA*° | 4.5±5.3 | 8.9±9.6 | 3.6±3.1 | 5.4±6.4 | 1±1.1 | 2.3±2.5 | 0.5±0.7 | 0.9±1.2 |

*Significant age difference (P≤0.05). °Significant gender difference (P≤0.05). MPA: moderate physical activity; VPA: vigorous physical activity; VVPA: very vigorous physical activity.

group 4 had no bouts of 30- and 20-min in both VPA and VVPA. In MPA, significant gender differences were found only in groups 2 and 3. In group 2, the differences occurred in the 30-, 20-, and 10-min bouts; in group 3 the differences occurred only in 30-min bouts. In all the cases, boys had more bouts than girls (Table I). In VPA, significant differences were found between boys and girls in groups 1, 2, and 4. The differences occurred in 10- and 5-min bouts. Boys had more bouts than girls (Table II). In VVPA, significant differences between genders were only found in group 1. The differences occurred in 20-, 10-, and 5-min bouts. Boys had more bouts than girls (Table III).

The oldest boys and girls revealed a lower number of PA bouts, independent of the duration. In 30-, 20-, 10-, and 5-min bouts of MPA, both boys and girls showed a significant decrease with age (J, both P≤0.031; Table I). In 30-, 20-, and 10- min bouts of VPA, there was no significant decrease with age, but the number of bouts was too low, 0 or close to 0, in all age groups. In 5-min bouts, there was a significant decrease with age in both boys (J, P=0.036) and girls (J, P=0.003). In 30-, and 20-min bouts of VVPA, only the youngest group had a mean different from 0 bouts. In 10-, and 5-min bouts, there was a significant decrease with age in both genders (J, both P≤0.01).

Table IV shows the non-transformed means and standard deviations for the average minutes of daily MPA, VPA and VVPA by age group and gender.

Significant gender differences were found in daily VPA, $F(1, 492)=37.67$, $P<0.001$, and VVPA, $F(1, 494)=24.11$, $P<0.001$; in all cases boys were more active than girls. There was no significant gender difference in MPA. In VPA, the difference between boys and girls increased with age. In VVPA, the difference between boys and girls remained almost the same in all age groups (between 33.3% and 56.5%). In MPA, girls of group 1 were 8.9% more active than boys, while boys of group 4 were 14.7% more active than girls. In VPA, boys of all groups were more active than girls: 35.4% more in group 1, and 67.7% in group 4.

Significant age group differences were also found in MPA, $F(3, 494)=87.4$, $P<0.001$, VPA, $F(3, 492)=78.15$, $P<0.001$, and VVPA, $F(3, 454)=54.89$, $P<0.001$. In both genders, MPA, VPA and VVPA revealed a decrease with age. In boys, the highest decrease in MPA, VPA, and VVPA happened between group 3 and group 4: 59%, 77%, and 155%, respectively for MPA, VPA, and VVPA. In girls, the decrease was also higher between group 3 and group 4: 71.2%, 229.2%, and 100% respectively for MPA, VPA, and VVPA, than between the previous age groups.

## Discussion

Accelerometry is an objective method of PA assessment especially recommended for young people. In Portugal, there have not been any studies with such a large sample to evaluate PA with accelerometry; up to now, most of the studies were done with questionnaires.

Although these studies have a cross-sectional design, it was found, in accordance with literature,[12, 22, 23] that in both boys and girls there was an apparent decline of PA with age. Telama *et al.*,[11] in spite of finding a general decline in PA, reported an increase of VPA. On the other hand, van Mechelen *et al.*[12] found an increase of MPA and an increase of VPA. In this study, the decline occurred in all three PA intensities evaluated: MPA, VPA, and VVPA. Most of the longitudinal studies assessed PA with questionnaires, but, even when objectively measured, PA showed a decline.[10, 23] Despite this decline, some studies assessing sport participation indicate a higher track value for sport participation than for non-organized activities.[24] When the decline of PA is analyzed, probably we will have to distinguish between spontaneous PA and non-spontaneous PA, such as sport participation or organized PA. It seems that the PA decline has a biological basis.[25] In fact, it is also observed in animals,[26] and it appears to be related with alterations of neurotransmissions associated with dopamine.[27, 28] Likewise, play, and in particular PA play, also showed a decline with age as the child matures.[29] In fact, some studies found that late mature subjects are more active than advanced mature ones.[30, 31] Maybe a good strategy for promoting PA in young people is to look at sport activities as, perhaps, the best way to maintain PA levels throughout life, since sports activities are generally organized and scheduled in a regular way, *i.e.*, as a routine, and this routine could lead to a PA habits.

Gender differences in PA are well documented: most of the studies show that boys are more active than girls.[10, 32, 33] In this study, boys had significantly more minutes a day of VPA and VVPA, but not in MPA. Trost *et al.*[10] found the same pattern of gender differences, with only slight differences in MPA and significant differences in VPA. Boys had also more bouts of MPA, VPA and VVPA in the cases where significant differences were found, especially in the longest bouts and older groups.

The reasons underlying gender differences in PA levels are not well known. Bjorklund *et al.*[34] suggested that the gender differences in PA play behavior could be related to gender differences in spatial cognition developed during the evolutionary process of the *Homo sapiens*. Free physical play of boys often involves activities that require eye-hand (or foot) coordination, such as playing soccer and other ball games.[35] These activities promote the development of spatial cognition to a higher level than what it was observed in girls,[34] and require a more intense movement, which can account for the higher PA levels in boys compared to girls. Conversely, girls are more likely to engage in less intense activities.[35] In the same way, girls and women engage in PA for appearance, health and fitness reasons, and boys and men for competition and demonstration of ability.[36] Others suggest that the socialization process could explain the gender differences in PA in adolescents. For instance, Sallis *et al.*[37] and Andersen *et al.*[38] found that boys are more likely to have physically active friends than girls. The gender differences in PA require differentiated PA promotion programs for boys and girls. In consequence, it is important to find the main reasons for gender differences in PA, in order to delineate appropriate PA promotion programs.

The most recent PA recommendation for American students aged 6-18 calls for 60 min or more per day of MPA to VPA.[1] The recommendation highlights the need for variety in physical activities that are developmentally appropriate and enjoyable. Other recommendations[15-17] call for 30 to 60 min of daily MPA to VPA, which could be achieved with the accumulation of short periods of activity. The recommendations of 60 min·day$^{-1}$ was defined based on the systematic analysis of the evidence effects of regular PA on several health and behavioral outcomes in children and youth.[1] Nevertheless, PA recommendations should be seen as a minimal target that everyone has to achieve.

In the sample of this study only the boys and girls of group 4 (15 to 18 years of age) did not fulfill the recommendations of 60 min a day of MPA to VPA (group 1: girls 152.7±63 min·day$^{-1}$ and boys 154.1±76.9 min·day$^{-1}$; group 2: girls 124.2±49 min·day$^{-1}$ and boys 137.8±50.1 min·day$^{-1}$; group 3: girls 79.6±30.6 min·day$^{-1}$ and boys 91.8±47.3 min·day$^{-1}$; group 4: girls 44.1±19.9 min·day$^{-1}$ and boys 56.3±31.9 min·day$^{-1}$), although they fulfilled the other recommendations of 30 to 60 min of daily MPA to VPA. Most of the PA is done in moderate intensity level and in short bouts. In fact, there were almost zero 30- and 20-min bouts of any of the studied PA intensity level. However, it is necessary to do continuous VPA for periods of 20 to 30 min, several days a week, so that one can develop some aspects of physical

fitness, such as cardiovascular fitness and muscular strength and endurance.[1] In this aspect, the sample did not reveal the adequate PA level.

## Conclusions

Boys had more minutes a day of VPA and VVPA than girls, but not in MPA. This difference increased with age. In both boys and girls, PA decreased with age. The children from 6 to 14 years of age fulfilled the recommendations of 60 min·day$^{-1}$ of MPA to VPA. The adolescents of 15 to 18 years of age did not fulfill this recommendation. None of the children or adolescents had the minimum of 3 of 30- or 20-min bouts of PA a week, necessary to the development of cardiovascular fitness and muscular strength and endurance.

## References


1. Strong WB, Malina RM, Blimkie CJR, Daniels SR, Dishman R, Gutin B *et al.* Evidence based physical activity for school-age youth. J Pediatr 2005;146:732-7.
2. Brown DW, Brown DR, Heath GW, Balluz L, Giles WH, Ford ES *et al.* Associations between physical activity dose and health-related quality of life. Med Sci Sports Exerc 2004;36:890.
3. Bouchard C, Deprés JP. Physical activity and health: atherosclerotic, metabolic, and hypertensive diseases. Res Q Exerc Sport 1995;66:268-75.
4. Reilly JJ, Jackson DM, Montgomery C, Kelly LA, Slater C, Grant S *et al.* Total energy expenditure and physical activity in young Scottish children: mixed longitudinal study. Lancet 2004;363:211-2.
5. Fontvieille AM, Herper IT, Spraul M, Ravussin E. Daily energy expenditure by five-year-old children, measured by doubly labelled water. J Pediatr 1993;123:200-7.
6. Hu FB, Li TY, Colditz GA, Willett WC, Manson JE. Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. JAMA 2003;289:1785-91.
7. Almeida MDVd, Graça P, Afonso C, D'Amicis A, Lappalainen R, Damkjaer S. Physical activity levels and body weight in a nationally representative sample in the European Union. Public Health Nutr 1999;2:105-13.
8. Rowlands AV, Eston RG, Ingledew DK. Relationship between activity levels, aerobic fitness, and body fat in 8- to 10-yr-old children. J Appl Physiol 1999;86:1428-35.
9. Sarkin JA, McKenzie TL, Sallis JF. Gender differences in physical activity during fifth-grade physical education and recess periods. JTPE 1997;17:99-106.
10. Trost SG, Pate RR, Sallis JF, Freedson PS, Taylor WC, Dowda M *et al.* Age and gender differences in objectively measured physical activity in youth. Med Sci Sports Exerc 2002;34:350-5.
11. Telama R, Yang X. Decline of physical activity from youth to young adulthood in Finland. Med Sci Sports Exerc 2000;32:1617-22.
12. van Mechelen W, Twisk JWR, Post GB, Snel J, Kemper HCG. Physical activity of young people: the Amsterdam longitudinal growth and health study. Med Sci Sports Exerc 2000;32:1610-6.
13. Kimm SYS, Glynn NW, Kriska AM, Fitzgerald SL, Aaron DJ, Similo SL *et al.* Longitudinal changes in physical activity in a biracial cohort during adolescence. Med Sci Sports Exerc 2000;32:1445-54.
14. Fulton JE, Garg M, Galuska DA, Rattay KT, Caspersen CJ. Public health and clinical recomendations for physical activity and physical fitness. Sports Med 2004;34:581-99.
15. Cavill N, Biddle S, Sallis JF. Health enhancing physical activity for young people: statement of the United Kingdom expert consensus conference. Pediatr Exerc Sci 2001;13:12-25.
16. Council for Physical Education for Children (COPEC) of the National Association for Sport and Physical Education. Physical activity for children: a statement of guidelines. Reston, VA: NASPE Publication; 1998.p.1-21.
17. Sallis JF, Patrick K. Physical activity guidelines for adolescents; consensus statement. Pediatr Exerc Sci 1994;6:302-14.
18. Trost SG, Ward DS, Moorehead SM, Watson PD, Riner W, Burke JR. Validity of the computer science and applications (CSA) activity monitor in children. Med Sci Sports Exerc 1998;30:629-33.
19. Ekelund U, Sjöström M, Yngve A, Poortvliet E, Nilsson A, Froberg K *et al.* Physical activity assessed by activity monitor and doubly labeled water in children. Med Sci Sports Exerc 2001;33:275.
20. Freedson PS, Sirad J, Debold E, Pate R, Dowda M, Trost S *et al.* Calibration of the computer science and application, inc. (CSA) accelerometer. Med Sci Sports Exerc 1997;29:S45.
21. Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and *tempo* of children's physical activities: an observation study. Med Sci Sports Exerc 1995;27:1033-41.
22. Trost SG. Objective measurement of physical activity in youth: current issues, future directions. Exerc Sport Sci Rev 2001;29:32.
23. Kimm SYS, Glynn NW, Kriska AM, Fitzgeral SL, Aaron DJ, Similo SL *et al.* Longitudinal changes in physical activity in a biracial cohort during adolescence. Med Sci Sports Exerc 2000;32:1445-54.
24. Telama R, Leskinen E, Yang X. Stability of habitual physical activity and sport participation. A longitudinal tracking study. Scand J Med Sci Sports 1996;6:371-8.
25. Sallis JF. Age-related decline in physical activity: a synthesis of human and animal studies. Med Sci Sports Exerc 2000;32:1598-600.
26. Ingram DK. Age-related decline in physical activty: generalization to nonhumans. Med Sci Sports Exerc 2000;32:1623-9.
27. Simonen RL, Rankinen T, Perusse L, Leon AS, Skinner JS, Wilmore JH *et al.* A dopamine D2 receptor gene polymorphism and physical activity in two family studies. Physiol Behav 2003;78:751-7.
28. Kelly MA, Rubinstein M, Phillips TJ, Lessov CN, Burkhart-Kasch S, Zhang G *et al.* Locomotor activity in D2 dopamine receptor-deficient mice is determined by gene dosage, genetic background, and developmental adaptations. J Neurosci 1998;18:3470-9.
29. MacDonald K, Parke RD. Parent-child physical play: the effects of sex and age of children and parents. Sex Roles 1986;15:367-78.
30. Kemper HC, Post GB, Twisk JW. Rate of maturation during teenage years: nutrient intake and physical activity between ages 12 and 22. Int J Sport Nutr Exerc Metab 1997;7:229-40.
31. Bradley CB, McMurray RG, Harrell JS, Deng S. Changes in common activities of 3$^{rd}$ through 10$^{th}$ graders: the CHIC study. Med Sci Sports Exerc 2000;32:2071-8.
32. Klasson-Heggebo L, Anderssen SA. Gender and age differences in relation to the recommendations of physical activity among Norwegian children and youth. Scand J Med Sci Sports 2003;13:293-8.
33. Guerra S, Santos P, Ribeiro JC, Duarte JA, Mota J, Sallis J. Assessment of childrens and adolescents' physical activity levels. Eur Phys Edu Rev 2003;9:75-86.
34. Bjorklund D, Brown R. Physical play and cognitive development: integrating activity, cognition, and education. Child Dev 1998;69:604-6.
35. Blatchford P, Baines E, Pellegrini A. The social context of school playground games: sex and ethnic differences, and changes over time after entry to junior school. Br J Dev Psychol 2003;21:481-505.
36. Koivula N. Ratings of gender appropriateness of sports participation: effects of gender-based schematic processing. Sex Roles 1995;33:543-57.
37. Sallis JF, Zakarian JM, Hovell MF, Hofstetter CR. Ethnic, socioeconomic, and sex differences in physical activity among adolescents. J Clin Epidemiol 1996;49:125-34.
38. Andersen N, Wold B. Parental and peer influences on leisure-time physical activity in young adolescents. Res Q Exerc Sport 1992;63:341-8.