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Changes in physical activity in pre-schoolers and first-grade children: longitudinal study in the Czech Republic

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Abstract

Background The transition from kindergarten to first year at school is associated with a variety of psychosocial changes in children. The aim of this longitudinal study was to identify the changes in children's physical activity (PA) upon entry to first year at school; and to identify the days of the school week that exhibit low PA.

Methods We monitored the PA levels of 176 children twice: initially in kindergarten and again in first-year classes at school. The age (mean ± standard deviation) of children at kindergarten was 5.7 ± 0.5 years and 6.7 ± 0.5 years at the first year of elementary school. We evaluated PA employing the activity energy expenditure (AEE – kcal/kg/day) from Caltrac accelerometer and daily amount of steps (STEPS) from Yamax pedometer. Participants were monitored over 7 days to include a weekend.

Results The mean AEE was 11.5 in pre-school girls and 12.9 kcal/kg/day in boys; and STEPS were 9923 steps/day in girls and 11 864 in boys on weekdays. At weekends, it was 11.5 kcal/kg/day in girls and 12.7 kcal/kg/day in boys and 10 606 steps/day in girls and 11 182 steps/day in boys. The mean AEE and STEPS in first-grade girls and boys was 9.9 and 9.8 kcal/kg/day respectively, and 7911 and 8252 steps/day respectively on weekdays, and 8.8 and 9.0 kcal/kg/day and 6872 and 7194 steps/day respectively at weekends. First-grade school children had significantly lower PA than pre-school children on weekdays ($P < 0.0001$) and at weekends ($P < 0.0001$). Decline in PA on weekdays was during time spent at school ($P < 0.0001$) and not during after-school children's leisure time.

Conclusion The parts of the week when first-grade school children show low PA are the times spent in lessons and in after-school nursery and at weekends. PA needs to be promoted using intervention programmes mainly during the after-school nursery programmes and at weekends.

Keywords
childcare, physical activity, pre-school children, school

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Introduction

The increase in child obesity and its impact on the development of severe health problems in youth and adulthood is documented worldwide (Lissau *et al.* 2004; Janssen *et al.* 2005). Hence in order to guide policy, there have been calls for effective ways to increase physical activity (PA) in children (Datar & Sturm 2004; Cottrell *et al.* 2005; Sharma 2006). In conjunction

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with healthy diet, adequate PA prevents or reduces child obesity (Moore *et al.* 2003; Datar & Sturm 2004; Janssen *et al.* 2005; Sharma 2006).

Regular PA in 4- to 11-year-old children prevents obesity and coronary heart disease (Sääkslahti *et al.* 2004), develops a positive attitude to aerobic fitness, and does not negatively influence healthy growth in adolescence (Fogelholm *et al.* 2000). Moreover, PA in pre-school age predicted being physically active 15 years later in adult men and women (Barnekow-Bergkvist *et al.* 1996; Kraut *et al.* 2003). However, increasing PA in pre-school and school children is effective when parents and the school are involved (Cottrell *et al.* 2005; Cale & Harris 2006; Sharma 2006).

The school environment represents an opportunity for implementing PA, nutrition and other lifestyle intervention programmes. As children spend much of their childhood there, healthy lifestyle habits can be instigated and maintained (Daley 2002; Cale & Harris 2006; Sharma 2006). Effective PA in adults needs to last for 20–60 min without a break, but health-enhancing PA in children can be carried out in shorter, 10- to 15-min intervals adding up to 60 min or more of moderate to vigorous PA daily (Strong *et al.* 2005). These shorter PA episodes are carried out in physical education (PE) lessons (Daley 2002; Datar & Sturm 2004; Strong *et al.* 2005; Cale & Harris 2006), in recess periods and at lunch breaks (Tudor-Locke *et al.* 2006; Verstraete *et al.* 2006). While PE lessons are primarily for PA, the increasing role of recess periods to increase PA in children has been emphasized using suitable games and equipment (Verstraete *et al.* 2006). This is important, as PA during lunch break accounted for ≈16% of daily PA in boys and girls, whereas recess periods and PE lessons accounted for about 9% and 11% of total steps per day respectively (Tudor-Locke *et al.* 2006).

Recommendations for duration of PA in present pre-school children are even more rigorous than in first-grade children. Pre-schoolers should collect at least 60 min daily of structured PA and moreover engage in unstructured PA at least 60 min and up to several hours per day (Timmons *et al.* 2007).

Educators and parents capitalize on the transition from kindergarten to first year at school to develop the child's nutritional (Stenhammar *et al.* 2007), behavioural, reading and mathematical skills (Burkam *et al.* 2007; Magnuson *et al.* 2007). However, enhancing the PA levels of children is seldom considered as a critical factor in this transition (Sääkslahti *et al.* 2004). Despite the importance of the kindergarten to first-grade elementary school transition, few studies examined the changes in PA levels across this period, and those that did examine such changes reported contrasting findings (Sallis *et al.* 1995; Sääkslahti *et al.* 2004).

A body of literature has employed cross-sectional studies to survey children's PA at kindergarten (Cardon & De Bourdeaudhuij 2007) or alternatively at first-grade elementary school. Existing valid longitudinal studies on 3- to 6-year-old children have shown decline in PA along with increasing age in pre-schoolers (Reilly *et al.* 2004; Kelly *et al.* 2007). However, the evidence base of longitudinal follow-up studies of children's PA levels during the transition from kindergarten to first-grade school is thin. Such baseline data are important for future PA intervention programmes and for evidence-based recommendations for PA. The study described in this paper undertook this task, and describes PA patterns of children during the transition from kindergarten to first-grade school. We measured: (1) the same children twice, 1 year apart; (2) their actual volume of PA (number of steps – STEPS, employing pedometers); (3) the actual intensity of their PA (activity energy expenditure – AEE, using accelerometers); and (4) for a longer period than previous studies (1-week duration, a minimum of 8 h daily).

The aim of the study was to longitudinally monitor kindergarten children in order to: identify the changes in their AEE and STEPS after they enter the first grade at school; and identify the parts of the school week that are low in PA.

Methods

Participants

The study was undertaken in the Moravian region in the Czech Republic, after approval by the Institutional Research Ethics Committee of Palacky University. Children participated in the study voluntarily and received no incentives. After a detailed presentation of the study by the first author, 11 kindergartens (out of the 22 kindergartens approached) agreed to participate. The study aims and PA monitoring procedures were explained to the parents, and written informed consents were obtained twice from all parents who agreed that their children would participate: before the monitoring at kindergarten and then again before the monitoring at first year at school. During September/October 2005, PA levels were monitored for 7 days in kindergarten children aged 5–7 years, and again for 7 days during September/October 2006 after their entry to elementary school. Only children who completed the whole 7-day monitoring both in kindergarten and at school were included in the present analysis.

Measures and procedures

A standardized methodology of PA field-based monitoring was adopted as described by Sallis and colleagues (1990). Weekly PA monitoring was based on continuous, all-day monitoring using the Caltrac accelerometer (AEE), the Yamax Digiwalker SW-200 pedometer (STEPS), and individual chart sheets (to record the data from Caltrac and Yamax).

The Caltrac one-axial accelerometer (Muscle Dynamics Fitness Network, Torrance, CA, USA) is small and light (<80 g), and measures vertical movement. Total and activity energy expenditure is estimated by entering the participant's age, height, weight and sex; and cumulative energy expenditure values are displayed on a screen (Westerterp 1999). The Caltrac functions are such that when the trunk accelerates, the accelerometer produces a charge proportional to the force exerted by the subject, generating an acceleration–deceleration wave. The area under this wave is summed to yield the final number value of AEE (Montoye *et al.* 1996). In determining caloric energy expenditure values, an equation calculates resting metabolism based on the participant's age, height, weight and sex (Bray *et al.* 1992): female [kcal/min] = ((331·weight [lb]) + (351·height [in.]) − (352·age [years]) + 49 854)/100 000; and male [kcal/min] = ((473·weight [lb]) + (982·height [in.]) − (531·age [years]) + 4686)/100 000. AEE from the Caltrac values represents the net value of energy of a given PA, i.e. total energy expenditure minus the resting metabolism (Westerterp 1999). Expressing AEE in a relative value (kcal/kg/day) is recommended for comparing different groups of girls and boys of various age categories (Puyau *et al.* 2004).

Caltrac is one of the first accelerometers used in research to assess energy expenditure. To estimate daily energy expenditure in children, it has been validated against 2-day heart rate monitoring ($r = 0.40$–0.54, $P < 0.02$) with high ($r = 0.96$) inter-instrument reliability (Harro 1997; Sallis *et al.* 1990). On the basis of significant correlations ($r = 0.80$, $P < 0.001$) between Caltrac accelerometer and indirect calorimetry in whole-room calorimeters and between Caltrac accelerometer and oxygen consumption (VO_2) at walking ($r = 0.85$, $P < 0.001$), this type of accelerometer is recommended for assessing energy expenditure for groups of children (Bray *et al.* 1992, 1994). At present, ActiGraphs accelerometers are being used worldwide to monitor PA in children allowing next to cumulative values also exact 'minute-by-minute' energy expenditure records (Cardon & De Bourdeaudhuij 2007).

The Yamax Digiwalker SW-200 (Yamax Corporation, Tokyo, Japan) is a light (20 g) and small commercial electronic pedometer that measures vertical oscillations. Yamax uses a spring-suspended lever that moves in response to the hip's vertical oscillations, the movement opens and closes an electrical circuit, and each vertical oscillation detected above a critical threshold (0.35 g) is registered as a step taken (Tudor-Locke *et al.* 2002). Total number of counted STEPS is displayed on a small screen.

In general, pedometers are most accurate in counting steps, less accurate in calculating distance, and least accurate at estimating energy expenditure (Crouter *et al.* 2003). Because steps are the most direct expression of what the pedometer actually measures, Tudor-Locke and Myers (2001) recommend reporting pedometer data as STEPS.

Age was computed from date of birth to date of monitoring. Height was measured using an Anthropometer A-319 (Trystom Corporation, Olomouc, Czech Republic) and weight was measured using calibrated Tanita WB 110 S MA (Quick Medical Corporation, Seattle, WA, USA). The first and second authors measured height and weight to the nearest 1 cm and 0.5 kg respectively.

Participants were provided with elastic belts with pouches containing the Caltrac accelerometer, Yamax pedometer and an individual record sheet. The elastic belts were secured tightly in position on the children's right hips. A criterion was that participants wore the belt continuously for 7 days excluding sleeping, hygiene and bathing for the minimum of 8 h a day.

Each individual chart sheet comprised two sections that were completed by parents/teachers: one for AEE readings and the other for STEPS readings. For each participating child, the AEE from Caltrac and STEPS from Yamax were recorded onto an individual chart four times a day [morning after waking up – by parent; start of kindergarten/school – by teacher; end of kindergarten/school (including after school club) – by teacher; evening before going to bed – by parent]. The first author provided training to all teacher/s and parents participating in the study that included information on the pedometer and accelerometer, and how to appropriately read the values expressed by each and correctly record on the individual chart sheets.

Statistical analysis

Data were analysed using SPSS for Windows, version 14.0 (SPSS, Chicago, IL, USA). Four one-way (two sexes) analyses of variance (ANOVA) for repeated measures were conducted to examine the association between AEE levels and the children's entry to school. Weekdays, weekends, school and leisure time were used as the dependent variables. ANOVA was used four times to also identify the association between STEPS and children's entry to school. In order to identify the differences in AEE or STEPS between kindergarten and first-grade school

Table 1. Basic somatic characteristics (mean ± standard deviation) of pre-school and first-grade school children

	Gender	Sets (*n*)	Age (years)	Weight (kg)	Height (cm)	Body mass index (kg/m²)
Pre-school children	♀	84	5.7 ± 0.3	21.1 ± 2.9	116.7 ± 4.3	15.5 ± 1.7
	♂	92	5.6 ± 0.5	22.3 ± 2.9	119.2 ± 7.2	15.7 ± 1.4
First-grade school children	♀	84	6.7 ± 0.3	23.7 ± 3.9	123.9 ± 5.9	15.4 ± 2.1
	♂	92	6.6 ± 0.5	25.2 ± 3.9	125.8 ± 7.4	15.8 ± 1.7

boys and girls in different times of day and time of week, a Tukey's HSD *post hoc* test was used. The estimate of the strength of the relationship between the independent and dependent variables was represented as coefficient Cohen's *d*. The values of 0.2, 0.5 and 0.8 were interpreted as small, medium and large effect sizes respectively (Thomas & Nelson 2001).

Results

In total, 244 kindergarten children started the week-long PA monitoring, but only 208 children (boys $n = 102$) completed the 7 days. For these 208 participants, their PA was monitored again for 7 days during September/October 2006 after their entry to elementary school. Only 72% of children (176 children, boys $n = 92$) completed the whole 7-day monitoring both in kindergarten and at school (Table 1).

None of the children was from ethnic minority groups, and all participated in the daily PA programmes of the kindergartens and elementary schools. Each participating kindergarten provided a daily 50- to 70-min walk outdoors and two 20-min carpet exercises (competitive movement games, steps and dance variations, relaxing, breathing, and other type of exercises). In contrast, first-grade elementary schools provided only two 45-min PE lessons per week. The PE lessons included non-competitive movement games (tag and running variations), movement games with balls (throwing and catching in pairs, throwing and rolling at a goal), skipping rope exercises and adapted competitive movement games (soccer and dodge ball). These PA programmes are common for all kindergartens and elementary schools in the Czech Republic.

After entry to elementary school, PA in longitudinally monitored children significantly decreased ($P < 0.0001$) both on weekdays and at weekends (Figs 1 & 2). The decline in PA on weekdays was apparent in the actual intensity of the children's PA as reflected by the AEE ($F_{1,352} = 107.36$, $P < 0.0001$, $d = 1.0419$) in addition to the actual volume of the children's PA as reflected by STEPS ($F_{1,352} = 181.90$, $P < 0.0001$, $d = 0.9146$). Using the Tukey's HSD *post hoc* test, we found the decrease in AEE significant both in girls ($P < 0.0001$, $d_{♀} = 0.7238$) and in

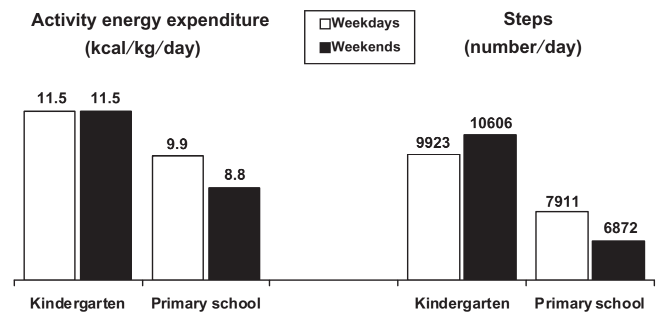

Figure 1. Activity energy expenditure on weekdays and at weekends for pre-school and first-grade school girls ($n = 84$).

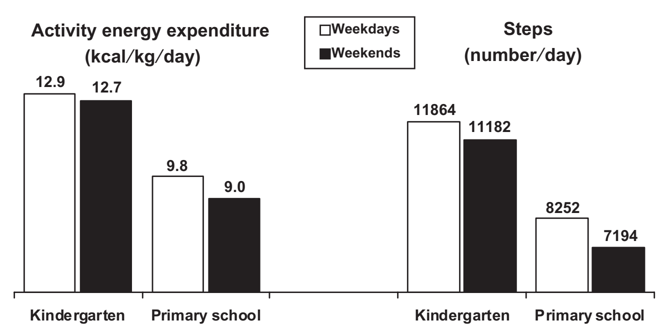

Figure 2. Activity energy expenditure on weekdays and at weekends for pre-school and first-grade school boys ($n = 92$).

boys ($P < 0.0001$, $d_{♂} = 1.2829$). Similarly, significant decline in STEPS upon the entry to school on weekdays appeared in girls ($P < 0.0001$, $d_{♀} = 1.0237$) and boys ($P < 0.0001$, $d_{♂} = 1.4295$). At weekends, there was also a significant decline in PA after the transition from kindergarten to elementary school (AEE: $F_{1,352} = 130.07$, $P < 0.0001$, $d = 1.4764$ and STEPS: $F_{1,352} = 179.634$, $P < 0.0001$, $d = 2.2282$). Tukey's HSD *post hoc* test revealed significant decline in PA at weekends both in girls ($P < 0.0001$, $d_{♀AEE} = 0.8511$, $d_{♀STEPS} = 1.1649$) and in boys ($P < 0.0001$, $d_{♂AEE} = 1.1303$, $d_{♂STEPS} = 1.1953$).

On weekdays, we did not find significant differences in AEE and STEPS in leisure time (Figs 3 & 4). However, spending time in kindergarten and at elementary school in relation to PA is significantly different (AEE: $F_{1,352} = 268.08$, $P < 0.0001$,

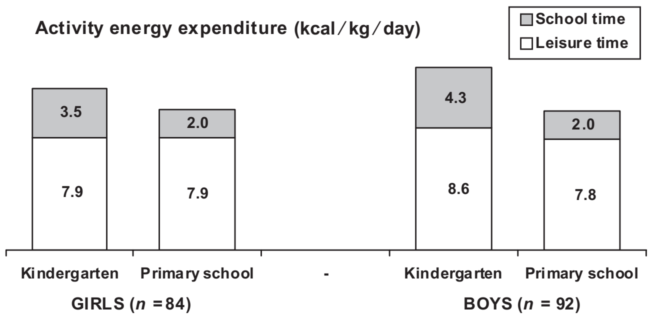

Figure 3. School and leisure time activity energy expenditure on weekdays for pre-school and first-grade school children.

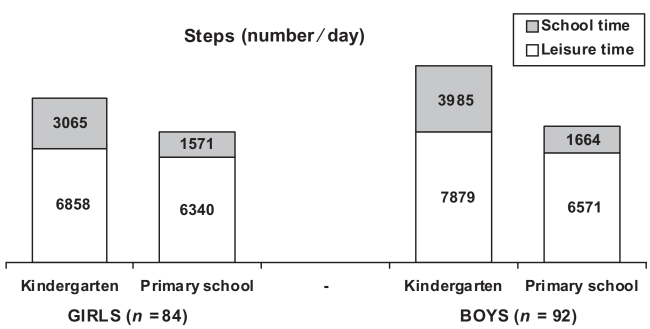

Figure 4. School and leisure time amount of steps on weekdays for pre-school and first-grade school children.

$d = 1.5646$; STEPS: $F_{1,352} = 241.12$, $P < 0.0001$, $d = 1.3231$). Using Tukey's HSD *post hoc* test shows significantly lower PA at school in girls ($P < 0.0001$, $d_{\text{♀AEE}} = 1.3501$, $d_{\text{♀STEPS}} = 1.2217$) and in boys ($P < 0.0001$, $d_{\text{♂AEE}} = 1.7803$, $d_{\text{♂STEPS}} = 1.5149$).

Discussion

Children's transition from kindergarten to school was reflected negatively as a significant decrease of PA both on weekdays and at weekends. Measured pre-school children are more physically active and fulfil the requirements for health benefits of PA better than first-grade school children, teenagers and young adults (Sigmund *et al.* 2007). Meeting 10 000 steps a day on average means that the health-oriented PA recommendations are met in pre-school children. However, the daily number of steps in first-grade schoolchildren is not considered sufficient to maintain health. Pre-school children do not exhibit significantly lower PA at weekends than on weekdays, a trend that has been observed in school children (Rowlands & Hughes 2006; Rowlands *et al.* 2008). These findings are likely to be due to the increase of school assignments and homework in children in first grade. The children appear to be under pressure to acquire basic reading, writing and mathematical skills within 4 months upon their entry to school. In addition, the number of children per class seems to increase from kindergarten to first-grade school, averaging from 10–15 children per class in kindergarten and rising to 20–30 children per class in school. This might require more attention and concentration on the side of children, and might cause teachers to compensate the numbers by assigning more homework to the children that might lower their opportunities for PA at home.

First-grade school children usually spend about 1–2 h at the after-school nursery after the very last lesson until parents come to pick them up. However, the space at after-school nurseries is usually not suitable or too small to carry out any locomotive PA or structured and unstructured games. In order to carry out PA of such kinds in after-school nurseries, schools would need to employ professionals and provide game equipment (Verstraete *et al.* 2006). This is in support of other studies: pleasant school or pre-school environments with PA-related equipments and with high levels of adult supervision stimulated children to be more physically active (Sallis *et al.* 2001; Hannon & Brown 2008). For instance, developing a 'safe routes to school' for walking and cycling; installing secure cycle storage in school; and allowing access to the sports halls and playgrounds after school hours are all important 'active-school' strategies (Fox *et al.* 2004). This also concurs with the primary recommendations to promote lifelong participation in daily PA: that all children should receive quality, daily PE lesson with certified PE specialists; should be accommodated in appropriate class sizes; and that there needs to be facilities, equipment and tools to help schools improve their PE and other PA programmes (Tappe & Burgeson 2004).

Similar to Cardon and De Bourdeaudhuij (2007), the Yamax Digiwalker SW-200 pedometer appears to be more accurate and easier to use for weekly PA monitoring in 4- to 8-year-old children as opposed to accelerometers. For instance, many children and parents have difficulty in understanding the concept of energy expenditure that accelerometers produce. Moreover, pedometers provide feedback information on PA which is comprehensible even to young children. The participants in this study, at the time of the second monitoring (1 year after the kindergarten monitoring), still remembered the pedometer and could associate it with running, walking and games. Teachers usually explained PA to children on the basis of number of steps on the pedometer display. Using pedometers to estimate daily number of steps at school, during recesses and in leisure time (Tudor-Locke *et al.* 2006), on weekdays and at weekends (Rowlands & Hughes 2006; Rowlands *et al.* 2008), in common life and intervention PA programmes in pre-adolescent children is well documented (Cottrell *et al.* 2005).

The sample size of this study limits the generalizability of the findings. Larger samples would be required to confirm any decrease in PA in children during the transition from kindergarten to elementary school. Among the other limitations of the study is the occurrence of reactivity (Vincent & Pangrazi 2002). Although the study did not monitor reactivity, we have not found higher PA in children on the first 2 or 3 days of monitoring in comparison with the rest of monitored days. Furthermore, the variety of the PA structure and PA patterns of girls and boys could influence the validity of the monitored PA. In order to estimate PA most accurately, monitoring was repeated exactly after 1 year after the first one. We used the same measuring devices and we analysed the groups of boys and girls separately.

Further research should focus on the school environment and its relation to PA regimes. The manner in which children spend recesses (including lunch break/s), the size and layout of play and exercise spaces, the sport equipment available to the schools, the organization of the supervision of play, and the possibilities of how to spend leisure time at schools outdoors are all important topics to consider. Possible enhancement of PA levels could be by promoting walking or cycling to school. We also recommend the use of electronic devices to assess the school environment in relation to children's PA regimes by producing a fine-grained picture ('minute-by-minute' records), e.g. ActiGraph accelerometers (Tudor-Locke *et al*. 2002; Kelly *et al*. 2007; Hannon & Brown 2008; Rowlands *et al*. 2008).

Key messages

- The transition from kindergarten to elementary school is associated with significant decline in PA in children during the time spent at school. The PA pattern common in kindergarten is not replaced with an adequate PA pattern at school.
- After the transition from kindergarten to school, a difference between PA levels on schooldays and weekends emerges which had not been apparent in pre-schoolers.
- The parts of the school week that are the lowest in PA are the times spent in after-school nursery and then at weekends. These parts of the week provide space for intervention programmes enhancing PA in children attending elementary schools.
- Yamax Digiwalker SW-200 pedometers seemed to be most suitable and easy to use devices to monitor PA of children.

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