Daily Physical Education Improves Motor Skills and School Performance

A Nine-Year Prospective Intervention Study

Ingegerd Ericsson
Department of Sport Sciences, Malmö University
Magnus K. Karlsson
Department of Clinical and Molecular Osteoporosis Research Unit, Lund University

Published on the Internet, www.idrottsforum.org/articles/ericsson/ericsson-karlsson/ericsson-karlsson120509.html, (ISSN 1652–7224), 2012–05–09

This is the pre-peer reviewed version of the following article: "Motor Skills and School Performance in Children with Daily Physical Activity in School – A Nine-Year Prospective Intervention Study", which has been published in final form in *Scandinavian Journal of Medicine & Science in Sports* at http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0838.2012.01458.x/abstract.

The aim of this nine-year prospective, controlled, population-based exercise intervention study was to investigate long-term effects on motor skills and school performance of increased Physical Education. All pupils born 1990-92 from one school were included in a longitudinal study during nine years. An intervention group (n=129) achieved daily PE (5x45 minutes/week) and if needed one extra lesson of adapted motor training. The control group (n=91) had PE two lessons/week. Motor skills were evaluated by the MUGI observation checklist and school achievements by marks in Swedish, English, Mathematics, PE and proportion of pupils who qualified for upper secondary school.

Findings: In school year 9 there were no motor skills deficits in 93% of pupils in the intervention group compared to 53% in the control group ($p<0.001$), 96% of the pupils in the intervention group compared to 89% in the control group ($p<0.05$) qualified for upper secondary school. The sum of evaluated marks was higher among boys in the intervention group than in the control group ($p<0.05$). *Interpretation:* Daily PEH and adapted motor skills training during the compulsory school years is a feasible way to improve not only motor skills but also school performance and the proportion of pupils who qualify for upper secondary school.

Introduction

Physical activity is important for health, and studies like the European Youth Heart Study and the Pediatric Osteoporosis Prevention (POP) study report high prevalence of risk factors for cardiovascular disease, low muscle strength and low bone mass in children with low physical activity (Andersen et al., 2006; Valdimarsson et al. 2006; Linden et al. 2007). Despite this there is a large proportion of children with a physically inactive lifestyle. For example, up to 25% of children in Australia are estimated to be at risk of not being physically active enough to optimize health (Booth et al., 2002) and similar data are reported in several pediatric settings (Hammar & Toss, 1994: Westerståhl et al, 2003; Dencker, 2007).

In Sweden 88% of all pupils participate regularly in the school subject Physical Education and Health (PEH) (Redelius, 2004; Lundvall & Meckbach, 2008) while only 61% of the pupils who did not achieve the goals of compulsory school 2008 attended PEH lessons during their ninth school year (Ericsson & Cederberg, 2010). Studies have also shown an association between level of physical activity, participation rate in PEH and the sum of marks in school subjects (Thedin Jakobsson & Engström, 2008; Ericsson & Cederberg, 2010). Thus, when children have a low degree of physical activity during the school day and do not develop adequate motor skills, this may lead not only to lack of fitness and health problems (Brown et al., 2004), but also to impaired academic achievements (Ericsson, 2003; 2008a).

Many pupils, especially boys, leave compulsory school without being qualified for the national upper secondary school programs. To be qualified, pupils in Sweden must, in certificates from compulsory school, attain at least the mark "Pass" in each of the subjects Swedish, Mathematics and English, a goal possible for all pupils to reach (Ekman & Dolan, 2010). Despite efforts, the proportion of unqualified pupils has increased during the last decade, more among boys than girls, so that the proportion of pupils unqualified for higher studies in Sweden in 2009 was 12%, the highest figure since 1998 (National Agency for Education, 2009). But the trend may hypothetically be reversed with increased physical activity and extra motor training, as this in younger school years has shown to be associated with improved school achievements (Ericsson, 2008a). The school would then be a logical arena for such an intervention, as the only arena in society that reaches all children.

This is why we designed a nine-year prospective, controlled, population-based exercise intervention study with the aim of evaluating whether daily PEH in the school curriculum could improve motor skills and the proportion of pupils that qualified for upper secondary school. We hypothesized that extended PEH and adapted motor training during the compulsory school years would (i) improve the pupils' motor skills, (ii) improve the proportion of pupils who qualify for upper secondary school and (iii) that motor skills and marks in PEH, Swedish, English, and Mathematics would correlate.

Materials and methods

All pupils within the first three school years, 7-9 years of age, in one Swedish school, were followed until they were 16 years old and left compulsory school. The school was situated ca six km from a large city and the children allocated to the school according to residential address. The study design was a prospective controlled exercise intervention study, the Pediatric Osteoporosis Prevention (POP) study, which has been presented in detail previously (Ericsson, 2003; 2008a; Valdimarsson, 2006; Dencker, 2007; Linden et al., 2007). All parents and pupils were informed and gave their written consent. The study was approved by the Ethics Committee of Lund University and conducted according to the Declaration of Helsinki.

To reduce bias based on changes that could possibly occur during the follow-up period in school staff, school curriculum and local or national changes when grading pupils, we included in this study all pupils who attended the three first school years in the same school in 1999, all living in the same region and all followed during the same period. Children born 1991 and 1992 were allocated to the intervention group and children born 1990 were allocated to the control group. A total of 253 children were invited but as two declined, 251 population-based pupils were included in the study. The intervention included daily PEH during all compulsory school years and comprised of general physical activities used in the Swedish school curriculum, five lessons (in total 225 minutes) per week and, if needed, one extra lesson (60 minutes) of adapted motor training according to registration with the Motor Skills Development as Ground for Learning (MUGI) method (Ericsson, 2003; 2008a; 2008b; 2011). The control group achieved the Swedish standard of two lessons (in total 90 minutes) of PEH per week.

All pupils were followed until school year 9, corresponding to the end of compulsory school. During this period they were taught by the same school teachers and followed the same school curriculum in all subjects, apart from the increased PEH. In addition, there were no differences between the intervention and the control group in leisure-time physical activity when registered in school years 2, 4, 7, 8, and 9 (unpublished data). There were no significant differences in the parents' or pupils' attitudes towards physical activity, 11% of the children in both groups spoke another language than Swedish at home and 40% of the parents in both groups had university education (Ericsson, 2003; 2008a). At baseline there was a small, but significant difference in academic performance between the intervention and control group; pupils in the control group had better reading ability at school start than pupils in the intervention group according to tests conducted by the school's special education teachers (Ericsson, 2003). After nine years of intervention 31 pupils had either moved out of the region or been absent during one or more motor skills observations, and were therefore excluded from further analyses. At follow-up 220 pupils (119 boys and 101 girls) were evaluated; 71 boys (55%) and 58 girls (45%) in the intervention group and 48 boys (53%) and 43 girls (47%) in the control group.

Motor skills were evaluated through the MUGI method, a method that relates the measured skills to expected motor skills for specific age. The MUGI observation checklist has been validated and tested for reliability, which has been reported in detail in previous publications (Ericsson, 2003; 2008a). Children in school years 1, 2, and 3 were rated according to the same expected level of skills, while pupils in school year 9 were rated according to a higher level of expected skills (Ericsson, 2003; 2008a; 2008b; 2011). Children in the intervention group were rated in school year 1 before the intervention was initiated and all pupils in both groups were evaluated at the end of school years 2, 3, and 9. In a drop-out analysis of excluded pupils there were no significant differences in motor skills at study start between the pupils who were to leave the study and the pupils who participated all nine years (data not shown).

Marks in Swedish (or Swedish as second language), English and Mathematics in school year 9 were registered, as these are the subjects where the pupils need to achieve at least a Pass mark to be qualified to apply for national upper secondary school programs (National Agency for Education, 2009). Each subject could be rated at four different levels: Fail (0 points), Pass (10 points), Pass with Distinction (15 points) and Pass with Special Distinction (20 points). Marks in PEH were also registered.

Data are reported as numbers and proportions or as mean with standard deviations (SD). Logistic regression was used to evaluate whether there were changes in motor skills from school year 1 to school year 9 in the intervention and the control group, by using the population-based values in school year 1 as baseline values, and whether the changes from school year 1 to school year 9 differed between the two groups. Chi square test and Student's t-test between means evaluated group differences in school years 2, 3, and 9. The size of group differences was reported as the mean value of relative risk (RR) with 95% confidence interval (95% CI). Correlation between motor skills and school marks and the proportion of qualified pupils was tested by Spearman's rank correlation test. $P<0.05$ was regarded as a statistically significant difference and correlation.

Role of the funding source

The study sponsors had no involvement neither in study design, data collection, analyses, or interpretation of data; nor in the writing of the report or the decision to submit the paper for publication. The corresponding author had full access to all data in the study and had final responsibility for the decision to submit for publication.

Results

Motor skills improved from school year 1 to school year 9 in both groups ($p<0.001$), more in the intervention than in the control group, so that motor skills were superior in the intervention compared to the control group in school year 2 ($p<0.001$), year 3 ($p<0.001$), and year 9 ($p<0.001$) (Table 1).

The sum of marks in evaluated subjects was higher in school year 9 in boys in the intervention group than in the control group ($p<0.05$) while no such difference was found in girls (Table 2). In the control group, girls had a significantly higher sum of marks than boys ($p<0.01$), while no such gender difference was found in the intervention group (Table 2). There was a larger proportion of pupils in the intervention than in the control group (96% versus 89%, $p<0.05$) who qualified for upper secondary school, the difference being due to a group difference in the boys (96% versus 83%, $p<0.05$) (Table 2).

The sum of marks was also higher in pupils with no motor skills deficit than among pupils with motor skills deficits, 57.5 (10.8) versus 51.8 (14.9); $p<0.01$), as was the propor-

Table 1 Number of pupils (n) and proportions (%) without any motor skills deficits. Motor skills were evaluated through MUGI observations where motor skill is estimated in relation to expected skill for studied school years. Relative risk (RR) is presented as mean with 95% confidence interval within brackets and with p-value. Significant differences highlighted in bold text.

	School Year 1	School Year 2			School Year 3			School Year 9		
	Intervention Group	Intervention Group	Control Group	Relative Risk and p-value	Intervention Group	Control Group	Relative Risk and p-value	Intervention Group	Control Group	Relative Risk and p-value
Boys										
Numbers	71	71	48		71	48		71	48	
No motor skills deficit	23 (32·4%)	55 (77·5%)	25 (52·1%)	**RR 1.49 (1.10–2.01) p<0.05**	64 (90·1%)	22 (45·8%)	**RR 1.97 (1.43–2.70) p<0.001**	65 (91·5%)	21 (43·8%)	**RR 2.09 (1.51–2.91) p<0.001**
Girls										
Numbers	58	58	43		58	43		58	43	
No motor skills deficit	29 (50·0%)	52 (89·7%)	31 (72·1%)	**RR 1.24 (1.01–1.53) p<0.05**	54 (93·1%)	37 (86·0%)	RR 1.08 (0.94–1.24) ns	55 (94·8%)	27 (62·8%)	**RR 1.51 (1.19–1.92) p<0.001**

Table 2 Number (n) and proportions (%) of pupils who in school year 9 qualified for upper secondary school. Mean value with standard deviation (SD) of sum of marks in Swedish, Mathematics, English and PEH are also presented. Significant differences highlighted in bold text.

	Boys			Girls		
	Intervention group (n=71)	Control group (n=48)	Relative risk/Group difference	Intervention group (n=58)	Control group (n=43)	Relative risk/Group difference
Qualified for upper secondary school	68 (95·8%)	40 (83·3%)	**RR 1.15 (1.00–1.32) p<0.05**	56 (96·6%)	41 (95·3%)	RR 1.01 (0·93–1·10) ns
Sum of marks in investigated subjects	56·13 (11·35)	51·46 (13·60)	**Difference 4.67 (0.12–9.22) p<0.05**	56·81 (11·23)	60·70 (11·16)	Difference -3.89 (-8·36–0·58) ns

Table 3. Number (n) and proportions (%) of pupils with and without motor skills deficits who in school year 9 qualified for upper secondary school. Motor skills were evaluated through MUGI observations where motor skill is estimated in relation to expected skill for studied school years. Mean value with standard deviation (SD) of sum of marks in Swedish, Mathematics, English and PEH are also presented. Significant differences highlighted in bold text.

	Boys			Girls		
	No motor skills deficit (n=86)	Motor skills deficit (n=33)	Relative risk/ Group difference	No motor skills deficit (n=82)	Motor skills deficit (n=19)	Relative risk/ Group difference
Qualified for upper secondary school	81 (94·2%)	27 (81·8%)	**RR 1.15 (0.97–1.36) p<0.05**	82 (100%)	15 (78·9%)	**RR 1.27 (1.00–1.60) p<0.001**
Sum of marks in investigated subjects	55·76 (11·39)	50·30 (14·36)	**Difference -5.45 (-10.43– -0.48) p<0.05**	59·39 (9·89)	54·47 (15·80)	Difference -4·92 (-10·57–0·74) p=0·09

tion of pupils who qualified for upper secondary school (97% versus 81%; p<0.001) (Table 3). In addition, in school year 9 there were correlations between motor skills and the sum of marks in evaluated subjects (r=0.26, p<0.001) and the proportion of pupils who qualified for upper secondary school (r=0.27, p<0.001).

Discussion

This study suggests that daily PEH and adapted motor skills training in primary school is a feasible way to improve not only motor skills but also marks in school subjects and the proportion of pupils that qualify for higher studies. The results support studies which suggest that physical activity is associated with cognitive achievements (Frisk, 1996; Cratty, 1997; Cantell et al., 1998; Kadesjö & Gillberg, 1999; Ericsson, 2003; 2008a; Åberg et al., 2009), and increases our knowledge by inferring that there is not only an association but actually that a population-based intervention strategy with increased physical activity and motor skills training could improve school performance. The benefits of daily PEH are of biological significance, as there were deficits in motor skills in school year 9 in only 7% among pupils (average of boys and girls) with daily PEH compared to 47% of the pupils with two lessons of PEH a week. Even more importantly, school performance was improved by daily PEH so that the sum of marks in investigated subjects in boys, and in the proportion of pupils who achieved the goals of compulsory school, that is, to qualify for upper secondary school, was 8% (or 7.1 percentage points) higher among pupils with daily PEH than among pupils with PEH twice a week. The benefits obtained through daily PEH were more obvious in boys than in girls, which is of the utmost interest since boys in Sweden perform less well in school results and qualify for continued studies to a lesser extent than girls (National Agency for Education, 2009).

Since the cohort in this study is population-based, as children in both the intervention group and the control group lived in the same village, and as all pupils attended the same school during the same period where, apart from the level of PEH, they were exposed to the same school curriculum and shared the same teachers, it seems that the inferences drawn could be generalized. This is further supported by the fact that 89% of the pupils in the control group in this study qualified for upper secondary school, similar to the during the evaluated years 88.9% qualification rate reported when including all pupils in Sweden (National Agency for Education, 2009).

The finding of 49% of the pupils in school years 1–2 with some motor skills deficits also supports the representativeness of the cohort, as the proportion is similar to reported deficits in other populations (Hendersen & Sugden 1992; Gjesing, 1997; Kadesjö & Gillberg, 1999. However, daily PEH actually improved development in motor skills, as the improvement was more marked in the intervention group than in the control group (Table 1). It must also be emphasized that absolute comparison between the proportions of pupils with motor skills deficits in different school years could only be done between school years 1, 2, and 3, as the criteria for being evaluated with no deficits in these years were the same. In school year 9, the requirements for being classified with no deficit were higher than during the first three school years. In other words, a pupil in school year 9 could hypothetically perform better in the tests in absolute values than in school year 3 and in spite of this, in relative values being classified with poorer motor skills than in school year 3 (Ericsson, 2008b; 2011) a classification probably explaining the high proportion of motor skills deficits in the control group in school year 9 compared to school year 3 (Table 1).

Motor skills seems to be of clinical importance for school performance, as previous research has reported that children with deficits in motor skills at school start may have problems in academic achievements (Frisk, 1996; Cratty, 1997; Cantell et al., 1998; Kadesjö & Gillberg, 1999; Ericsson, 2003; 2008a). Therefore it seems important to identify children with impaired motor skills already at school start to intervene with the aim of improving motor skills development. The results of this study support this view, showing that an intervention program with increased physical activity and motor skills training could improve school achievements. However, it must be emphasized that the current study could not clarify the mechanism, even if the literature suggests hypotheses that try to explain this (Moser, 2000). The *sensory-motor hypothesis* focuses on the importance of the child's early motor experiences for sensory and perceptual development and for cognitive processes. Deficits in motor skills could lead to a negative effect on self-esteem. Negative self-esteem confers inferiority in skills at play, attention and other cognitive functions, which may lead to impaired school achievements (Cratty, 1997; Gjesing, 1997). The *neurophysiologic hypothesis* assumes that motor training affects the nervous system in a positive way, and studies have shown that physical activity, motor skills training, problem solving and cognitive learning increase the blood flow and the metabolism in the same region of the brain, the pre-frontal cortex (Shephard, 1997; Jensen, 1998). This fact is highlighted as an explanation of the association between increased motor skills, higher degree of arousal, improved attention and increased school achievements (Shephard, 1997). *The psychological hypothesis* focuses on an indirect relationship between motor skills and cognition. Changes in psychological functions such as motivation, communication, social competence and self-esteem, as a result of increased physical activity, are highlighted in this hypothesis as the basis for better learning skills, fewer disturbances and improved school performance (Kiphard, 1979; Stenberg & Schwanhässer, 2000). Finally, *the social cognitive theory,* formulated by Bandura (1997) focuses on the belief in an association between cognitive and social development. In this hypothesis, perceived self-efficacy is important for personal competence (Ericsson & Karlsson, 2011). Regular physical activity has been reported to promote self-esteem (Kernis et al., 1993; Steptoe & Butler, 1996) and perceived physical self-esteem (Fox, 2000; Lindwall, 2004). Through regular and repeated training, motor skills become automatized and will then confer motor skills to be regulated by lower sensory-motor systems, without requiring higher cognitive control (Bandura, 1997). This disengagement of thought from action performing has considerable functional value, as it requires less of the brain's attention and cognitive resources, which will improve the prerequisites for attention and learning according to Bandura (1997).

Strengths of this study include the population-based, controlled study design that followed children in the same village who attended the same school, had the same teachers, had the same school curriculum apart from PEH, prospectively during the same time period through all compulsory school years with the same intervention program, with few drop-outs, evaluation of a clinically relevant end point of school achievements, the proportion of pupils who qualified for higher studies. Confounders could be group differences in motivation, attitudes and leisure-time activities. However, as reported, there were no significant group differences in the parents' education, income, attitudes towards physical activity or leisure-time physical activity. An obvious weakness is the lack of separate baseline motor skills data for the intervention and the control group. However, since all children who started school in 1999 were included when evaluating motor skills in school year 1 before the intervention was initiated it must be regarded as acceptable that these data are used as baseline data in both the intervention and the control group.

In summary, this study implies that by including daily PEH in the school curriculum and one hour per week of motor skills training in pupils with specific needs, improvements could be achieved in motor skills, school results, and the proportion of pupils who qualify for upper secondary school.

Acknowledgments

This study was conducted as a part of the *Bunkeflo Project*, also called *the Pediatric Osteoporosis Prevention (POP)* study. It was funded by the Swedish Public Health Institute, Malmö University, the Swedish National Centre for Research in Sports, and the Swedish Physical Education Teacher Federation. Valuable support was given by the teachers, parents and their children who participated in the study. More information about the research can be found on www.mugi.se and on www.bunkeflomodellen.com.

References

Andersen LB, Harro M, Sardinha LB, et al. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006;**368**:299–304.

Bandura A. Self-efficacy. The exercise of control. New York: W.H. Freeman and Company 1997.

Booth ML, Okely AD, Chey T, et.al. Epidemiology of physical activity participation among New South Wales school students. *Aust N Z J Public Health* 2002;**4**:26.

Brown L, Walkley J, Holland B, editors. Relationships between Physical Activity and Fundamental Motor Skill Proficiency in Victorian Children. ACHPER National Conference Proceedings. Wollongong: University of Wollongong 2004.

Cantell M. Developmental coordination disorder in adolescence: perceptual-motor, academic and social outcomes of early motor delay [dissertation]. University of Lancaster, England, Jyväskylä, Finland: Foundation for Sport and Health Sciences 1998.

Cratty B. Coordination Problems Among Learning Disabled, In: Cratty B, Goldman R, eds. Learning Disabilities, Contemporary Viewpoints. Amsterdam: Harwood Academic Publishers 1997:143–83.

Dencker M. Daily Physical Activity, Body Fat and Aerobic Fitness in Children [dissertation]. Lund: Dept of Clinical Sciences, Malmö, Faculty of Medicine 2007.

Ekman R, Dolan T. Kunskap om hjärnan kan ge bättre skola [Knowledge about the brain can lead to a better school]. *Sydsvenska Dagbladet* 2010; **Oct 21**:A5.

Ericsson I. Motorik, koncentrationsförmåga och skolprestationer – En interventionsstudie i skolår 1–3 [Motor skills, attention and academic achievements – An intervention study in school year 1–3] [dissertation]. Malmö: School of Teacher Education, Malmö University, Lund University 2003.

Ericsson I. Motor skills, attention and academic achievements - an intervention study in school year 1–3. *Br Educ Res J* 2008;**34**:301–13.

Ericsson I. To measure and improve motor skills in practice. *Int J Pediatr Obes* 2008;**3**:21–7.

Ericsson I. Effects of increased physical activity on motor skills and marks in physical education: an intervention study in school years 1 through 9 in Sweden. *Physical Education Sport Pedagogy 2011;***16**: 313–29.

Ericsson I, Cederberg M. School Marks and Physical Activity: A Survey among Pupils not qualified for Upper Secondary School. Submitted 2010.

Ericsson I, Karlsson M. Effects of Increased Physical activity and Motor training on Motor Skills and Self-esteem: An Intervention Study in School years 1 through 9. Accepted for publication in *Int J Sport Psychol,* 2011; in press.

Fox KR. Self-esteem, self-perceptions and exercise, *Int J Sport Psychol* 2000;**31**:228–40.

Frisk M. Läs- och skrivsvårigheter samt dyslexi. In: Ericson B, ed. Utredning av läs- och skrivsvårigheter [Analysis of difficulties in reading and writing]. Lund: Studentlitteratur 1996:37–61.

Gjesing G. Kropumulige Unger [Clumsy Children]. Copenhagen: DHLs förlag 1997.

Hammar M, Toss G. Fysisk aktivitet bland barn. I: Idrottsämnets betydelse i grundskolan [Physical activity in children. In: The significance of physical education in compulsory school]. Stockholm: Riksidrottsförbundet 1994:3–4.

Henderson S, Sugden D. Movement ABC (Assessment Battery for Children). London: The Psychological Coop Ltd 1992.

Jensen E. Teaching with the brain in mind. Alexandria, VA: Association for Supervision and Curriculum Development 1998.

Kadesjö B, Gillberg C. Developmental co-ordination disorder in Swedish 7-year-old children. *J Am Acad Child Adolesc Psychiatry* 1999;**38**:820–28.

Kernis MH, Cornell DP, Sun CR, et al. There's more to self-esteem than whether it is high or low: the importance of stability of self-esteem. *J Pers Soc Psychol* 1993;**65**:1190–204.

Kiphard E. Psychomotorik als Prävention und Rehabilitation. Gutersloh: Flöttmann 1979.

Linden C, Alwis G, Ahlborg Het al. Exercise, bone mass and bone size in prepubertal boys: one-year data from the pediatric osteoporosis prevention study. *Scand J Med Sci Sports* 2007;**17**:340–7.

Lindwall M. Exercising the self: On the role of exercise, gender and culture in physical self-perceptions [dissertation]. Stockholm: Department of Psychology, Stockholm University 2004.

Lundvall S, Meckbach J. Lärandets form och innehåll– lärares och elevers uppfattning om lärande och kompetens inom ämnet idrott och hälsa [Teachers' and pupils' views on learning and competence in the subject physical education and health], SIH 2001 till SIH 2007. *Svensk Idrottsforskning* 2008;**4:**17–22.

Moser T. Skaper fysisk aktivitet kloke og selvsikre menne-sker? *Sport & Psyke* 2000;**Aug**:14–22.

National Agency for Education. Betyg och provresultat i grundskolan [Marks and test results in Compulsory school] [Internet]. Stockholm: National Agency for Education. http://siris.skolverket.se/portal/page?_pageid=33,90009&_dad=portal&_schema=PORTAL (accessed 5 May 2009).

Redelius K. Bäst eller pest. In: Larsson H, Redelius K, editors. Mellan nytta och nöje: Bilder av ämnet idrott och hälsa [Pictures of the school subject physical education and health]. Stockholm: Idrottshögskolan i Stockholm 2004:149–72.

Shephard R. Curricular physical activity and academic performance. *Pediatr Exercise Sci* 1997;**9**:113–26.

Stenberg D, Schwanhäusser B. Psykomotorik i skolan, förskolan och på fritidshem. Växjö: Institutionen för pedagogik, Växjö University 2000.

Steptoe A, Butler N. Sports participation and emotional wellbeing in adolescents. *Lancet* 1996;**347**:1789–92.

Thedin Jakobsson B, Engström L-M. Vilka fortsätter - vilka slutar? – förändringar i idrottsvanor bland yngre tonåringar [Changes in adolescents' sports habits]. *Svensk Idrottsforskning* 2008;**14**:27–31.

Valdimarsson Ö, Linden C, Johnell O, et al. Daily physical education in the school curriculum in prepubertal girls during 1 year is followed by an increase in bone mineral accrual and bone width-data from the prospective controlled Malmo pediatric osteoporosis prevention study. *Calcif Tissue Int* 2006;**78**:65–71.

Westerståhl M, Barnekow-Bergkvist M, Hedberg G, et al. Secular trends in sports: participation and attitudes among adolescents in Sweden from 1974 to 1995. *Acta Paediatrica* 2003;**92**:602–9.

Åberg M, Pedersen N, Torén K et al. Cardiovascular fitness is associated with cognition in young adulthood. *Proc Natl Acad Sci U S A* 2009;**106**:20906–11.