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Daily Physical Activity in Swedish Children Aged 8-11 Years.

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Abstract

Introduction: Physical inactivity is hypothesized to be a contributing factor in the development of a variety of diseases. Recommendations for an adequate level of physical activity have been proposed. There are few studies in which the physical activity in children has been objectively assessed. The purpose of this study was to estimate objectively the level of physical activity in Swedish children.

Materials and Methods: We studied 248 children (140 boys and 108 girls) aged 7.9-11.1 years from Malmö, Sweden. Physical activity was measured with accelerometers. Children were instructed to wear the accelerometers for four days. Mean daily activity was expressed as mean counts/minute of recording. The time the child spent performing moderate or vigorous activity was calculated by using previously established cut-off points.

Results: Mean daily activity was higher in boys than in girls, 751±243 vs. 618±154 counts/min ($p<0.001$). All children fulfilled the recommendation for moderate physical activity for 60 minutes or more per day. Ninety two percent of the boys and 86% of the girls performed vigorous activity for 20 minutes or more per day.

Conclusion: All children, aged 8-11, who participated in this study reached the recommended level of physical activity with boys being more active than girls.

Keywords: Accelerometers, physical activity recommendations, epidemiology, children

Introduction

Physical inactivity is associated with an increased risk of a wide range of diseases such as cardiovascular disease (CVD), hypertension, diabetes mellitus type 2, obesity, osteoporosis, depression and colon cancer (U.S. Department of Health and Human Services, 1996). Although the diseases associated with physical inactivity seldom manifest themselves before adulthood, promotion of physical activity in children and youth may be important as low physical activity early in life is associated with physiological risk factors for diseases (U.S. Department of Health and Human Services, 1996). Physical inactivity may also predispose children to a future sedentary lifestyle (Telama et al., 1997; Malina, 2001) and therefore have an increased risk for diseases (U.S. Department of Health and Human Services, 1996). The knowledge about the health benefits with regular physical activity has lead to formation of public health guidelines for children and adolescents concerning adequate levels of physical activity (Sallis & Patrick, 1994; Cavill, Biddle, Sallis, 2001; US Department of Health and Human Services, 2004). Compliance with these guidelines has been evaluated in several studies (Department of Health. London, 1997; Gregory & Lowe, 2000; Brener et al., 2004; Grunbaum et al., 2004). All these studies use self-reported evaluations, which are known to have limitations in their ability to estimate the actual level of physical activity in people of all ages and are considered inappropriate in children below age ten (Sallis & Saelens, 2000; Kohl, Fulton, Casperson, 2000). Therefore, uncertainties concerning the true compliance with physical activity guidelines in children prevail.

Accelerometers provide objective and detailed measurements about physical activity and can be used, by children, over a relatively long period of time (Rowlands, Eston and Ingledew, 1999; Trost et al., 2000; Pate et al., 2002; Trost et al., 2002; Riddoch et al., 2004). Only a few studies have reported data from larger samples of children (Pate et al., 2002; Trost et al., 2002; Riddoch et al., 2004). The aim of this study was to measure physical activity in Swedish boys and girls and to estimate the proportion of children that reached the recommended level of health-related physical activity.

Materials and Methods

Subjects

The study population was recruited among children at four different schools in Malmö, Sweden, that were enrolled in a longitudinal study estimating the effect of daily physical activity, the Bunkeflo Study. All schools were situated in socially homogeneous middle class areas with inhabitants of non-immigrant origin. All 477 children (boys=259, girls=218), attending third or fourth grade, were invited to participate in the study and 248 accepted the invitation. The study group consisted of 140 boys with mean age (years) 9.9±0.6 (range 8.6-11.1), mean height (cm) 141.2±6.8 (122-162) and mean weight (kg) 35.0±7.6 (20-65) and 108 girls with mean age 9.7±0.6 (7.9-11.0), mean height 140.4±7.8 (124-160) and mean weight 34.6±7.7 (23-61). All children in one of the schools (n=139) had 45 minutes of physical education (PE) every day; the children in the other three schools (n=109) had PE 45 minutes twice per week. Standing height was measured to the nearest centimetre and body weight to the closest kilogram. Height and weight of all invited children were retrieved from the general health data registered by the school nurses.

The institutional ethics committee of the University of Lund, Sweden, approved the study. Written informed consent was obtained from the parents of all participating children.

Measurement of physical activity

Physical activity was assessed using the MTI (Manufacturing Technology Incorporated, formerly known as the Computer Science Applications, Fort Walton Beach, Fl, USA) accelerometer, model 7164. This is a single plane (vertical) accelerometer. The accelerometers are small (5 x 4 x 1.5 cm) and light (about 40 g) and are worn on the hip secured by an elastic waist belt. An electronic filter, within the accelerometer, rejects high-frequency motions outside the range of normal human movements. Movement in a vertical plane is detected and movement counts are averaged over a period of time, defined as epochs (usually between ten seconds and one minute). The data are stored in the memory of the accelerometer and then downloaded into a computer for later analysis. Accelerometer measured activities have been well validated in children against a range of outcomes (Freedson et al., 1997; Trost et al., 1998; Eston, Rowlands, Ingledew, 1998; Louie et al., 1999; Trost et al., 2000; Ekelund et al., 2001, Brage et al., 2003a).

The measurements in our study were undertaken equally distributed during autumn school term (August till December). Children were instructed to use the accelerometer for four consecutive days, including both weekdays and weekend days. They wore the accelerometer during the entire day and only removed the equipment during activities that could damage the accelerometer, e.g. swimming. Accelerometers were programmed to start recording in the morning of the first day and measured continuously for four days. A recording epoch of ten seconds was selected for this study. A SAS-based software (SAS Institute Inc, Cary, NC, USA) was used to analyse all accelerometer data. This software analyse accelerometer measurements according to time. Also, automatically deletes missing data defined as continuous sequences of 60 or more consecutive zero counts. This was done based on the assumption that all sequences of zeros longer than ten minutes were caused by the accelerometer not being worn. That is, all such sequences were not included in the analysis. Children failing to provide a minimum of three separate days of eight hours of valid recording, after removal of missing data, were excluded from the study. In order to minimise inter-instrumental variation, all accelerometers were calibrated against a standardised vertical movement. This calibration factor was then used when calculating physical activity variables in each child.

The primary physical activity variable, estimating mean physical activity, was considered to be the total accelerometer counts per valid minute of recording (counts/minute). This was achieved by multiplying the value for mean calibrated counts/epoch with six, since we use a 10 second epoch. A previous study has shown that accelerometer measured mean physical activity correlates with mean physical activity measured by doubly labelled water in children (Ekelund et al., 2001). The secondary variables were the time that the child was engaged in activity of different intensities. Age and weight-specific cut-off points exist for accelerometer counts representing activity of varying intensities (Freedson et al., 1997; Trost et al., 1998). These cut-off points made it possible to roughly estimate the number of minutes the child was engaged in activity above a specific intensity threshold. The intensity was described as METs (metabolic equivalents). The time the child spent performing a minimum of 3 METs was considered to reflect moderately intense activity, such as brisk walking and the time spent above 6 METs was considered to reflect vigorous activity such as running. Cut-off points used for all children were >167 counts/epoch for a minimum of moderate activity and >583 counts/epoch for vigorous activity (Freedson et al., 1997; Trost et al., 1998), which are similar to the cut-off points used in some previous studies (Pate et al., 2002; Trost et al., 2002; Riddoch et al., 2004).

Finally, the proportion of children that reached current health-related physical activity recommendations was calculated. We used the United Kingdom Expert Consensus Group recommendation (Cavill, Biddle, Sallis, 2001) that recommends a minimum daily accumulation of at least 60 minutes of moderately intense activity. In addition, the proportion of children that reached more than 20 minutes of vigorous activity per day was calculated.

Statistics

All statistical analyses were performed using Statistica 5.0 (StatSoft Inc, Tulsa, OK, USA). Means and standard deviations (SD) were calculated for all variables. Student's t-test between means was used to analyse group differences. A value of $p<0.05$ was regarded as a statistically significant difference.

Results

There were no statistically significant differences in height, weight or BMI between children who participated in the study and those who did not. One hundred and eighty-five children (75%) achieved the full four days of at least eight hours of valid recording and 44 children (18%) achieved three days. Eighteen children (7%) were excluded for failing to achieve at least three days of valid registrations and one child lost the accelerometer. Complete data were thus evaluated from a final study group consisting of 229 children (128 boys and 101 girls). No significant differences in anthropometrics or physical activity were detected between children who had daily PE and those who had not (table 1). All children were therefore pooled in the further analysis. Physical activity, including gender differences, in children with valid recordings is presented in table 2.

All children fulfilled the recommendation for >3 METs during 60 minutes per day. Furthermore, 92% of the boys and 86 % of the girls achieved >6 METs during 20 minutes per day. Both boys and girls who had three days of valid registrations had a slightly higher mean activity than those who had four days of registrations, in boys 861 vs. 725 counts/min (p=0.01) and in girls 698 vs. 599 counts/min (p=0.01). However, there was no difference in neither boys nor girls in minutes spent above 3 or 6 METs per day, when comparing children who achieved three or four days of valid registrations, in boys for >3 METs 219 vs. 208 minutes (p=0.34) and for >6 METs 51 vs. 45 minutes per day (p=0.18). The corresponding values in girls was for >3 METs 201 vs. 188 minutes (p=0.18) and for >6 METs 39 vs. 34 minutes per day (p=0.10), respectively. There was no significant difference in recording time per day between children that achieved three and four days of valid recording, in boys (692 min vs. 722 min, p=0.10) and in girls (694 min vs. 717 min, p=0.26), respectively.

A separate analysis was performed to calculate mean physical activity on the first and last day of registrations. In boys with three days of valid recordings the mean activity was 836 counts/min on the first day vs. 765 counts/min on the last day (p=0.20) and in boys with four days 785 vs. 705 counts/min (p=0.049). The corresponding values in girls were 667 vs. 634 counts/min (p=0.39) and 625 vs. 582 counts/min (p=0.17), respectively.

Discussion

This is the first study to report objectively the daily physical activity in a large sample of Swedish children. The study reveals two important findings. First, all children, regardless of school PE-time, reach the current recommendations for physical activity. Secondly, gender differences in daily physical activity are confirmed. Mean physical activity was 22 % higher in boys; boys spent 31 % more time performing vigorous activity and 11% more time performing at least moderate intensity activity.

The introduction of objective measurements of daily physical activity with for example accelerometers represents a new era compared to previous studies that have mainly used self-report methods in the assessment of children's activity. This improvement is essential if we are to use such studies as a reference when forming health policies. Self-report methods are known to overestimate vigorous activity in children while moderately intense activity appears to be under-estimated (Sallis & Saelens, 2000; Kohl, Fulton, Casperson, 2000). For example, The National Diet and Nutrition survey (Gregory & Lowe, 2000) reported that 70% of boys and 49% of girls aged 7-10 years fulfilled the recommendations set by the United Kingdom Expert Consensus Group (Cavill, Biddle, Sallis, 2001), figures that are far below those found in our report and other reports using accelerometers (Pate et al., 2002; Riddoch et al., 2004). A likely explanation for this discrepancy is that moderate activity tends to be sporadic and therefore less memorable and quantifiable, especially when it comes to younger children. The overestimation of vigorous physical activity with the use of self-reported methods is highlighted in the report from the US Youth Risk Surveillance Survey (Grunbaum et al., 2004) where 68% of boys and 51% of girls, age 15-17, fulfilled the recommendation of a minimum of 20 minutes of vigorous physical activity at least three days per week (HP 2010, goal 22.7, US Department of Health and Human Services, 2004). Conversely, using accelerometers, in a different US population of children with a similar age only 5% of the boys and 2% of the girls fulfilled the same recommendation (Pate et al., 2002).

The use of accelerometers may introduce other limitations to studies of daily activity in children. Firstly, the very fact that the child wears an accelerometer may modify the child's habitual activity. In our study, analysis of mean physical activity on the first and last day of recording suggests no systematic differences, as only a small difference was found in boys with four days of valid measurements. This does, however, not rule out changes in habitual activity throughout the study, although we feel that this is unlikely. Secondly, a malfunctioning accelerometer could register data that would underestimate the actual activity level. Calibration of all accelerometers and the inclusion of the calibration factor in the analysis were done to eliminate this potential source of error. Thirdly, accelerometers underestimate activity levels during activities that involve a minimal vertical displacement of the body, as for example skating, weightlifting or cycling. In addition, accelerometers may underestimate vigorous activity because of a linear relation to differences in speed during walking, but not during running (Brage et al., 2003a; Brage et al., 2003b). Also, the accelerometer has to be removed during activities that could damage the motion sensor (e.g. this type of accelerometer is not waterproof). Failure to monitor these activities may result in underestimation of physical activity levels in some children. Finally, whenever a child forgets to wear the monitor, recorded counts will be zero during this period. The practice in our study to automatically delete missing data compensates to a large degree for this in the calculation of the mean physical activity (mean count/minutes). Our software excluded 17 children (7 %) who failed to achieve three valid days of eight hours of registration after deletion of missing data. This figure is similar to that of Pate et al (Pate et al., 2002) who report an exclusion rate of 6.3% over a 7-day recording period even though they did not report deleting missing data. In contrast, Riddoch et al (Riddoch et al., 2004) reported an exclusion rate of 25%, when deleting missing data, but this was in a multinational multicentre setting. In our study there was a significant difference in mean physical activity for both boys and girls, where those children who had three days of valid measurements had higher values. This oppose to the data from Riddoch et al (Riddoch et al., 2004) where children who had three days of measurements tended to have lower mean physical activity. Since the protocol of physical activity measurements in their study is practically identical to ours, the diverging results of the two studies in this respect may be stochastic. Also, since differences in observed time did not affect the estimation of time spent above thresholds for moderate or vigorous activity we do not think that any major systematic error is introduced by using three- and four-day measurements together. The MTI accelerometer may underestimate vigorous activity, especially when using longer epoch time, e.g. one-minute epochs (Nilsson et al., 2002). A possible strength of our study, especially in the estimation of vigorous activity is therefore the use of a short epoch time of 10 seconds. Overall, we think that our attempts to minimize the methodological shortcomings of this method of activity registrations have been successful and that we have obtained a reasonably good estimate of the daily activity patterns of the children in this study.

Our study group included children that have above average weekly hours of school PE, but the mean physical activity as well as time spent at activity of different intensities of these children were not different from the rest of the children. This suggests that no fundamental error was introduced when pooling all children together in the analyses. Since the anthropometrics of the children that took part in the study did not differ from those who did not, this suggests that a fairly representative cross-sectional sample of native Swedish children, aged 8-11 years, participated. It should be noted, however, that the children do not represent a cross-sectional sample of the population of Malmö, where the parents of a large proportion of the children at this age are immigrants with a highly diverse ethnic background. It has been speculated that children from these groups, particularly girls, are less physically active and further studies including groups with different ethnic background are necessary. Also, as mentioned previously, all children participating in the present study lived in residential areas in the city of Malmö. Our result may not be representative to children living in rural areas or in northern Sweden, which have a much harsher climate. Sampling over an entire school term, as in our study, would in northern Sweden perhaps be more affected by seasonal variation in physical activity (Shephard et al., 1980). However, Malmö is located in the southern most part of Sweden, which has a relatively mild climate. One could therefore speculate that the effects of seasonal variations in activity patterns would not be substantial and compatible to other western and central European countries.

A salient finding was that all children fulfil current physical activity recommendations (Cavill, Biddle, Sallis, 2001). If the recommendations are appropriate, then all children in our study are sufficiently active to achieve optimal health benefits. However, as pointed out in previous studies (Pate et al., 2002; Riddoch et al 2004), this belief would be based on a number of uncertainties. Firstly, the current recommendations for health-related physical activity are uncertain (Twisk, 2001) and the selection of 3 and 6 METs as appropriate intensity cut-off points is arbitrary. Also, the end-points to be used when defining potential health hazards in children have not yet been established. Should activity levels observed in children with normal risk for CVD, diabetes and other diseases be accepted as appropriate? Or should the results of tracking studies, where the activity of children that develop into healthy as adults be used? We intend to address this issue in the prospective portion of this longitudinal study. Secondly, the accelerometer cut-off points defining different activity intensities for children (Freedson et al., 1997; Trost et al., 1998) have been established in laboratory settings using treadmill exercise protocols and may not be representative of the movements performed by free-living children during the course of a full day.

We are aware of only three previous reports (Pate et al., 2002; Trost et al., 2002; Riddoch et al., 2004) that have assessed the prevalence of physical activity in relatively large numbers of children using accelerometers. In a US population of 187 children aged 7-10 years (Pate et al., 2002; Trost et al., 2002) 90-100% were found to fulfil the recommendations of physical activity set by the United Kingdom Expert Consensus Group (Cavill, Biddle, Sallis, 2001). Mean values for a minimum of moderate physical activity per day ranged from 50-340 minutes, which is similar to our data (75-325 minutes per day). As in our study, boys were more active than girls. Gender differences in moderate activity were ranging between 17-31% whereas in our study gender differences were no more than 11%. Only two to five percent of the children (Pate et al., 2002) fulfilled US guidelines for vigorous activity (Healthy People 2010, goal 22.7), which recommends, as mentioned previously, continuous physical activity above 6 METs for 20 or more minutes three or more days per week (US Department of Health and Human Services, 2004). This strict definition of vigorous activity, which probably requires formal physical training three times per week to be achieved, most certainly explains the low proportion of children that fulfilled these criteria. Since we did not require any continuous bouts of exercise to fulfil the requirements for vigorous activity our findings are not comparable in this respect. Recently accelerometer data from 2185 children aged 9 and 15 years in four different countries (Denmark, Portugal, Estonia and Norway) in the European Youth Heart Study was reported (Riddoch et al., 2004). There are striking similarities between the younger population (aged 9) in that report and our findings (Fig 1) when it comes to mean physical activity and gender differences. There was only a slightly greater gender difference in daily moderate activity of 20 % vs. our finding of 11 %. As in our study, they found that a very high percentage of 9-year olds (boys 97 % and girl 98 %) fulfilled the recommendations for moderate activity set by the United Kingdom Expert Consensus Group (Cavill, Biddle, Sallis, 2001). These studies (Trost et al., 2002, Pate et al., 2002, Riddoch et al., 2004) agree with our study that younger children might be engaged in more moderate intensity physical activity than previously thought. On the other hand, the daily physical activitiy levels of the older children in these studies (Trost et al., 2002, Pate et al., 2002, Riddoch et al., 2004) were much lower.

Perspective

The accumulation of accurate data is critical if better estimates of the true association between physical activity and health risk factors are to be achieved, and if secular trends in physical activity in the population should be monitored. In this study accelerometers have successfully been used in a large field-based epidemiological study to determine the daily physical activity of native Swedish children. Our data suggest that virtually all children age 8-11 achieve current physical activity recommendations with boys being more active than girls. This could have important implications for public health policies and recommended levels of activity for children of different age. Maybe health campaigns promoting physical activity should primarily be directed towards older children? It is by no means clear, however, that the current physical activity recommendations for young children are appropriate to evaluate risk factors for disease in youth and adulthood.

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Table 1. Physical activity in children who had daily physical education (PE) in school and those who had regular PE, two times per week. Values are mean ± SD.

	Boys			Girls		
	Daily PE n=72	Regular PE n=56	p-value	Daily PE n=54	Regular PE n=47	p-value
Valid recording per day (min)	700±79	737±85	0.01	710±79	715±78	0.78
Mean physical activity (mean counts/min)	770±267	727±209	0.32	645±179	589±115	0.07
Time of moderate activity per day (min)	211±55	209±45	0.80	196±41	184±35	0.14
Time of vigorous activity per day (min)	44±21	48±19	0.24	35±14	34±12	0.88

Table 2. Gender differences in physical activity in children with valid accelerometer recordings (n=229). Values are mean ± SD and range.

	Boys n=128	Girls n=101	p-value
Valid recording per day (min)	716±83 505-987	712±78 516-987	0.58
Mean physical activity (mean counts/min)	751±243 189-1505	618±154 211-1121	<0.001
Time of moderate activity per day (min)	210±51 75-325	190±38 89-283	<0.001
Time of vigorous activity per day (min)	46±20 4-116	35±13 6-70	<0.001

Figure legend;

Figure 1. Distribution mean values of mean physical activity (mean counts/min), current study compared to previous study by Riddoc et al 2004. All black bars (Sweden), represent current study.