Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study)

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Background **Atherosclerosis develops from early childhood; physical activity could positively affect this process. This study's aim was to assess the associations of objectively measured physical activity with clustering of cardiovascular disease risk factors in children and derive guidelines on the basis of this analysis.**

Methods **We did a cross-sectional study of 1732 randomly selected 9-year-old and 15-year-old school children from Denmark, Estonia, and Portugal. Risk factors included in the composite risk factor score (mean of *Z* scores) were systolic blood pressure, triglyceride, total cholesterol/HDL ratio, insulin resistance, sum of four skinfolds, and aerobic fitness. Individuals with a risk score above 1 SD of the composite variable were defined as being at risk. Physical activity was assessed by accelerometry.**

Findings **Odds ratios for having clustered risk for ascending quintiles of physical activity (counts per min; cpm) were 3·29 (95% CI 1·96–5·52), 3·13 (1·87–5·25), 2·51 (1·47–4·26), and 2·03 (1·18–3·50), respectively, compared with the most active quintile. The first to the third quintile of physical activity had a raised risk in all analyses. The mean time spent above 2000 cpm in the fourth quintile was 116 min per day in 9-year-old and 88 min per day in 15-year-old children.**

Interpretation **Physical activity levels should be higher than the current international guidelines of at least 1 h per day of physical activity of at least moderate intensity to prevent clustering of cardiovascular disease risk factors.**

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Introduction

Physical activity guidelines for young people were first formulated in 1988 by the American College of Sports Medicine, which produced an opinion statement on the amount of physical activity needed for optimum functional capacity and health.[1] The American College of Sports Medicine based their proposals on guidelines for adults and recommended that children and adolescents should achieve 20–30 min of vigorous exercise every day. In 1993, an international consensus conference on physical activity guidelines for adolescents was convened to develop empirically based guidelines.[2]

In 1998, the Health Education Authority in the UK commissioned a series of reviews of scientific paediatric publications that updated those of the international consensus conference and, after a similar consensus conference, proposed a different set of recommendations for the physical activity of young people.[3] Their primary recommendation was that all young people should participate in physical activity of at least moderate intensity for 1 h per day and that young people who did little activity should participate in physical activity of at least moderate intensity for at least 0·5 h per day. Their secondary recommendation was that, if done at least twice a week, some of these activities should help to enhance and maintain muscular strength, flexibility, and bone health.[3] Recently, Strong and co-workers did a systematic review of the evidence base for health and physical activity in school-age children.[4] The conclusion of the review was close to the existing guidelines.

However, the evidence base for these guidelines is not strong enough to preclude the possibility that they could be biased. There is little evidence for a particular dose-response relation from which physical activity guidelines for children and adolescents can be obtained.[5]

There have been two major problems in the analysis of the association between physical activity and health in children. First, previous studies have relied on subjective measures of physical activity, since obtaining accurate measures of habitual physical activity is difficult, especially in children. Second, health outcomes are not well defined in children. Many studies have analysed the associations between physical activity and single cardiovascular disease risk factors, and these associations are often very weak. Clustering of cardiovascular disease risk factors has recently proved a better measure of cardiovascular health in children than single risk factors.[6]

Our aims were to examine different measures of accelerometry-assessed physical activity with clustering of cardiovascular disease risk factors and to examine whether a dose-response relation exists from which guidelines for young people can be obtained.

Methods

Setting

Data from the European Youth Heart Study were used.[7] This investigation is a multicentre international study addressing the prevalence and cause of cardiovascular disease risk factors in children aged 9 and 15 years. Data from Estonia, Denmark, and Portugal were used.[7] Study protocols were much the same in all countries and conformed to the international guidelines on biomedical research, and all research teams complied with the ethical procedures of that country. Written informed consent was obtained from the child's parent or legal guardian after they were given a detailed written explanation of the aims of the study, its possible hazards, discomfort, and inconvenience, and the option to withdraw at any time.

Participants

Boys and girls aged 9 and 15 years old—ie, children on either side of puberty—were randomly selected. At every study location, a defined population of children was identified and from this population a two-stage cluster sample of children randomly selected. The primary sampling units were schools, and secondary units were the children on the school registers. The overall participation rate was 76% in Estonia, 73% in Portugal, and 75% in Denmark. In total, 1725 girls and 1592 boys participated. There were no exclusion criteria, but only individuals with complete data on all risk factors were included.

Measurements

Blood pressure was measured with a Dinamap paediatric and adult neonatal vital signs monitor (model XL, Critikron, Inc, Tampa, FL, USA). Five measurements were taken at 2-min intervals with the mean of the final three measurements used in all analyses. Waist circumference was measured at the end of gentle expiration, midway between the lower rib margin and the iliac crest. Weight was measured in light clothing to the nearest 0·1 kg with a calibrated beam balance scale. Height was measured without shoes to the nearest 0·5 cm with a transportable Harpenden stadiometer. Pubertal status was assessed by trained personnel with Tanner's classification.[8] Skinfold thicknesses were measured with a Harpenden caliper at the biceps, triceps, subcapsular, and suprailiac sites.

Blood samples were obtained after an overnight fast and stored at –80°C before analysis. All samples were analysed at clinical pathology accredited laboratories (Bristol and Cambridge, UK).[9] Insulin resistance was estimated according to the homoeostasis model assessment (HOMA) as the product of fasting glucose (mmol/L) and insulin (μU/mL) divided by the constant 22·5.[10]

Physical activity was assessed with an accelerometer (Actigraph model 7164, Manufacturing Technology Inc, Fort Walton Beach, FL, USA). This accelerometer measures the vertical acceleration of body movement and the validity and reliability of the instrument has been tested.[11,12] Physical activity was monitored for 4 consecutive days: 2 weekdays and 2 weekend days. Instruments were attached tightly at the hip. Minute-by-minute data were stored as counts in memory and subsequently downloaded to a computer. Data were reduced to derivative variables with customised macros. Derived variables were mean counts per min (cpm), and number of minutes in bouts above 2000 cpm (equivalent to walking about 4 km/h) of at least 5 min or at least 10 min, respectively. Two sets of data were constructed for bouts, and in the second set we allowed one observation to be below the intensity cutoff point, as has been recommended.[13] Total counts in the bouts and the number of bouts were also calculated.

Time periods of at least 10 consecutive minutes of zero counts were deemed to represent periods when the monitor was not worn and were thus disregarded before analysis. Criteria for a successful recording were a minimum of 3 days of 10 h recording per day. Days with more than 10 h of recordings, but periods for which the accelerometer was not worn, were adjusted to a full day of 14 h (estimated awake time for this population). The average time the accelerometer was worn was 13·6 h per day, and the number of minutes in the different intensity intervals was proportionally adjusted to 14 h with the following equation: adjusted minutes=(observed in interval)×(14×60/total minutes).

Aerobic fitness (VO_{2max}) was assessed as the maximum power output in a cycle test with progressively increasing workload on an electronically braked cycle ergometer (Monark 839 Ergomedic, Varberg, Sweden).[7] Criteria defined for a maximal effort were heart rate of 185 beats per minute or more and a subjective judgment by the observer that the participant could no longer continue, even after encouragement. Aerobic fitness was expressed as maximum power output relative to bodyweight (watts/kg).

Statistical analysis

All analyses were done with SPSS version 13.0. Mean and SD for components of the metabolic syndrome were calculated by country, sex, and age group of the children with complete measurements. Insulin, glucose, HOMA score, and triglyceride concentrations were positively skewed and were thus transformed (natural log). *Z* scores by age, sex, and country were computed for all risk factor variables. In the logistic regression, *Z* scores of the individual risk factors were summed to construct a clustered risk score, and individuals with more than 1 SD in this score were defined as being at risk. *Z* scores were also constructed by age group and sex only to enable comparison of the risk factor profile between countries. Risk factors included in the risk profile were systolic blood pressure, triglyceride, ratio of total cholesterol to HDL, HOMA score, sum of four skinfolds, and aerobic fitness. Sum of four skinfolds was used instead of body-mass index (BMI) because physical fitness is included in our outcome variable, and fitness is expressed relative to bodyweight. Thus the use of sum of four skinfolds avoided counting bodyweight twice.

A preliminary analysis was done by comparison of the recorded number of children with zero to six risk factors (defined as the least favourable quartile) with an expected number calculated from an independent distribution of the risk factors according to the binominal formula.[14] This preliminary analysis was done to define how many children had clustering of risk factors and biological inform a cutoff point for at risk in the continuous *Z* score variable. The expected proportions from a binomial distribution for

	Girls				Boys			
	Denmark	Portugal	Estonia	Difference (p value)	Denmark	Portugal	Estonia	Difference (p value)
9-year-old children								
Number	206	154	172		180	171	168	
Age (years)	9·6 (0·4)	9·8 (0·3)	9·4 (0·5)	P>DK>E (0·0001)	9·7 (0·4)	9·7 (0·3)	9·6 (0·5)	NS (0·0922)
Height (cm)	138·4 (6·6)	137·8 (6·7)	136·6 (7·0)	DK>E (0·0340)	139·7 (6·2)	137·1 (6·0)	137·6 (6·5)	DK>E,P (0·0001)
Weight (kg)	33·2 (6·4)	35·0 (8·5)	30·8 (6·5)	P>DK>E (0·0001)	33·9 (6·3)	34·2 (8·1)	32·0 (5·5)	P,DK>E (0·0058)
BMI (kg/m²)	17·2 (2·5)	18·3 (3·3)	16·4 (2·3)	P>DK>E (0·0001)	17·3 (2·4)	18·0 (3·2)	16·8 (1·9)	P>E,DK (0·0001)
Sum of four skinfold (mm)	39·4 (18·5)	46·6 (20·6)	30·1 (13·6)	P>DK>E (0·0001)	33·6 (16·9)	36·1 (20·5)	24·8 (10·1)	P,DK>E (0·0001)
Diastolic blood pressure (mm Hg)	62·6 (5·6)	55·9 (6·0)	60·0 (6·6)	DK>E>P (0·0001)	63·3 (5·8)	55·3 (7·0)	59·3 (7·5)	DK>E>P (0·0001)
Systolic blood pressure (mm Hg)	104·6 (7·8)	96·7 (8·6)	101·2 (9·0)	DK>E>P (0·0001)	106·0 (7·3)	96·6 (9·4)	102·4 (9·9)	DK>E>P (0·0001)
Fitness (watts/kg)	2·86 (0·50)	2·03 (0·46)	2·77 (0·56)	DK,E>P (0·0001)	3·23 (0·55)	2·56 (0·60)	3·20 (0·48)	DK,E>P (0·0001)
Glucose (mmol/L)	5·08 (0·38)	5·20 (0·37)	4·93 (0·42)	P>DK>E (0·0001)	5·17 (0·36)	5·22 (0·33)	5·12 (0·38)	P>E (0·0486)
Insulin (μU/mL)	8·65 (4·27)	8·66 (4·86)	6·60 (3·51)	P,DK>E (0·0001)	7·33 (4·13)	6·22 (3·36)	6·03 (3·05)	DK>P,E (0·0018)
Cholesterol (mmol/L)	4·55 (0·69)	4·22 (0·80)	4·55 (0·84)	DK,E>P (0·0001)	4·52 (0·71)	4·13 (0·70)	4·33 (1·46)	DK>E>P (0·0001)
HDL (mmol/L)	1·45 (0·25)	1·51 (0·31)	1·44 (0·28)	NS (0·0890)	1·54 (0·31)	1·55 (0·30)	1·49 (0·31)	NS (0·1270)
Triglyceride (mmol/L)	0·90 (0·35)	0·66 (0·31)	0·79 (0·28)	DK>E>P (0·0001)	0·79 (0·31)	0·59 (0·25)	0·69 (0·31)	DK>E>P (0·0001)
Insulin resistance (HOMA score)	1·98 (1·04)	2·03 (1·20)	1·47 (0·83)	P,DK>E (0·0001)	1·71 (1·03)	1·46 (0·83)	1·39 (0·72)	DK>P,E (0·0027)
Physical activity (cpm)	590 (211)	601 (169)	656 (202)	E>P,DK (0·0001)	721 (272)	731 (237)	789 (258)	E>DK (0·0001)
Sum of *Z* scores	0·89 (3·35)	0·48 (3·74)	–0·84 (3·58)	DK,P>E (0·0001)	0·19 (3·22)	–0·91 (3·91)	–1·33 (3·17)	DK>P,E (0·0005)
15-year-old children								
Number	111	82	190		91	82	125	
Age (years)	15·5 (0·5)	15·5 (1·0)	15·4 (0·5)	NS (0·0986)	15·5 (0·4)	15·6 (0·7)	15·5 (0·5)	NS (0·6070)
Height (cm)	165·3 (6·3)	158·4 (6·7)	165·0 (5·7)	DK,E>P (0·0001)	174·9 (6·7)	168·4 (8·1)	175·0 (7·6)	DK,E>P (0·0001)
Weight (kg)	56·5 (8·8)	54·9 (8·1)	55·4 (8·3)	NS (0·4129)	63·9 (9·6)	59·0 (11·0)	63·1 (10·8)	E,DK>P (0·0047)
BMI (kg/m²)	20·6 (2·7)	21·8 (2·9)	20·3 (2·5)	P>DK,E (0·0001)	20·8 (2·5)	20·7 (3·0)	20·5 (2·9)	NS (0·7445)
Sum of four skinfold (mm)	50·8 (19·1)	52·3 (15·2)	43·6 (15·0)	P,DK>E (0·0001)	37·0 (17·3)	32·3 (14·9)	28·9 (12·9)	DK>E (0·0005)
Diastolic blood pressure (mm Hg)	64·9 (5·9)	58·5 (5·9)	63·8 (6·4)	DK,E>P (0·0001)	63·6 (6·3)	57·9 (6·7)	61·9 (7·1)	E,DK>P (0·0001)
Systolic blood pressure (mm Hg)	109·5 (9·0)	101·0 (5·4)	107·3 (9·0)	DK,E>P (0·0001)	118·6 (10·1)	106·9 (10·5)	115·1 (13·3)	E,DK>P (0·0001)
Fitness (watts/kg)	3·03 (0·48)	2·15 (0·37)	2.61 (0.41)	DK>E>P (0·0001)	3·76 (0·64)	3·31 (0·55)	3·50 (0·56)	DK>E,P (0·0001)
Glucose (mmol/L)	5·16 (0·43)	5·15 (0·42)	5·04 (0·39)	NS (0·0311)	5·30 (0·42)	5·34 (0·52)	5·20 (0·37)	P>E (0·0411)
Insulin (μU/mL)	13·57 (4·95)	9·94 (4·02)	12·01 (5·30)	DK>E>P (0·0001)	13·11 (6·87)	8·46 (4·36)	10·46 (4·69)	DK>E>P (0·0001)
Cholesterol (mmol/L)	4·36 (0·75)	4·00 (0·69)	4·37 (0·71)	DK,E>P (0·0003)	4·05 (0·67)	3·69 (0·72)	3·97 (0·69)	E,DK>P (0·0021)
HDL (mmol/L)	1·40 (0·27)	1·44 (0·29)	1·43 (0·28)	NS (0·6282)	1·33 (0·28)	1·31 (0·26)	1·27 (0·26)	NS (0·2481)
Triglyceride (mmol/L)	1·09 (0·39)	0·65 (0·24)	0·84 (0·35)	DK>E>P (0·0001)	1·02 (0·59)	0·70 (0·35)	0.81 (0.76)	DK>E,P (0·0024)
Insulin resistance (HOMA score)	3·13 (1·26)	2·29 (0·97)	2·72 (1·30)	DK>E>P (0·0001)	3·13 (1·75)	1·98 (0·91)	2.43 (1·11)	E>DK>P (0·0001)
Physical activity (cpm)	412 (132)	469 (118)	498 (177)	E,P>DK (0·0001)	477 (162)	616 (176)	659 (247)	E,P>DK (0·0001)
Sum of *Z* scores	1·48 (2·25)	–0·37 (3·26)	0·56 (3·27)	DK>E,P (0·0006)	1·23 (3·61)	–0·89 (3·03)	0·04 (2·93)	DK>E,P (0·0002)

BMI=body mass index. DK=Denmark. E=Estonia. NS=not significant. P=Portugal. All data expressed as mean (SD).

Table 1: **Components of the metabolic syndrome and anthropometric measures by country and sex in 9-year-old and 15-year-old children**

increasing number of risk factors were 0·178, 0·356, 0·297, 0·132, 0·057, 0·0044, and 0·0002, respectively. Observed percentages of children with zero to six risk factors were: 28·0%, 28·9%, 21·4%, 11·1%, 3·3%, 3·4%, and 1·3%. Therefore, we examined the following proportions compared with expected numbers (observed/expected): 1·57, 0·81, 0·72, 0·84, 1·79, 7·70, and 55·4 for zero to six risk factors, respectively. An excess number of children was identified with four, five, and six risk factors, and 10·6% of the population (n=235) was noted to have at least four risk factors. We defined 1 SD above the mean in summed *Z* score to be at risk, which is a little more (16%) than in the calculation above. This decision is conservative, because a more extreme cutoff point will increase odds ratios between groups, but also increase confidence intervals.

Role of the funding source

The study sponsors had no role in the study design, the collection, analysis, or interpretation of the data, the writing of the report, or the decision to submit the paper for publication. The corresponding author had full access to all the data in the study and had final responsibility to submit for publication.

	Adjusted physical activity (mean cpm)	p value
BMI	−0·03	0·1564
Sum of four skinfold	−0·08	0·0001
Waist circumference	−0·05	0·0230
Diastolic blood pressure	−0·09	0·0001
Systolic blood pressure	−0·10	0·0001
Fitness	0·14	0·0001
Glucose	−0·12	0·0001
Insulin	−0·13	0·0001
Cholesterol	−0·09	0·0001
HDL	0·01	0·7276
Triglyceride	−0·10	0·0001
Insulin resistance	−0·17	0·0001
Sum of *Z* scores	−0·18	0·0001

***Table 2:* Correlation between physical activity (mean cpm) and cardiovascular disease risk factors after adjustment for age and sex**

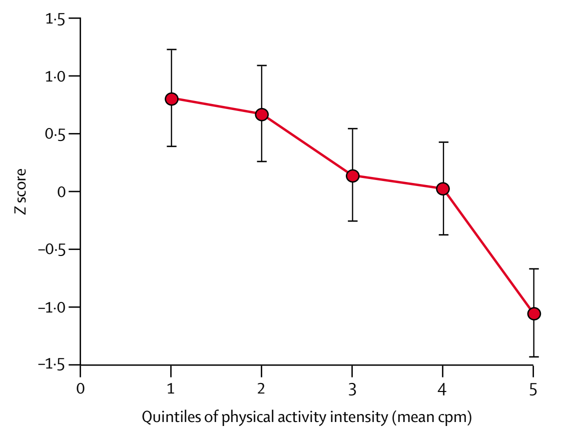

***Figure 1:* Mean *Z* score in every quintile of average physical activity intensity**
Vertical bars=95% CI.

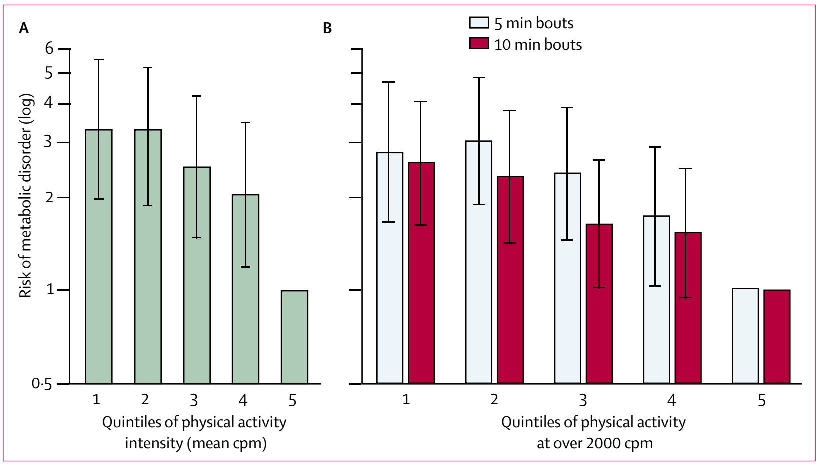

***Figure 2:* Odds ratios for clustered risk by quintiles of average physical activity intensity**
(A) Odds ratios for clustered risk by quintiles of average physical activity intensity. (B) Odds ratios for clustered risk by quintiles of physical activity with intensities above 2000 cpm in bouts of at least 5 min and 10 min in duration. Vertical bars=95% CI.

Results

Of the 1725 girls and 1592 boys who initially participated, only 1156 girls and 1045 boys had valid activity variables because of the criteria for valid accelerometer measurements. Of these children, 915 girls and 817 boys had complete data on risk factors, and these individuals form the basis of the present investigation. No difference was seen between individuals with complete data and those who were excluded with respect to age, height, weight, BMI, HDL cholesterol, sum of four skinfold, and waist circumference. Differences between groups with complete and incomplete data were seen in fitness (SD 0·17, $p<0·0001$), systolic blood pressure (–0·06, $p<0·0001$), glucose (–0·07, $p=0·0355$), total cholesterol (–0·11, $p=0·0011$), triglyceride (–0·10, $p=0·0039$), insulin (–0·20, $p<0·0001$), and HOMA score (–0·19, $p<0·0001$); all SD values are participants compared with excluded individuals.

Table 1 shows the distributions of components of the metabolic syndrome and additional anthropometric measurements by sex and age group of the included children in every country. In general, there was a pattern of higher risk in Denmark than in Portugal, and Estonia had the lowest risk in the 9 year olds. In adolescents, Denmark also had the most adverse risk profile and Portugal had the lowest risk. There was a slight attenuation of the country differences in components of cardiovascular risk after adjustment for anthropometric measures but differences remained significant even after adjustment for BMI, waist-to-hip ratio, and height.

The associations between single cardiovascular disease risk factors, sum of *Z* scores, and physical activity were calculated with adjustment for sex and age (table 2). Further adjustment for country changed associations only slightly. Significant but weak associations were observed, with all *r* values being below 0·2. The strongest association with physical activity was with HOMA score. Further, the linear association between the sum of *Z* scores (continuous variable) and several physical activity variables derived from the accelerometer data were assessed. These variables included mean cpm and variables for bouts of activity. Bouts of different duration were constructed (≥5 and ≥10 min) at an intensity of over 2000 cpm. The degree of association between physical activity and risk factor score (sum of *Z* scores by sex, age group, and country) was closely similar for all physical activity variables (data not shown). Figure 1 shows the mean *Z* score (continuous variable) for quintiles of physical activity. A graded decrease was noted in metabolic risk across quintiles of general physical activity level.

Figure 2 shows the risk of having clustered risk factors (dichotomous *Z* score above 1 SD) for mean cpm and the number of counts in bouts of at least 5 min and at least 10 min of duration, respectively. The odds ratio for having clustered risk (dichotomous variable) was analysed by logistic regression in quintiles of these variables. Risk decreased with increased activity, and a graded relation was noted for all physical activity variables. Odds ratios for ascending quintiles of physical activity compared with the most active quintile were 3·29 (95% CI 1·96–5·52), 3·13 (95% CI 1·87–5.25), 2·51 (95% CI 1·47–4·26), and 2·03 (95% CI 1·18–3·50), respectively. Odds ratios for quintiles of physical activity did not change when normal weight and overweight children were analysed separately. Compared with the most active quintile, risk was raised in the third quintile in all analyses. The strongest association was with mean cpm. The least active quintile had an odds ratio of clustered risk around 3 compared with the most active quintile. Table 3 shows the number of minutes of physical activity above 2000 cpm by quintiles of physical activity, and the average intensity (in cpm) during these minutes.

	Time >2000 cpm (min per day, SD)	Mean intensity of the minutes spent >2000 cpm (cpm, SD)
9-year-old children		
Least active quintile	38 (20)	2869 (1286)
Second quintile	69 (20)	3487 (786)
Third quintile	92 (26)	3649 (746)
Fourth quintile	116 (32)	3728 (651)
Most active quintile	167 (49)	4125 (1117)
15-year old children		
Least active quintile	34 (15)	3253 (1080)
Second quintile	53 (24)	3684 (850)
Third quintile	70 (24)	3744 (754)
Fourth quintile	88 (32)	3941 (956)
Most active quintile	131 (47)	4119 (820)

***Table 3:* Time per day spent at physical activity intensities above 2000 cpm in the five quintiles of physical activity, and the mean intensity**

Discussion

The main findings of this study were a graded negative association between clustering of risk factors and physical activity. Risk was raised in the first to third quintile of physical activity compared with the most active quintile. Time spent at moderate and vigorous intensity activity (ie, above 2000 cpm, corresponding to a walking speed of around 4 km/h[15,16]) in the fourth quintile was 116 min in 9 year olds and 88 min in 15 year olds, respectively. Thus, the current guidelines of at least 1 h per day of physical activity of at least moderate intensity could be an underestimation of the activity necessary to prevent clustering of risk factors in younger children.

The main strengths of this study were the availability of measures of insulin resistance and other cardiovascular risk factors in a large population of children, together with details of objectively measured physical activity. Present guidelines, by contrast, are based on studies in which the associations between self-reported physical activity and single risk factors have been assessed, or the health effects of specific types of training have been analysed.[4] Although training studies are important, they assess the effects of specific types of training in addition to the daily physical activity level. Despite more children participating in leisure-time sports, the epidemics of metabolic disorders and obesity continue to occur, and the total habitual physical activity, including commuting and random play, could therefore be important. Further, present guidelines emphasise the importance of moderate intensity physical activity that could mainly be achieved through everyday living; this type of less conscious physical activity is likely to be underestimated by self-report.

The present study has some limitations. We are aware of the limitations of a cross-sectional study, but we doubt that a randomised controlled trial in children could be done to qualify the present physical activity recommendations. Such a trial would create ethical problems and quantification of habitual activity, and not just a specific type of training, would be very difficult.

We used a composite score of the risk factors related to the metabolic syndrome, and the guidelines derived from our analyses are only related to metabolic health and not bone health, psychological wellbeing, or other dimensions of health. Single risk factors relate weakly to physical activity, and one reason for this is variation caused by day-to-day fluctuations in both risk factors and physical activity. A composite score could, to some extent, compensate for fluctuations in the single risk factors. We chose to use logistic regression to predict poor health, which allowed us to detect non-linear relations. Even if none of the participants had clinical disease, clustered risk is certainly an undesirable condition, and has been shown to track into young adulthood.[17] Cutoff points in single risk factors for having metabolic syndrome are not established in children, but suggestions have been made.[18–20] We showed that risk factors clustered in 11% of the population and included individuals with a score above 1 SD (around 16%). Thus, we could have classified individuals who are not at risk as being at risk, but such misclassification would only result in an underestimation of the true association between physical activity and clustered risk.

Determination of those individuals in whom risk is increased might be possible. Significantly higher risk was recorded in the third quintile compared with the most active in all analyses. Whether the recommendation should be that all children ought to be as physically active as children in this quintile is a subjective judgment but the present data show consistently raised risk in the three lowest quintiles.

One limitation of the measure of physical activity used is the inability to capture cycling, swimming, and load-bearing activity. Assessment of physical activity for only 4 days might not indicate a person's true activity level, but the error introduced is random, and it could weaken associations between exposure and outcome, but it will not create bias. Further, the recording of data at 1-min intervals could underestimate the amount of high intensity activity if such activity occurred in shorter intervals. Thus, the time spent above 2000 cpm could be underestimated.

Future validation studies that include habitual physical activity might be able to more accurately convert the accelerometer cutoff points used here into physiological intensity. Validation studies have shown that walking at 4 km/h on a treadmill or on ground corresponds to about 2000 cpm.[15,21–23] Although this walking speed is probably at the low end of moderate intensity, we note that the average intensity during the time spent above 2000 cpm was close to 4000 cpm in the fourth quintile of physical activity.

In conclusion, physical activity is important for metabolic health in children. To prevent clustering of cardiovascular disease risk factors, physical activity levels should be higher than the current international guidelines of at least 1 h per day of physical activity of at least moderate intensity.[3,4] Achieving 90 min of daily activity might be necessary for children to prevent insulin resistance, which seems to be the central feature for clustering of cardiovascular disease risk factors.

Contributors

L B Andersen, S A Anderssen, M Harro, L B Sardinha, and K Froberg were responsible for the study concept and design, and also for the acquisition of the data. L B Andersen, S A Anderssen, S Brage, and U Ekelund were responsible for the analysis and interpretation of data. L B Andersen and S A Anderssen drafted the manuscript. All authors took part in critical revision of the manuscript. Statistical expertise was provided by L B Andersen, S A Anderssen, and S Brage. Funding was obtained by L B Andersen, M Harro, L B Sardinha, S A Anderssen, and K Froberg.

Conflict of interest statement

We declare that we have no conflict of interest.

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