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Secular trends in physical fitness and obesity in Danish 9-year-old girls and boys: Odense School Child Study and Danish substudy of the European Youth Heart Study

N. Wedderkopp[1], K. Froberg[1], H. S. Hansen[2], L. B. Andersen[3]

[1]Institute of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense University, [2]Department of Cardiology, Odense University Hospital, [3]Institute for Exercise and Sport Sciences, University of Copenhagen, Odense NV, Denmark
Corresponding author: Niels Wedderkopp, Østrupvej 18, 5210 Odense NV, Denmark. Tel: 65-9108016, E-mail: nwedderkopp@health.sdu.dk

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Introduction: **Low physical fitness and obesity have been shown to be associated with cardiovascular disease (CVD) risk. Obesity is on the increase in many countries, but little is known about physical fitness trends. Monitoring of changes in fitness and obesity in the population is important for preventive strategies, and the aim of this study was to analyse the secular trends in fitness and body composition in Danish children.** ***Materials and methods:*** **Two representative population studies were conducted 12 years apart on 9-year-old children in the same location: the Odense School Child Study in 1985–86 and the European Youth Heart Study in 1997–98. In both studies, physical fitness was determined by a maximal cycle ergometer test, and obesity was assessed by skinfolds.** ***Results:*** **Boys had a lower physical fitness and were fatter in 1997–98 than in 1985–86. In addition, an increased polarization is emerging, with the difference between the fit and the unfit and the difference between the lean and the fat being greater in 1997–98 than in 1985–86. In girls, a similar polarization was found, but no overall change in fitness or obesity.** ***Conclusion:*** **The negative trend and increased polarization for physical fitness and obesity in Danish children suggest a future generation with a higher degree of CVD risk.**

Risk factors for cardiovascular disease (CVD) are manifest already in childhood, with studies in the USA (Berenson et al., 1980), England (Armstrong et al., 1991) and Northern Ireland (Boreham et al., 1993) indicating that approximately 70% of 12-year-old children have at least one modifiable CVD risk factor.

In epidemiologic studies, low levels of physical fitness and obesity have been associated with a higher prevalence of CVD risk factors and a higher CVD mortality (Blair et al., 1996; Nielsen & Andersen, 2003). In addition, we have earlier shown that physical fitness is associated with CVD risk factors and risk factor clustering in children (Wedderkopp, 2000). Fitness, obesity and other CVD risk factors track from childhood into adulthood (Andersen & Haraldsdottir, 1993). There is therefore a rationale for monitoring trends in these traits in the young population in order to create early preventive strategies against CVD.

Secular trends towards an increase in obesity have been shown in many countries, but the knowledge is mainly based on measurements of height and weight (Kikuchi et al., 1992). Little is known about secular trends in fitness, and no other studies using maximal testing have reported changes in a population in fitness. The aim of the study was to analyse the secular trends in fitness and obesity in children.

Materials and methods

Secular trends were analysed through two cross-sectional studies performed 12 years apart on representative samples of 9-year-old children from the Danish city of Odense: the Odense School Child Study 1986 (Hansen et al., 1990) and the European Youth Heart Study 1997–98 (Wedderkopp, 2000). Odense is the third largest city of Denmark. The total population of third grade children in Odense were invited to participate in the first study, of which 1369 children (85%) (670 girls and 699 boys) participated in the study in 1985–86. In 1997–98, 693 children were randomly selected from the population of Odense and invited to participate, of which 589 children (85%) (310 girls and 279 boys) participated in the study.

Measurements

Body height to the nearest millimetre and body mass to the nearest 100 g were determined by standard anthropometric methods (Council of Europe, 1988) using a stadiometer and a beam-scale weight. Body height was measured with shoes on in the first study, and without in the second study.

Fat percentage was assessed by using the triceps and the subscapular skinfolds as described by Slaughter et al. (1988). Skinfolds were measured with Harpenden callipers over the m. triceps brachii, m. biceps brachii, subscapularly. The jaws of the callipers were placed around the skinfolds 1 cm below where it was held by the thumb and first finger. The observer waited for 2–3 s before taking the reading and kept hold of the skinfold while making the measurement. Measurements were performed on the left side of the body with the child standing. Two measurements were taken on each position. If there was a difference of more than 2 mm, a third measurement was taken, and the mean of the two closest measurements was then used. Measurement was performed over the centre of the muscle on a line drawn between olecranon and acromion at the midpoint between olecranon and acromion. Subscapularly, the skinfold was measured under the angulus inf. on a line with a 45° downward tilt compared with the vertical line.

The following equations were used to calculate the fat percentage for boys and girls:

boys: fat percent $= 1.21 \times$ (triceps skinfold+subscapular skinfold) $- 0.008 \times$ (triceps skinfold+subscapular skinfold)^2 $- 1.7$,

girls: fat percent $= 1.33 \times$ (triceps skinfold+subscapular skinfold) $- 0.013 \times$ (triceps skinfold+subscapular skinfold)^2 $- 2.5$.

Changes in the proportions of children exceeding internationally accepted cut-points of BMI were analysed using the cut-points published by Cole et al. (2000).

In both studies, physical fitness was determined by a maximal work test, the watt-max test.

When performing the watt-max test, the children started at 20 W, when their body mass was less than 30 kg with a rise in workload of 20 W for each 3 min, and 25 W with a body mass of 30 kg or more with an increment in workload of 25 W for each 3 min.

The cycle ergometers were a Monark 839 Ergomedic in 1997–98 and a Meditronic 40-3 in 1985–86. The bikes were pre-programmed to increase the workload every third minute with 20 or 25 W. The workload was increased until exhaustion, and the time and heart rate (HR) were registered. Criteria for exhaustion were HRs above 185 bpm and a levelling off of HR, that the child could not keep a pedalling frequency of 30 rpm or more, and a subjective judgement of the observer that the child could no longer keep up, even after vocal encouragement. All tests were performed by only two researchers, one in each cross-sectional study. The maximal power output (Wattmax) was calculated as the watts in the last completed workload (W_l), plus the increment in watts (W_i) of the last step divided by 180 s multiplied by the number of seconds completed of the last step (t_{ls}).

$$\text{Wattmax} = W_1 + (W_i \times t_{ls}/180\,\text{s}).$$

Physical fitness was assessed as the volume of oxygen extracted at exhaustion in mL O_2 per kg body mass per minute (VO_2). This was calculated in both studies through separate equations derived from separate validation studies using the maximal power output. The test has been validated in several studies, and has been found to have high correlation ($r = >0.9$) to directly measured VO_{2max} (mL $\times$ kg^{-1} $\times$ min^{-1}), and a high reproducibility ($r>0.9$) (Hansen et al., 1989; Andersen, 1995).

HR was measured using Polar heart rate monitors: Polar 3000 in the first study and Polar Vantage NV in the second study. The Polar 3000 used integration of the heart rate for every 5 s for calculating the reported heart rate per minute, whereas the Polar Vantage NV used beat by beat integration for the heart rate per minute measurement.

The Odense School Child Study

This study has been described in detail earlier (Hansen et al., 1989). In all, 1369 children participated: 1284 children performed the watt-max test, while 85 children (6.2%) were excluded for not meeting the criteria of exhaustion.

The Danish substudy of the European Youth Heart Study

A total of 539 children performed the test, while 50 children (8.5%) were excluded for not meeting the criteria of exhaustion.

Validity of the maximal work test, the watt-max test

A validation study was performed for each of the two cross-sectional studies on a sub-sample of the participating children to test the validity of the watt-max test and to create the algorithms for calculating VO_{2max} from the maximal watt performed by the children.

Thirty-nine and 22 subjects, respectively, pedalled the same cycle ergometer as used in the Odense School Child Study and in the Danish part of the European Youth Heart Study. They performed the test twice 2 days apart and the subjects were randomized to direct measurement of VO_{2max} at either the first or the second test round. In both validation studies, multiple linear regression was used after subtraction of resting metabolic rate, which was defined in mL O_2 as five times body mass in kg, for constructing the formulae. In both cases, the calculated maximal oxygen uptake provided an accurate and valid estimate of actual oxygen uptake, with a correlation between predicted and measured VO_{2max} higher than 0.9 (Hansen et al., 1989).

In the Odense School Child Study, $VO_{2max} = (12.00 * \text{Watt-max} + 5 * \text{body mass})$, and in the Danish part of the European Youth Heart Study: $VO_{2max} = (13.16 * \text{Wattmax} + 5 * \text{body mass})$.

Separate validation studies were used because different cycle ergometers were available in the two studies.

Statistics

Comparisons of physical fitness were made between the calculated VO_{2max} using the algorithms obtained in the individual validation studies. A comparison of obesity was performed by comparing fat percentages calculated from skinfolds according to Slaughter et al. (1988).

For each study, the children were split into deciles by their fat percentage and their fitness level. The 10th to 90th percentiles of fat percentage and fitness level were plotted with 95% CI. We had several reasons for looking at the populations in this way: (i) It would show if only part of the populations were changing. (ii) Polarization of data is possible without the mean or median changing. (iii) Systematic error in assessment might be found. The rationale for this is that the upper level of fitness a subject can obtain primarily is genetically determined, but the lower level may be determined by inactivity, obesity and disease. We therefore did not expect a major change in fitness among the fit subjects.

ANOVA was used to test for differences between deciles in 1985–86 and 1997–98 in fitness, and the Mann–Whitney *U*-test was used to test between deciles of obesity, because the upper and lower deciles of obesity were skewed. Linear regression was used to test for trend in the differences between the 1985–86 and 1997–98 values over the ten deciles to test for polarization.

All statistical analyses were performed on a personal computer using STATA 7.

Results

Key variables are described in Table 1. The boys in 1997–98 had a lower fitness level ($P<0.001$) and a higher fat percentage than those in 1985–86 ($P<0.001$), whereas no overall differences in fitness ($P=0.63$) and fat percentage ($P=0.14$) were found between girls in 1997–98 and 1985–86 (Table 1).

The median values of the first to tenth deciles of fat percentage are illustrated in Fig. 1 for girls and in Fig. 2 for boys. The difference between the fat and the lean increased over time in girls, with a difference between the upper 10% and the lower 10% of 15.5% fat in 1985–86 and 17.9% fat in 1997–98 ($P<0.001$ for trend in difference). No change was found in the mean values for girls. For boys, the fat boys are fatter today than in 1985–86, with no difference in the fat percentage in the slim boys. Polarization was found in boys ($P<0.001$ for trend in difference), and an overall increase in obesity level was found in boys.

In all, 2.3% of the children in 1985 exceeded the internationally accepted BMI cut-points of obesity, whereas the corresponding proportion in 1997 was 4.1% ($P=0.039$).

The first to tenth deciles of fitness are illustrated in Fig. 3 for girls and in Fig. 4 for boys. In 1997–98, the most fit boys have the same level of fitness as in 1985–86, and the most fit girls have a significantly higher level of fitness in 1997–98 than in 1985–86, whereas both the girls and boys with the poorest fitness level in 1997–98 have a significantly lower level of fitness than the poorest fitness levels of girls and boys from 1985–86, respectively. A polarization was found in both sexes. The difference between the least fit and the most fit increased over time in boys, with a difference between the top 10% and the lowest 10% of 38% in 1985–86 and 45% in 1997–98 ($P<0.001$ for trend in difference). The same polarization was found in girls, with a difference between the top 10% and the lowest 10% of 37% in 1985–86 and 44% in 1997–98 ($P=0.001$ for trend in difference).

Figure 5 plots the differences in absolute VO_{2max} and in body weight between 1985–86 and 1997–98 values for each decentile of fitness (mL min^{-1} kg^{-1}). The decrease in fitness level (mL kg^{-1} min^{-1}) from 1985–86 to 1997–98 in the least fit is partly explained by a higher body weight and partly by lower VO_{2max} (L min^{-1}).

Table 1. Descriptives of the two populations. Mean (SD) except for fat percent, where median with 95% CI are described

	1985–86		1997–98	
	Girls	Boys	Girls	Boys
Number	670	699	310	279
Age (years)	9.6 (0.4)	9.6 (0.4)	9.6 (0.4)	9.7 (0.4)
Height (cm)	140 (6)	142 (6)	138 (6)	140 (6)
Weight (kg)	33 (6)	34 (6)	33 (6)	34 (6)
Fat percent (median with 95% CI)	23.2 (22.8; 23.7)	14.6 (14.3; 14.9)	22.8 (21.9; 24.1)	15.9 (15.3; 16.4)
Fitness (mL min^{-1} kg^{-1})	43 (6)	49 (6)	42 (7)	47 (8)

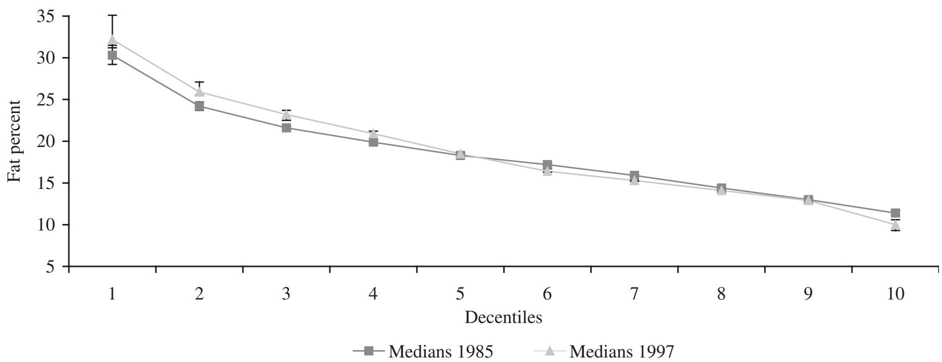

Fig. 1. Body composition by decentiles in girls 1985 and 1997 in medians with 95% CI. A significant polarization has occurred from 1985 to 1997; the difference between the fat and the lean has increased ($P=0.0003$).

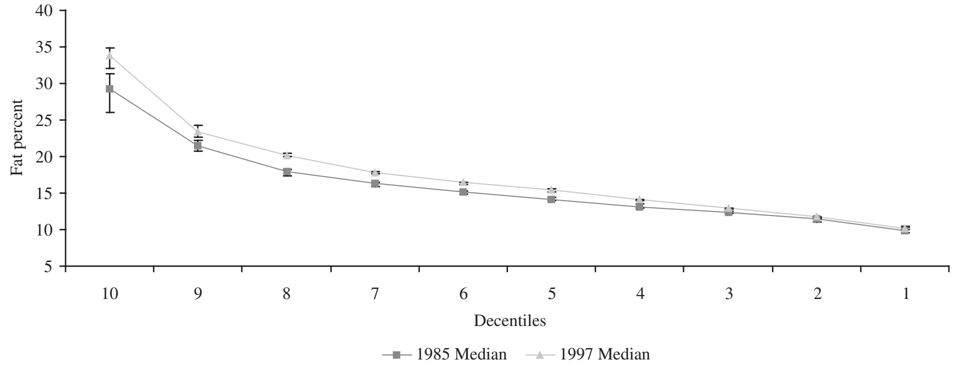

Fig. 2. Body composition by decentiles in boys 1985 and 1997 in medians with 95% CI. A significant overall increase in obesity has occurred ($P = 0.01$), and a significant polarization has occurred from 1985 to 1997; the difference between the fat and the lean has increased ($P = 0.001$).

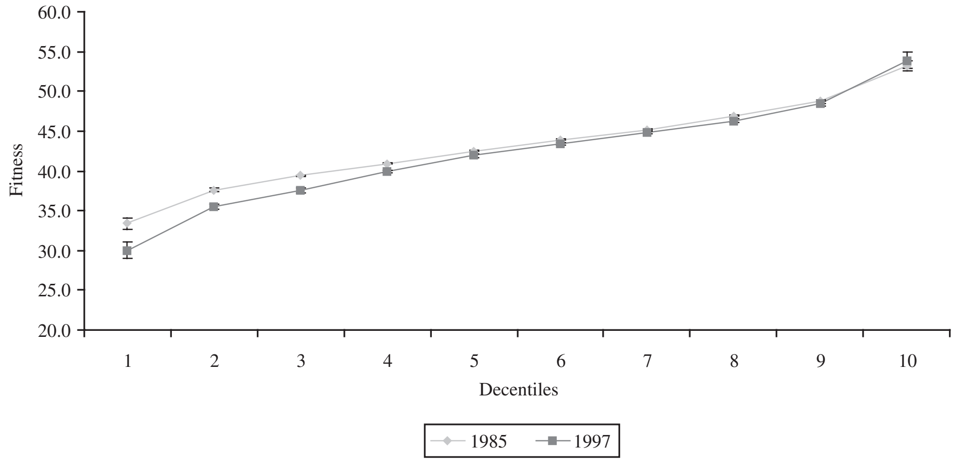

Fig 3. Fitness of girls by decentiles in mL O_2 $min^{-1} kg^{-1}$ with 95% CI. A significant polarization in fitness has occurred from 1985 to 1997; the difference between the girls with the highest and the lowest fitness has increased ($P = 0.0002$).

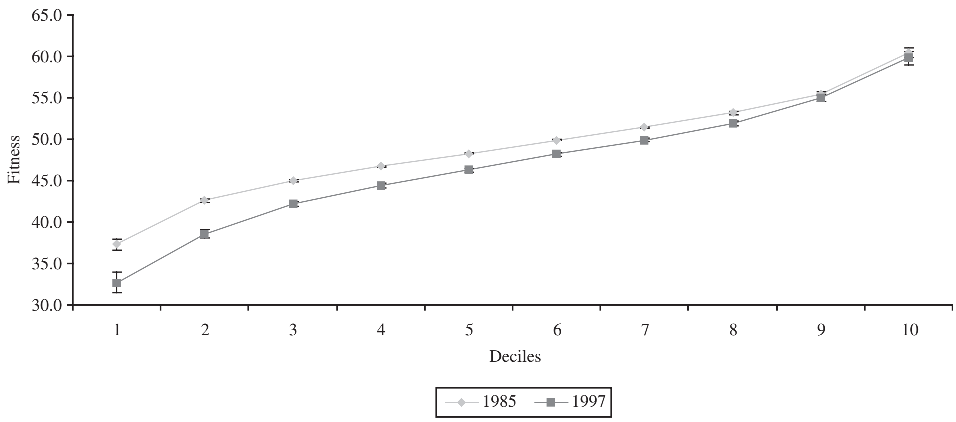

Fig. 4. Fitness of boys by decentiles in mL O_2 $min^{-1} kg^{-1}$ with 95% CI. A significant polarization in fitness has occurred from 1985 to 1997; the difference between the boys with the highest and the lowest fitness has increased ($P < 0.0000$).

The mean maximal HR was 203 in 1985 and 200 in 1997 ($P < 0.01$). If a linear relationship between HR and VO_2 is assumed, three beats will correspond to 1 mL kg^{-1} min^{-1}.

Discussion

The main findings of this study were a polarization in fitness and obesity over a 12-year period, and

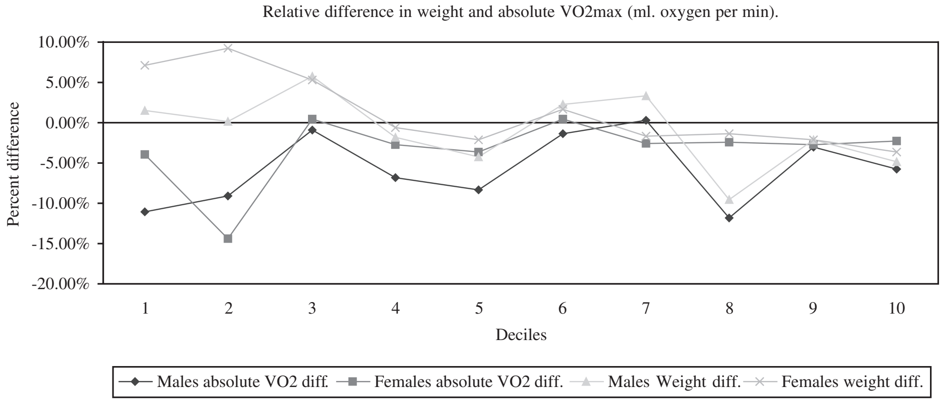

Fig. 5. Relative difference in absolute VO_{2max} and weight; the difference in fitness (mL $O_2\,kg^{-1}\,min^{-1}$) in the girls and boys with the lowest fitness level is partly explained by the decrease in VO_{2max} and partly by the increase in weight.

children with low fitness were less fit than their counterparts 12 years previously. The fat children were generally fatter at the second time point.

Importance of obesity and low physical fitness as risk factors for CVD

Obesity and low physical fitness are important risk factors for CVD. Physical fitness has earlier been used as a proxy of physical activity (Hansen et al., 1990), but physical fitness might by itself be an important independent factor associated with CVD risk factors in both children and adults (Blair et al., 1996; Rowlands et al., 1999). This relationship has been shown in adults, where there is a clear negative relationship between physical fitness and CVD regardless of body composition. It has even been suggested that being fit, per se, may reduce the hazards of obesity (Lee et al., 1999). In children, an increased level of CVD risk factors and a 6–7 times increased risk of clustering of high levels of risk factors have been found to be associated with low fitness (Wedderkopp, 2000).

The high correlation of obesity with CVD risk (Kikuchi et al., 1992; Boreham et al., 2001) and the clustering of risk factors in the obese (Voors et al., 1982; Smoak et al., 1987; Chu et al., 1998) makes it imperative to follow trends in the population in an attempt to control and lower the number of obese and the degree of obesity. This is especially pertinent because of the increase in the degree of obesity and the proportion of obese in both Denmark and other countries (Aristimuno et al., 1984; Sorensen, 1988; Heitmann, 1999; Thomsen et al., 1999).

Secular trends in fitness

The strength of the present study is the use of a reliable fitness test in the comparison of two large cohorts. To our knowledge, a secular decline in fitness has previously been described only by Dollman et al. (1999), but they used different and less reliable tests, the 1 mile run/walk test, the 50 m sprint and broad jump as fitness variables. In a validation study, Rowland et al. (1999) found that the "one mile run performance in children may not serve as a strong indicator of cardiovascular fitness". With this in mind, Dollman et al. (1999) still found a lower fitness in 10–11-year-old children of today of the same magnitude as we found in the 8–10-year-old children and also a trend towards a greater difference between the low-fitness and high-fitness groups.

The difference in maximal HR of three beats was constant across the deciles of fitness. The difference could be explained by the use of two different heart rate monitors using two different methods for calculating the HR. Even if subjects were not fully exhausted at the second test, the difference is too small to explain the large difference in fitness among the least fit.

Secular trends in body composition

Skinfolds were chosen as measures of obesity because it is one of the few good validated measures of fat percentage in children (Slaughter et al., 1988). The increases in obesity have been found in many other countries (Troiano et al., 1995; Dollman et al., 1999), and obesity has been suggested to be a growing problem (Seidell, 1999).

Perspectives

The negative trend inand polarization of, physical fitness and obesity in Danish children suggests a future generation with a higher degree of CVD risk.

To change this trend, it is imperative to encourage more physical activity. One way of doing this could be an increase in the number of compulsory physical education lessons in school. Parents also have a great responsibility, to encourage and support active living with high levels of physical activity in children.

Key words: physical fitness, obesity, secular trend, population, children.

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