PHYSICAL FITNESS AND OVERWEIGHT IN SWEDISH YOUTHS

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He jer sannt, je’ar sagt de till flair
ABSTRACT

The aim of the present thesis was to describe the level of physical fitness and prevalence of overweight and obesity in Swedish youths, and their trends over 14 years. Additionally, the relation between fitness and overweight on the one hand and physical activity on the other was examined. In 2001, a total of 2118 children, aged 10, 13 and 16 years, were invited from 48 randomly selected schools in Sweden. Out of these, 1732 or 81.8% participated in the testing. For trend analyses, data collected in 1987 from a sample of 516 children were used.

When subjects in the 2001 sample were analysed according to proposed cut-off values, 15.7% (95% CI: 14.1% to 17.6%) of all subjects were found to be overweight and 4.3% (95% CI: 3.4% to 5.4%) were obese. The total prevalence accordingly being 20.1% (95% CI: 18.3% to 22.0%). This sample proved to be heterogeneous concerning overweight status. When obesity and overweight were combined the highest prevalence (26.6%, 95% CI: 21.2 to 32.7) was found in 10-year-old girls and the lowest (17.5%, 95% CI: 13.6 to 22.2) in 16-year-old girls. The prevalence in 2001 was nearly 2.5 times higher, compared to the 1987-sample. Girls attending schools in smaller towns or on the countryside had a nearly two-fold prevalence of overweight and obesity, compared to girls living in the major cities. The difference was less pronounced in boys. The prevalence of overweight and obesity was related to level of physical activity in 10 and 13 years old children but not in 16 years old.

Results from the performance tests in the 1987 and 2001 samples were compared. Concerning cardio-respiratory performance, girls aged 16 years showed only small differences, whereas boys in the 2001 sample performed worse compared to boys in the 1987-sample (46 ml x kg\(^{-1}\) x min\(^{-1}\) vs. 41 ml x kg\(^{-1}\) x min\(^{-1}\) for 1987 and 2001, respectively, and median difference 9.2 %, 95% CI: -16.7 to -2.2).

Concerning neuro-muscular performance, the comparisons of results between the 1987 and 2001 samples showed varying results. Generally, performance on the upper body and trunk muscles strength and endurance tests was lower in 2001 compared to 1987. Neuromuscular performance in the lower body differed less.

For both boys and girls, differences in neuro-muscular performance between subjects in different activity strata increased with age. Results showed only small differences in neuro-muscular performance between active and less active strata at age 10, but larger at age 13 and 16 years in both boys and girls. And at age 13 and 16 years, neuro-muscular performance differed widely between active and less active girls. At age 10, only small differences were found in cardio-respiratory performance between active and less active subjects (both girls and boys). At age 13 and 16 years both girls and boys showed large differences in cardio-respiratory performance between activity levels, with better performance in more active children.

Keywords: Adolescents, children, physical performance, fitness, trend, overweight, Sweden
LIST OF PUBLICATIONS


III. **Ekblom Ö**, Oddsson K, Ahlbom A and Ekblom B. Effect of physical activity on prevalence of overweight and level of physical performance in children. In manuscript

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INTRODUCTION

Living conditions in the developed world have changed profoundly over the last 20 to 30 years. Among other things, everyday life now requires less physical activity. Additionally, many children and adults seem to develop an interest for sedentary leisure time activities.

Through physical activity, children and adolescents may learn many of the physical skills needed through life. One possible effect of decreased physical activity is decreased physical function or fitness. Another consequence, if not met by a decrease in energy intake, is an increase in fat deposits, leading to overweight or even obesity. The extent to which these relations are present probably vary between populations and therefore need further description. Determining the association between physical performance, overweight and physical activity is one of the aims of the present thesis.

There are several indications showing that we in the early twenty-first century are still in the midst of a rapid change in life style, and therefore detailed knowledge of development of physical activity levels, overweight and physical performance is important. Knowledge of changes over time concerning physical fitness and the prevalence of overweight and obesity may help to make predictions for future conditions. Establishing such trends in Swedish youths is another aim of the present thesis.

To be able to launch effective and successful disease-preventive or health-promoting interventions, it is important to have detailed knowledge on which parts of a population include the highest frequencies of overweight, obese or unfit individuals. The evaluation of such interventions must be done with care to avoid misinterpreting the results. The precision of some measures of physical fitness and anthropometry were studied in this thesis.

1.1 OVERWEIGHT AND OBESITY

Overweight and obesity are now widespread in adults, adolescents and children. They are today regarded as one of the major threat to good health in the general population in many developed countries. Overweight in both children and adults may be assessed using the measure body mass index (BMI, kg × m⁻²). There are several measures, but BMI is the most commonly used, due to its simplicity. Using the BMI, children may be classified as “normal weight”, “overweight” or “obese”, based on age- and gender specific cutoff limits, which are based on a large reference sample (Cole et al., 2000).

Adiposity in both children and adults is ultimately an outcome of a long-term energy surplus, where the energy intake exceeds the energy expenditure from basal metabolic rate, physical activity and thermogenesis. The depots of fatty acids in the adipose tissue may give rise to elevated blood lipids, decreased insulin sensitivity, other hormonal disturbances and changed haemodynamics, which all have been proposed as mechanisms for increased risk of illness.
1.1.1 Prevalence of overweight and obesity in Sweden

The prevalence of overweight and obesity has increased since the 1970s in Swedish children adolescents and young adults (fig 1). In Swedish conscripts (aged 17 and 18 yrs), the prevalence of overweight in 1995 was 16.3% and 3.2% for obesity (Rasmussen et al., 1999). Lower prevalences, 9% in girls and 7% in boys, have been reported in 16-year-olds in 1995 (Westerstahl et al., 2003), where other cut-off limits were used. Petersen et al. showed a prevalence of 23.1% (95% CI: 20.0 to 26.4) in 2001, with a slightly higher prevalence in girls (Petersen et al., 2003). In children aged 7 to 14 years, 13.2% of the boys and 14.5% of girls were overweight and 4.5% of both genders were obese (Raustorp et al., 2004). Using somewhat older (lower) BMI-cut-off limits for children, Berg et al (Berg et al., 2001) found a prevalence of overweight between 11.4% and 12.3% for boys and between 4.8% and 6.8% for girls. In the same study, prevalence of obesity was between 7.3% and 8.9% for boys and 3.9% and 5.1% for girls.

Figure 1. Reported prevalence of overweight and obesity. Data have been taken from Rasmussen (Rasmussen et al., 1999), Westerståhl (Westerståhl et al., 2003), Petersen (Petersen et al., 2003), Johansson-Kark (Johansson-Kark et al., 2002), Lissau (Lissau et al., 2004), Raustorp (Raustorp et al., 2004) and data from Paper 1 in the present thesis. Prevalence in young adults (17–18 yrs) was taken from a study (Rasmussen et al., 1999) on the compulsory medical exams of military recruits.

1.1.2 Adult risk

In adults, numerous studies show that both the amount and localisation of an individual’s adipose tissue affect health-related factors and are linked to illness and premature death. The sagittal diameter (Gustat et al., 2000, Rosell et al., 2004), waist-to-hip ratio (Rosmond et al.,
and waist circumference (Lissner et al., 2001) have been proposed to be related to increased risk of disease and premature death. However, no generally spread cut-off limits, defining increased risk for illness in adolescents or children are available yet.

The measure of choice in many epidemiological studies has often been BMI, together with waist circumference or waist-to-hip circumference ratio. In studies using BMI, overweight has been associated with all-cause mortality (Calle et al., 1999), cardio-vascular disease including coronary heart disease, ischemic stroke, but not hemorrhagic (Larsson et al., 1984, Rexrode et al., 1997), cancers (Calle and Thun, 2004), and hypertension (Huang, Willett et al., 1998, Yong et al., 1993).

1.1.3 Tracking

What is the importance of studies on the prevalence of overweight and obesity in children and adolescents? Some studies show that overweight and obese adolescents and young adults exhibit non insulin-dependent diabetes mellitus (Srinivasan et al., 1996), arterial lesions (Berenson et al., 1998), signs of the so-called metabolic syndrome (Cook et al., 2003, Cruz and Goran, 2004, Weiss et al., 2004), and other risk factors (Freedman et al., 1999). However, these associations between overweight and obesity on the one hand, and illness on the other, are much stronger in adults. It may seem strange to put a lot of effort into studies on the prevalence of overweight and obesity in children, since it is rather unusual that children become sick from their overweight.

One reason for studying childhood anthropometry is that some of these factors persist into adulthood, a phenomena known as tracking. Tracking is often expressed either as a correlation coefficient (sometimes called “tracking coefficient”), between two measures of overweight status or using risk expressions such as relative risk or odds ratio to describe the association between overweight status at two separate occasions.

Generally, studies show that the longer follow-up time, the lower the tracking. A Norwegian study (Kvaavik et al., 2003) reports that the relative risk of an adult BMI above 25 was 0.07 (95% CI: 0.03 – 0.14) for children (age: 14.7 yrs) with BMI under 16.9 and 16.7, for girls and boys, respectively. A Belgian study (Hulens et al., 2001), showed a relative risk of adult (40 yrs) overweight (BMI>25), for children with BMI> 20.3, 21.6 and 22.9 at age 13, 15 and 17 yrs, respectively to be between 5.0 and 6.9.

Increases in leisure time physical activity from adolescence to adulthood, normal weight parents and high educational level of parents are all factors related to decreased risk of adult overweight, while smoking cessation increased the risk (Kvaavik et al., 2003). Also urban residence, an increase in fat intake, reduction of carbohydrate intake and high meat intake have been proposed as factors enhancing tracking of overweight (Wang et al., 2003).
1.2 PHYSICAL FITNESS

Physical fitness as exposure parameters is rather common in studies of human health. Partly it is used as an objective measurement of bodily function, and partly it is used as a substitute evaluation for physical activity. The precision of the assessment of physical fitness is higher, compared to that of physical activity. Misclassifications will lead to a dilution of the effect and hence a lowered contrast between strata. Therefore, measuring fitness has some advantages over less precise measurements of physical activity.

Both physical activity and fitness correlate to beneficial outcomes in adults, but they are not complete synonyms. Firstly, fitness is to some extent dependent upon genetics. Furthermore, it is possible, and probably quite common to perform perhaps large amounts of physical activity in such a manner that physical performance is little affected, i.e. at intensities far below maximal intensity.

A central issue is the choice of parameter. Which aspect of fitness is the most tightly connected to beneficial health outcomes? A generally used measure is aerobic fitness (VO$_2$ max). Good aerobic fitness indicates that several vital systems (for example the central circulation, the vascular system and respiration) are well functioning and can withstand stress during the test. Furthermore, it indicates indirectly the status of other capacities as well, namely those necessary for the aerobic exercise or work, such as the skeletal system, joints and balance. Therefore aerobic fitness is an interesting measure from a health perspective. Other studies have focused on neuro-muscular function. In these cases, fitness is often used as a predictor of chronic pain, overuse injuries or accidents, and more seldom in studies of metabolic diseases.

1.2.1 Physical fitness in children

Children are different compared to adults concerning the effects of training. The response to intensive resistance training in children seems to give marked increases in strength (Falk and Tenenbaum, 1996, Payne et al., 1997). However, the magnitude of the increase seems to be dependent on gender and training mode. As in adults, the initial increase may be in the form of higher levels of neuronal activity. Epidemiological data on the relation between habitual physical activity and neuro-muscular fitness generally show weak to moderately strong relationships (Ara et al., 2004).

The response to aerobic fitness exercise seems to be lower in children than in adults. In experimental studies on children, maximal aerobic power typically raises 5-10% over a training period (Baquet et al., 2003), or less than half in adults (Walsh et al., 2001). Some studies, however, report no adaptation at all in children (Stoedefalke et al., 2000), (Williams et al., 2000). Several reasons for this have been suggested. The low blood pressure in children during exercise may leave the cardiac muscle without enough resistance training, which minimizes hypertrophy and prevents increases in stroke volume. Another explanation may be that sedentary children are more active than sedentary adults, in absolute values. This would give a lower effect of training, since the initial levels are higher. However, a study on pre-pubertal children, who began to exercise after a 10–week immobilization shows that the increase in maximal aerobic power was only around 13%, indicating that also very inactive children show smaller effects from aerobic exercise compared to adults (Rowland, 1994). To some extent, consensus is lacking concerning epidemiological data on the relation between level of habitual

1.2.2 Adult risk

It has been discussed whether physical activity or fitness is the most important variable to assess in a health context. In a large review by Steven Blair et al. (Blair et al., 2001), the effects of these two factors were compared. The authors concluded that it was not possible to state which of the two being most important, although striking differences in some groups and for some diagnosis were found.

Low physical performance has been identified as an independent risk factor in several studies in adults (Church et al., 2001, Farrell et al., 1998, Sandvik et al., 1993), both men and women (Huang, Macera et al., 1998, Villeneuve et al., 1998), (Blair et al., 1989). Longitudinal studies have been focused towards different outcomes, such as all-cause mortality (Blair et al., 1991, Church et al., 2001), cancer mortality (Kampert et al., 1996) as well as circulatory mortality (Lee et al., 1999, Slattery and Jacobs, 1988). Physical fitness seems related to beneficial health outcome also in subjects with diseases or risk factors present (Farrell et al., 1998).

The strength of the relation between physical fitness and adverse health outcome has been tested against that between fatness and illness. In a study on almost 22 000 men (Lee et al., 1999), cardiovascular fitness was assessed by a maximal treadmill test and body composition was determined by either densitometry, skin fold thickness or both. Subjects were assigned to one of six groups according to level of fitness (fit or unfit, where the least fit 20% were classified as unfit) and percentage body fat (lean, normal or obese, based on quartiles). Results show that unfit lean men had a higher risk, compared to active men in the highest body fat strata.

1.2.3 Tracking

As with overweight and obesity, fitness seems to track over the years (Falk et al., 2001, Janz et al., 2000, Kemper et al., 1990, McMurray et al., 2003), although some studies show poor tracking(Boreham et al., 2004). Compared to overweight and obesity, fitness in general tracks to a similar extent. Tracking for low neuro-muscular fitness however seems to be higher, compared to low aerobic fitness from adolescence to adulthood (Twisk et al., 2000). Aerobic fitness has been shown to correlate to beneficial CVD risk profile, but the relation to neuro-muscular fitness was weaker (Twisk et al., 2000). Good neuro-muscular fitness in adolescence, however, has been linked to lower risk for future pain symptoms in neck, shoulder and lower back (Barnekow-Bergkvist et al., 1998). Studies show a stronger relationship between physical fitness in adolescence and CVD-risk factors in young adulthood, than between physical activity and CVD risk factors (Twisk et al., 2002). Changes in fitness from adolescence to adulthood are related to beneficial changes in CVD risk factors (Hasselstrom et al., 2002, Janz et al., 2002). These studies provide important rationales to follow trends in physical performance.
1.3 PHYSICAL ACTIVITY

In the present thesis, physical activity is defined as all types of muscle actions, regardless of intensity, duration or context. All of these may be registered as increased oxygen consumption, immediately or later. This definition makes it difficult to operationalize and to cover using one single instrument or method.

1.3.1 Physical activity in children

Assessment of physical activity is difficult. Golden standard for use in larger samples are absent, although different approaches, both objective and subjective, have been tested. Validation of these methods has often been done using the doubly labelled water technique, first reported in humans by Scholler and van Santen in 1982 (Schoeller and van Santen, 1982) or indirect calorimetry by for example the Douglas bag technique. Of the objective measures both heart rate recordings (so called FLEX HR) (Livingstone et al., 1992) and accelerometers (Ekelund et al., 2001) have been validated. Results generally show the highest agreements for accelerometers, although correlations are weak. Agreements vary between the questionnaires (Craig et al., 2003), recall records (Washburn et al., 2003) and activity diaries (Conway et al., 2002) that have been tested for validity. Also, interviews have been validated (Slinde et al., 2003) showing slightly better relation to the validity criterion, compared to questionnaires.

The level of physical activity and fitness in children and adolescents has been intensively debated during the last five to ten years. Several investigators have reported levels of physical activity among children and adolescents. Some studies report differences in physical activity between genders (Hoos et al., 2003) or obese and normal weight subjects (Ekelund et al., 2002). Physical activity levels (PAL, daily energy expenditure as a multiple of basic metabolic rate) in British children have been reported to be between 1.2 and 1.9 in prepubertal children (Henry et al., 1999). In Swedish adolescents, corresponding values are somewhat higher, or 1.8 to 1.95 (Bratteby et al., 1997). Other studies refer to the recommendations for physical activity in children, stating that children should aim at the accumulation of 60 minutes of moderately intense activity per day. Results from such a study in Swedish adolescents (Ekelund et al., 2000) showed that the mean minutes at moderate intensity (>4.5 MET) equalled these recommendations.

1.3.2 Adult risk

Intervention studies and randomized control studies with sufficient follow-up periods are very difficult to perform. Therefore, much of the present knowledge on the relation between physical activity and health outcomes comes from observational studies and short-term intervention studies, although some randomized control trials have been conducted, for example Pereira et al. (Pereira et al., 1998). Also, selection bias may be regarded as a serious problem in this type of studies.

Physical activity as a mean of preventing illnesses has been studied for a long period of time. It appears that a dose-response relationship is present between amount of physical activity and mortality (Lee and Skerrett, 2001). Many of the longitudinal studies focus on middle-aged men. In studies of both men and women, results show a stronger relation between activity and health
in men, hypothetically due to that the instruments of PA (mainly questionnaires) assessment are constructed for men and may have lower validity for women.

Risk assessment for low physical activity is limited to some extent by the low validity in the quantifications. Investigations have quantified the amount of physical activity as energy expenditure, some converted to number of blocks walked or flights of stairs climbed per day or minutes at certain intensities. For energy expenditure, the lower limits for beneficial effect on health seem to be around 4200 MJ per week from leisure time physical activity (Lee and Skerrett, 2001), generating a 20 to 30% lower risk. A general recommendation (Report of the Surgeon General, 1996), based of several studies, is that adults should engage in moderately intense exercise for 30 minutes, on most or preferably all days of the week. To prevent overweight, newer recommendations stated the same frequency, but during 60 minutes per day (WHO, 2000).

1.3.3 Tracking

As for the risk assessment, studies on the tracking of physical activity are limited by measurement shortcomings. However, physical activity seems to track to a lower extent compared to fitness and overweight. The risk of staying in the most sedentary quartile over a 15-year period was 3.6 (95%: 2.4 to 5.4) for subjects in a Dutch study (Twisk et al., 2000). Corresponding values for cardio-respiratory and neuro-muscular fitness were 4.4 (95% CI: 2.6 to 7.4) and 14.2 (95% CI: 8.0 to 25.0), respectively. Another study shows that the likelihood to remain in the same activity group (tertiles) over a seven-year period during adolescence was as low as between 14 and 30% (McMurray et al., 2003). It might be concluded that the present knowledge on tracking of physical activity is limited and that further research is needed.

Additionally, in analogy with the studies on the tracking of overweight and obesity, future studies should also include the tracking of inactivity, which may differ from that of activity. In this case the difference may be large, since the prevalence of inactivity increases vastly from childhood into adulthood.
2 AIMS

The aims of the present thesis were to:
- Assess changes in physical performance over that same period.
- Describe the relation between physical performance and prevalence of overweight and obesity on one hand and self-reported physical activity on the other.
- Assess variability of data from repeated anthropometrical measurements and fitness tests.
3 SUBJECTS

3.1 SELECTION PROCESS

3.1.1 The 2001 sample

In 2001, forty-eight schools were randomly selected from a national register of schools, containing close to 5800 schools with children in the compulsory education. Number of schools was chosen to ensure a total number of subjects exceeding 2000. This register contained all public schools in Sweden and randomisation was made within them, with the exception of very small schools, (<15 pupils) or the social services schools (where pupils attend only temporarily). All children in 3rd, 6th and 9th grades in the selected schools were invited to participate in the study, resulting in a total of 2118 invited children. No attempt was made to include schools including both 3rd, 6th and 9th grades, resulting in that only six schools out of the forty-eight contributed with children from all three grades.

Table 1. Subject characteristics in the 2001 sample

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Height (cm) mean (min-max)</th>
<th>Body mass (kg) mean (min-max)</th>
<th>Sports club membership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls</td>
<td>10 yrs</td>
<td>226</td>
<td>139.4 (124.6–163.2)</td>
<td>35.7 (22.3-67.0)</td>
</tr>
<tr>
<td></td>
<td>13 yrs</td>
<td>318</td>
<td>158.2 (139.0 -175.2)</td>
<td>49.9 (31.5-89.2)</td>
</tr>
<tr>
<td></td>
<td>16 yrs</td>
<td>298</td>
<td>164.4 (149.7-187.8)</td>
<td>59.2 (37.1-101.2)</td>
</tr>
<tr>
<td>Boys</td>
<td>10 yrs</td>
<td>282</td>
<td>139.7 (126.0-162.5)</td>
<td>35.6 (21.8-75.5)</td>
</tr>
<tr>
<td></td>
<td>13 yrs</td>
<td>323</td>
<td>157.1 (128.5-177.1)</td>
<td>49.6 (31.6-95.8)</td>
</tr>
<tr>
<td></td>
<td>16 yrs</td>
<td>290</td>
<td>175.9 (157.3-199.0)</td>
<td>66.3 (46.1-101.4)</td>
</tr>
</tbody>
</table>

In 2001, testing took place at three specially arranged test centres (Stockholm, Malmö and Gothenburg), with trained test staff performing the tests. The children as a group (their school class), were asked to come to one of these three test centres where subjects were tested and filled out a questionnaire. Travel and other expenses were paid for. The parent or guardian of each participating child gave written consent to the child’s participation. Subjects were given an extensive questionnaire including questions on lifestyle, health, membership in sport clubs and socio-economic status (SES). Data on family possession of car, personal computer, summer house and living in villa made ground for classification of SES. Membership in sports club was defined as being active in a sports club at least two times per week.
| **Table 2. Reasons for not participating in the 2001 sample.** |
|----------------|----------------|----------------|
| **Reason**        | **Frequency** | **Percent** |
| Participated      | 1732          | 81.8         |
| Unknown (did not arrive) | 251         | 11.9         |
| Illness           | 82            | 3.9          |
| Not interested    | 23            | 1.1          |
| Holiday           | 16            | 0.8          |
| No parental permit| 6             | 0.3          |
| Other (religious, disability) | 8            | 0.4          |
| **Total**         | **2118**      |              |

This sample (S01) initially consisted of 2118 children, of which 1732 or 81.8% participated in height and body mass measurement and physical performance testing. In paper 3, analyses were made on physical performance and anthropometry in children and adolescents with different levels of physical activity. A total of 1761 answered the questionnaire, whereas data on both tests and questionnaire were obtained from 1660 subjects. The extent to which the 251 children whose reason for not participating is unknown differ from the participants is not known. However, it is reasonably to assume that if they differ at all, they were less physically fit and/or had a higher prevalence of overweight and obesity. Conversely, the studied sample was leaner and more fit, compared to what would have been the case if all the invited children had participated.

**Geographical distribution**

Of the 1732 participating subjects, 259 attended schools in the two largest cities in Sweden (Stockholm and Gothenburg). Dichotomisation was made based on living in the cities or within the sub-way-covered parts of Stockholm or tram-covered in Gothenburg. No school in the Malmö-area (the third largest city in Sweden) was situated in or close to the city. In the 2001 sample, 283 subjects came from schools in geographical regions not covered by the 1987 sample. Therefore, these subjects were excluded when analysing the trends in body mass index distribution and physical performance. Of the remaining 1835 subjects, 1470 participated in the height and body mass measurements and were used in the analysis of trends in BMI distribution. This, smaller, part of the S01 is called S01T. In S01, seven out of the forty-eight schools were situated in cities, and the others in either the countryside or in small towns. Six of the schools were combined schools, with both compulsory education and secondary education, providing 226 subjects.

**3.1.2 The 1987 sample**

In 1987, ten schools in the middle and southern parts of Sweden were selected to cover different geographic areas and invited to participate in the study. Due to the small number of schools studied, they were not selected randomly, but schools were manually selected. Selection was made to avoid very small schools with few accessible subjects, to use educated physical education teachers who were interested in the participation and to have subjects from both populated and rural areas. All the invited schools accepted the invitation. Seven of the schools
were situated in the countryside or in small towns while the remaining three were situated in larger cities. Geographically, none of these ten schools came from communities north of the city of Sundsvall, and therefore they do not represent the northern part of Sweden in 1987. Four of the ten schools were combined schools for grades 7 to 9 of the compulsory and secondary education, providing a total of 285 invited subjects. The 1987 sample consisted of 2299 children and 546 of them were in the ages of interest (10, 13 and 16 years). Out of these, 516 provided data on height and body mass and 479 participated in the physical performance testing. The reasons for not participating are unknown in the 1987 sample. All testing took place in the schools’ own gymnasiums, where the physical education (PE) teachers acted as testing staff after being specially trained in the testing procedures. All schools had professionally trained PE teachers.

Table 3. Mean (min-max) height and body mass of the subjects in the 1987-sample

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>n</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>10 yrs</td>
<td>41</td>
<td>138.6 (126.0-153.0)</td>
<td>33.6 (22.1-48.8)</td>
</tr>
<tr>
<td></td>
<td>13 yrs</td>
<td>36</td>
<td>159.3 (145.0-172.5)</td>
<td>47.8 (37.1-61.7)</td>
</tr>
<tr>
<td></td>
<td>16 yrs</td>
<td>171</td>
<td>165.4 (151.5-183.5)</td>
<td>56.3 (42.8-81.4)</td>
</tr>
<tr>
<td>Boys</td>
<td>10 yrs</td>
<td>38</td>
<td>140.0 (129.5-160.1)</td>
<td>34.1 (24.0-59.5)</td>
</tr>
<tr>
<td></td>
<td>13 yrs</td>
<td>41</td>
<td>157.6 (116.5-172.2)</td>
<td>47.1 (34.2-69.3)</td>
</tr>
<tr>
<td></td>
<td>16 yrs</td>
<td>189</td>
<td>176.0 (158.0-191.6)</td>
<td>64.3 (42.0-103.2)</td>
</tr>
</tbody>
</table>

3.1.2.1 Differences between the 2001 and 1987 samples

(Paper 1 and 2) One basic difference between the two samples is the proportion trained PE-teachers. One sign of whether this might be important is to study differences in key parameters within the 2001 sample. One hypothesis might be that having a PE teacher is associated with lower prevalence of overweight or better performance in tests, and since all children in the 1987 sample had an educated PE teacher, this might be an important confounder. Table 4 gives prevalence of overweight and obesity in the different gender and age groups in classes with and without educated PE teachers (less than one year vs. one year or more of education). The presence of an educated PE-teacher seems to be unrelated to the prevalence of overweight and obesity in this sample. It should be mentioned that among the proportion trained PE-teachers (>1yr) were only 25% in the youngest group and approximately 80% in the oldest.

Table 4. Prevalence of overweight and obesity in children with and without educated PE-teachers.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>PE-teacher’s level of education</th>
<th>Difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 1 yr</td>
<td>≥1 yr</td>
</tr>
<tr>
<td>Girls</td>
<td>10</td>
<td>27.7</td>
<td>24.2</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>18.6</td>
<td>19.6</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>16.4</td>
<td>18.3</td>
</tr>
<tr>
<td>Boys</td>
<td>10</td>
<td>22.3</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>20.3</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>17.3</td>
<td>19.2</td>
</tr>
</tbody>
</table>
3.1.3 The test-retest sample

In *Paper 4*, other subjects than in the first three papers were used. 115 children (54 girls, 61 boys) were invited to the study and their teacher asked them for participation as a group. 109 children participated and were tested twice, one week apart to assess variability of repeated anthropometrical measurements and selected field-tests of physical performance. Schools were selected via personal communication with PE-teachers who were interested in contributing. Children aged 10 and 13 years were recruited from one elementary school and those aged 16 years from another school. Both were sub-urban schools in the Stockholm region. The schools served mainly geographical areas of a higher-than-average socio-economic status, on basis of average household income and prevalence of residents with high academic education (Sweden, 2004).

Children in the test-retest sample performed better, compared to their peers in the 2001 sample. Results of the performance tests as well as anthropometrical measurements in these children (from the first test) were compared to the 2001-sample, by assessing the mean difference between the two samples and its 95% confidence interval (CI). Subjects in *Paper 4* performed slightly better in the sit-ups test in all age- and gender groups, in the arm hang test in boys and vertical jump in children aged 16. Also, BMI was lower in all age and gender groups in the test-retest sample.

Table 5. Mean (min-max) height and body mass of the test-retest sample.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Height(cm)</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls</td>
<td>10 yrs</td>
<td>17</td>
<td>139.9 (134.4-148.8)</td>
</tr>
<tr>
<td></td>
<td>13 yrs</td>
<td>15</td>
<td>158.0 (148.3-173.7)</td>
</tr>
<tr>
<td></td>
<td>16 yrs</td>
<td>18</td>
<td>169.4 (159.3-183.0)</td>
</tr>
<tr>
<td>Boys</td>
<td>10 yrs</td>
<td>22</td>
<td>140.8 (128.3-156.3)</td>
</tr>
<tr>
<td></td>
<td>13 yrs</td>
<td>18</td>
<td>155.8 (142.5-172.6)</td>
</tr>
<tr>
<td></td>
<td>16 yrs</td>
<td>19</td>
<td>180.3 (171.9-190.1)</td>
</tr>
</tbody>
</table>
4 MEASUREMENTS

4.1 PHYSICAL ACTIVITY

In the present thesis, physical activity was assessed by self-reported questionnaires. Two measures have been used. Based on the self-reported frequency (one item) of high intensity physical activity (HiPA), defined as activities that caused sweating and intense breathing, each subject was assigned to one of the three following groups; None or Irregular HiPA, Low HiPA (high-intensity physical activity once or twice a week) and High HiPA (Several times per week or almost every day high-intensity physical activity). Additionally, a total physical activity index (TPA) was formed. This index was based on data on (a) level of participation during compulsory physical education classes, (b) participation in supervised leisure-time sports or other physical activities, (c) participation in non-supervised leisure-time sports or other physical activities, (d) type and duration of any physical activity performed when coming to or leaving school, (e) type and duration of any physical activity performed when coming to or leaving any leisure time activity, and (f) type and duration of any physical activity performed when coming to or leaving friends. In cases (b) and (c), type, frequency (times/week plus variations over the year) and duration (minutes/session) was recorded. When added together, all questions were weighted equally. Subjects with TPA-score in the lowest quartile were assigned to the “Low TPA”-group and the highest quartile were assigned to the “High TPA”-group. The middle two quartiles were assigned to the “Moderate TPA”-group.

4.2 SOCIO-ECONOMIC STATUS

The term socio-economic status (SES) often refers to a person’s position in societal structure. Originally, occupation was used to classify individuals, but later income (Goodman et al., 2003), education (Gordon-Larsen et al., 2003) and possession of certain physical properties, assets or material standard (Borrell et al., 2004) have been used in epidemiological studies. In this study, the youngest subjects were younger than 10 years old, and the validity of other measures than possession were ruled out. Self-reported family possession of a) summer-house or cabin, b) car, c) home computer or d) living in a villa, each gave one point. SES-groups in the present thesis were defined as follows: Low SES (0 – 1 p.), Medium SES (2 p.) and High SES (3 – 4 p.). For subjects living on two locations, for example due to separated parents, presence of these items in any of the two homes was noted.

However, in doing so, several potential artefacts may have been introduced. First, it is possible that families with a poor economic situation will “cover” this by the possession of property that will enhance their status. Secondly, living for example in Stockholm city often means living in an apartment and not needing a car, whilst living in a rural part of northern Sweden requires a car and most often means living in a villa. However, as measured with an income based SES measure, Stockholm County has a comparatively high mean income from employment and business, whilst rural areas in northern Sweden have a lower mean income (Sweden, 2004), pp 313-315). Therefore, results presented in this thesis should be compared only with other studies using the same methods for SES-classification.
4.3 ANTHROPOMETRY

The reason for studying anthropometry in the present studies was two-fold, partly to normalize performance parameters and partly to be able to estimate percentage body fat via the BMI measure. For normalization, body mass has been used. Percent body fat is of interest mainly for health reasons. The correlation between the BMI-measure and other measures of body fatness in children and adolescents has been assessed in several studies. Zhang et al. (Zhang et al., 2004) assessed correlation between BMI and body composition measured with double-energy x-ray anthropometry (DEXA), reporting correlations between 0.59 and 0.83 for children between 10 and 13 yrs. Tyrell et al. (Tyrrell et al., 2001) report higher correlation (r=0.94) between BMI and percent body fat in children also measured with DEXA.

4.3.1 Body mass index

In a study by Warner (Warner et al., 1997), the sensitivity and specificity for obesity as measured with BMI in this age group was 66% and 94%, respectively, when compared to body composition measured with DEXA-methodology. In a recent study (Eto et al., 2004), authors state that BMI should be used with caution as an indicator of childhood obesity, since that study showed low sensitivity. However, that study used bioelectrical impedance analysis (BIA) as reference method, a method that has failed to show high validity, when compared to DEXA or densitometry. Similar results, using skin fold as a reference technique, have been reported by Malina et al (Malina and Katzmarzyk, 1999), with sensitivity for BMI of overweight including obesity being between 0.14 and 0.60 and specificity of 0.96 and 1.0.

These data indicated that most normal weight children are classified correctly, but that a larger proportion of the overweight or obese are not identified accurately, using the BMI measure. Prevalence of overweight and obesity reported in the present thesis and other studies using BMI, may therefore underestimate the prevalence.

4.3.2 Classification

Height and body mass were recorded with subjects dressed in light clothing, without shoes, using calibrated standard scale and stadiometer. Height was recorded in centimetres, with one decimal. Body mass was recorded in kilograms, with one decimal using a SECA scale.

Body mass index (BMI) was defined as body mass in kilograms divided by body height in metres squared (kg x m$^2$). To classify subjects as either normal weight, overweight or obese, the standard definition proposed by Cole et al. (Cole et al., 2000) was adapted. These standards are based on a large sample of subjects from different countries (however not from any Nordic country) and these cut-off limits for overweight and obesity are age- and gender specific.
4.4 PERFORMANCE TESTS

The methods chosen in the 2001 testing were partly governed by the methods in the 1987 sample, since one of the aims of the thesis was to establish trends in physical performance. So-called field tests are used as integrative measures of speed, agility, neuro-muscular function and/or endurance. They are often based on simple sports-activity like tasks, from which measures such as seconds, centimetres or numbers of events are taken as the result. The integrative aspect contains the notion that several single capacities or functions are tested simultaneously. For example, in the vertical jump test, leg muscle strength, coordination, balance, motivation and body size will affect the result. Therefore that test should not be proposed as a “leg-strength” test, but rather a “lower-limb function” test. The skills giving the result of such functional tests may be learnt during activities such as running or cycling or more of complex types of activities like climbing trees. Therefore the results from these tests may to some extent be used as a parallel measure of physical activity.

4.4.1 Flexed-arm hang

The test was performed with a supinated handgrip (palms pointing toward the chest) with chin clear of the bar (the “correct” position). Subjects were helped into correct position and any pendulum movement of the body whilst hanging was stopped. The bar used was a standard gymnasium steel bar (diameter $\approx 3$ cm). Results were recorded as time (seconds, with one decimal) in correct position. To compensate for changes or differences in body mass between the two tests, results are given in seconds multiplied by body mass$^{1/3}$.

4.4.2 Sit-ups

The test was performed with knees in 90 degrees angle and feet fixed. To minimize the movement of the arms during the trunk flexion, a non-flexible textile band was used to keep the hands still. The band ran behind the neck and was held by index-and long fingers. The band was long enough to allow the hands to be held close to the ears. Elbows were pointing forward. Since the band ran behind the neck, potential dorsal-ventral head movements influenced the arms position less. Numbers of completed sit-ups (from a complete horizontal position on the floor to the position where the elbows touched the knees) during a 30-s period were recorded.

4.4.3 Vertical jump

Hands were held on the hips, thumbs pointing backwards, during the jump test. Subjects were instructed to jump vertically, and to land on the same spot as they jumped from. Jump height was measured as the vertical displacement of the hip. A measuring tape was attached to a belt running around the subject’s waist. The measuring tape then ran under a plastic profile attached to the floor. Jump height was calculated as the difference between the reading on the measuring tape before and after the jump; to the nearest 0.5 cm. Vertical jump height was multiplied by body mass, thus measuring the maximal functional power output in kilojoules (kJ).

4.4.4 Quiet stance

The task in the quiet stance-test was to balance for 60 seconds on one leg standing on a narrow (3 cm) steel profile. The instructions told the subject that the free foot must not touch the other foot, but could otherwise move freely. A brief test (3-5 seconds) was given to decide which leg
to use, where after the test begun. Number of ascents was recorded. Compared to the EUROFIT subtest “Flamingo-test” this test allowed the subject to move freely, instead of holding the resting leg.

4.4.5 Sit-and-reach

During the sit-and-reach test subjects sat with straight legs performing a maximal trunk flexion, aiming to reach as far as possible. Ankles were sustained at a 90° angle. Reaching distance was recorded as centimetres past the toes where the value 0 denoted having just reached the toes. Reaching five centimetres shorter or longer than the toes gave a result of -5 and 5 cm, respectively.

4.4.6 Grip strength

Subjects were asked to maximally compress the handles of the grip dynamometer (Cardionics AB, Bandhagen, Sweden) for two to three seconds, using their preferred hand. Grip size was adjusted to fit the subject’s hand size. The test was performed with the arm straight down and the dynamometer not touching the body. Three attempts were given and results were recorded in kilopond (kg) with one decimal. The best trial was used for analysis.

4.4.7 Cardio-respiratory performance

For testing of maximal cardio-respiratory capacity, direct measurement of volume and composition of expired is regarded as the golden standard. In larger studies, the Åstrand-Ryhming (Åstrand and Ryhming, 1954) nomogram for estimating maximal oxygen consumption is frequently used. However, this nomogram is not primarily used for children and the age coefficient used to adjust for changes in maximal heart rate is not known for subjects under the age of 15 years. In the present studies, no age or maximal heart rate correction has been applied. This means that comparisons between age groups must be done with caution.

Heart rate response to a sub-maximal work rate on a Monark ergometer was recorded using telemetry (Polar Electro Oy, Kempele, Finland), to estimate the cardio-respiratory performance. Cadence was set at 50 rpm. Heart rate was measured and noted after five minutes of work. If the heart rate was found to be stable (i.e. varied less than 5 b.p.m) at the end of the sixth minute, the last of the two readings was considered as the heart rate response to the work rate. If not, the test was prolonged one minute or more, until a stable heart rate was at hand. Results from the 1987 and 2001 sample were then converted into estimated VO$_2$ max via the Åstrand-Ryhming nomogram. In Paper 2, these values were divided by body mass, and in Paper 3 by body mass$^{2/3}$. In the 1987 and the 2001 samples, all subjects worked at 50 W for one minute. Thereafter, the test leader changed work rates, based on the subject’s age, gender, body size, heart rate and self-reported level of fitness. Work rates used ranged from 50 W to 175 W. In the test-retest study (Paper 4), all subjects started on a work rate of 50 W for two minutes, and then work rate was altered according to age and subjective fitness. For subjects aged 10, 13 and 16 yrs, the work rates used in both tests were 50 W, 75 W and 100 W, respectively, except in four subjects aged 16 yr, who worked at 150 W. Results from the cycle ergometer test (CE) in Paper 4 were reported as raw heart rate data.
4.4.8 Combined data

Although different in many aspects, the tests used in papers 2, 3 and 4 all assess multi-factorial aspects of muscular strength, endurance and/or function, with the possible exception of cardio-respiratory performance. It might be interesting to study the relations between these tests. No formal factor analysis has been done, but in table 6, partial correlation coefficients between the four tests in the thesis, controlled for age and gender are given. These relations are weak to moderate and the strongest values are found between FAH and CRP and FAH and SU. The different tests thus measure to some extent different capacities.

Table 6. Partial correlation between tests, controlled for age and gender.

<table>
<thead>
<tr>
<th></th>
<th>SU (n)</th>
<th>CRP (ml x min⁻¹ x kg⁻²/₃)</th>
<th>FAH (kgs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRP (ml x min⁻¹ x kg⁻²/₃)</td>
<td>0.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAH (kgs)</td>
<td>0.29</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>VJ (kJ)</td>
<td>0.09</td>
<td>-0.01</td>
<td>0.20</td>
</tr>
</tbody>
</table>

In studies where physical performance is used as an alternative measurement of habitual physical activity or in a health context, it is important that the tests used assess several different aspects of performance (i.e. neuro-muscular, cardio-vascular and motor ability). This is especially true when the studies are made from a health perspective, since health has been showed to benefit from many types of physical activity in addition to the independent effect of performance. One way to asses several aspects is to combine results from several tests, into some sort of “performance index”. When constructing these indices, focus ought to be to find a correct weighting between sub-tests. In the present thesis, where indices or summa-scores have been applied, no weighting has been used.

Two different types of combined data have been used. In paper 2, a z score based index of the arm-hang, sit-ups, vertical jump and the cycle ergometry tests was applied based on age- and gender specific means and standard deviations. In paper 3, a “strength index” based on the above-mentioned tests minus the cycle ergometry was formed. In this case, age-and gender specific ranking was used; the lowest achievement was given the rank “1” and the best achievement was given the n th rank, where n is the number of subjects in the age and gender strata. Ranks for the three tests were the added to each individual’s “Strength index”.
5 STATISTICS

A main technique for assessing random variation in the present thesis has been the confidence interval (Papers 1 – 4). Most often the level of confidence was set to 95%, but in paper 3, it was 99%. The reason for this was the large numbers of comparisons made in that study. In this case, three groups were compared and to ascertain that single outliers did not create a trend, the level of confidence was increased.

When assessing the differences between medians, results are sometimes confusing, since the point estimates not always equal the difference between the medians in the two samples. The reason for this is that this point estimate is found as the median either of all possible differences (unpaired samples) or the median averages differences (paired samples). For further reading, see Altman (Altman et al., 2003).

In Paper 4, linear associations between results from the two trials were studied using correlation coefficients. The variability between trials was expressed as the difference between trials and its variance. Furthermore, the intervals containing the central 70, 80 and 95 percentiles were used to illustrate the distribution of individual differences.

More details are given in the respective papers.
6 RESULTS AND DISCUSSION

6.1 OVERWEIGHT AND OBESITY

6.1.1 Prevalence in the 2001 sample

(Paper 1) When subjects in the 2001 sample were analysed according to proposed cut-off values, 15.7% (95% CI: 14.1% to 17.6%) of all subjects were found to be overweight and 4.3% (95% CI: 3.4% to 5.4%) were obese, the total prevalence accordingly being 20.1% (95% CI: 18.3% to 22.0%). This sample proved to be heterogeneous concerning overweight status, with the highest prevalence of overweight found in 10-year-old girls (21.7%, 95% CI: 16.3 to 27.1) and the lowest in 13-year-old boys (13.3%, 95% CI: 9.6 to 17.0). The highest prevalence of obesity was found in 13-year-old boys (6.2%, 95% CI: 3.6 to 8.8) and the lowest in 13-year-old girls (2.9%, 95% CI: 1.0 to 4.7). When obesity and overweight were combined the highest prevalence was again found in 10-year-old girls (26.6%, 95% CI: 21.2 to 32.7). These prevalences are shown in table 7.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Mean (95% CI)</th>
<th>Median (95% CI)</th>
<th>Prevalence (95% CI)</th>
<th>Prevalence (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls</td>
<td>10</td>
<td>18.3 (17.9 to 18.6)</td>
<td>17.5 (17.2 to 17.8)</td>
<td>21.7 (16.3 to 27.1)</td>
<td>4.9 (2.1 to 7.7)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>19.9 (19.5 to 20.2)</td>
<td>19.2 (18.7 to 19.7)</td>
<td>16.2 (12.1 to 20.3)</td>
<td>2.9 (1.0 to 4.7)</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>21.9 (21.5 to 22.2)</td>
<td>21.3 (20.9 to 21.7)</td>
<td>14.1 (10.1 to 18.1)</td>
<td>3.4 (1.3 to 5.5)</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>17.0 (14.6 to 19.7)</td>
<td>-</td>
<td>3.6 (2.5 to 5.1)</td>
<td>-</td>
</tr>
<tr>
<td>Boys</td>
<td>10</td>
<td>18.1 (17.8 to 18.4)</td>
<td>17.4 (16.9 to 17.7)</td>
<td>15.6 (11.4 to 19.8)</td>
<td>5.7 (3.0 to 8.4)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>19.9 (19.5 to 20.3)</td>
<td>19.1 (18.8 to 19.5)</td>
<td>13.3 (9.6 to 17.0)</td>
<td>6.2 (3.6 to 8.8)</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>21.4 (21.1 to 21.8)</td>
<td>20.9 (20.5 to 21.2)</td>
<td>15.2 (11.1 to 19.3)</td>
<td>3.1 (1.1 to 5.1)</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>14.6 (12.5 to 17.1)</td>
<td>-</td>
<td>5.0 (3.8 to 6.7)</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>15.8 (14.1 to 17.6)</td>
<td>-</td>
<td>4.3 (3.5 to 5.4)</td>
<td>-</td>
</tr>
</tbody>
</table>
6.1.2 Regional differences

One major demographic difference between regions in Sweden is the level of urbanisation. Therefore, prevalence of overweight and obesity was compared between children in schools in or in the proximity of the three major cities in Sweden (Stockholm, Gothenburg and Malmö) on one hand and children in smaller towns or on the countryside on the other. No school in the Malmö area was classified as “city school”. Results are shown in table 8. Girls attending schools in smaller towns or on the countryside had a nearly two-fold prevalence of overweight and obesity, compared to girls living in the major cities. The difference was less pronounced in boys.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Median BMI (95% CI)</th>
<th>Percentage overweight and obese</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cities</td>
<td>Towns/ Countryside</td>
</tr>
<tr>
<td>Girls</td>
<td>10</td>
<td>16.9 (15.9 to 17.9)</td>
<td>18.5 (18.0 to 18.9)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>19.7 (18.9 to 20.3)</td>
<td>19.9 (19.5 to 20.4)</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>21.1 (20.5 to 21.7)</td>
<td>22.2 (21.7 to 22.6)</td>
</tr>
<tr>
<td>Boys</td>
<td>10</td>
<td>17.5 (16.7 to 18.3)</td>
<td>18.2 (17.8 to 18.6)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>19.2 (18.6 to 19.8)</td>
<td>20.2 (19.7 to 20.7)</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>21.2 (20.6 to 21.8)</td>
<td>21.6 (21.1 to 22.0)</td>
</tr>
</tbody>
</table>

6.1.3 Socio-economic differences

As described in the method section, socio-economic difference was measured using an assets-based parameter, i.e. the possession of certain commodities. Children belonging to the low SES-groups had a combined prevalence of overweight and obesity of 19.8% (95% CI: 15.2 to 25.5), compared to 21.0% (95% CI: 18.8 to 23.4) in the high SES-group. The middle group had a somewhat lower prevalence (16.3%, 95% CI: 12.4 to 21.1). We were thus unable to find a socio-economic difference across SES-groups. The choice of method may be especially sensitive in this analysis. Consensus is lacking from earlier studies, maybe due to different methods.

6.1.4 Relation to physical activity

(Paper 3) The relationship between prevalence of overweight and obesity on one hand and levels of physical activity on the other was assessed in the 2001-sample. As described in the method section, self-reported data on type, frequency and duration on both total physical activity (TPA) and high intensity activity (HiPA) were assessed.

The combined prevalence of overweight and obesity differed across activity strata at age 10 and 13 years, but not at age 16 years. The combined prevalence in the younger children was close to doubled in the least active TPA and HiPA strata, compared to the most active strata (table 9).
The level of HiPA and TPA was associated with combined prevalence of overweight and obesity to a comparable degree in both genders. These findings are in line with other Swedish studies, where weak relations have been found between activity and prevalence of overweight and obesity in 16-year-old school children (Rasmussen F et al., 2004).

The lack of relation in these ages may come from the use of BMI as a measure, which may not be suitable or applicable at this age. Most of the 16-years old children have recently passed peak height velocity age (PHV_{age}) and the height-mass relation may be altered compared to other times in life. Studying this phenomena using densiometry or double-energy x-ray anthropometry (DEXA) may reveal other results.

Table 9. Combined prevalence of overweight and obesity (99% CI) in the different HiPA- and TPA-groups, with genders merged

<table>
<thead>
<tr>
<th>Age</th>
<th>HiPA</th>
<th>Combined prevalence (99% CI)^a</th>
<th>Age</th>
<th>TPA</th>
<th>Combined prevalence (99% CI)^a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Age 10 yrs</td>
<td></td>
<td>Age 13 yrs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>None / Irregular</td>
<td>34.9 (24.3 to 47.2)</td>
<td>TPA Low</td>
<td>31.1 (22.7 to 41.0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Once or twice per week</td>
<td>23.0 (16.2 to 31.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>More frequent / Daily</td>
<td>19.1 (12.8 to 27.7)</td>
<td>TPA Moderate</td>
<td>21.1 (15.2 to 28.6)</td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>None / Irregular</td>
<td>30.4 (18.4 to 45.9)</td>
<td>TPA Low</td>
<td>29.6 (19.7 to 41.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Once or twice per week</td>
<td>23.0 (15.7 to 32.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>More frequent / Daily</td>
<td>15.7 (11.5 to 21.6)</td>
<td>TPA High</td>
<td>12.6 (8.0 to 19.3)</td>
</tr>
<tr>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>None / Irregular</td>
<td>21.9 (12.1 to 36.3)</td>
<td>TPA Low</td>
<td>18.4 (11.1 to 28.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Once or twice per week</td>
<td>16.7 (10.2 to 26.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>More frequent / Daily</td>
<td>17.9 (13.3 to 23.7)</td>
<td>TPA High</td>
<td>19.3 (13.1 to 27.5)</td>
</tr>
</tbody>
</table>

^a Overweight and obesity are reported combined. Definition of overweight and obesity was done according to Cole et al., 2000. The 99% CI was computed using the method proposed by Wilson (20).

When all age groups were merged and genders were compared for prevalence of overweight and prevalence of obesity separately, a gender specific pattern could be observed. In girls, activity was related to the prevalence of overweight but not the prevalence of obesity. In boys, this pattern was the opposite (figure 2). Girls in the High and Moderate TPA strata had a lower prevalence of overweight (13.2%, 99% CI 8.0-21.0% and 15.5%, 99% CI: 11.4 to 20.7, respectively) compared to low TPA girls (25.2%, 99% CI: 18.5 to 33.4). In boys, prevalence of overweight did not differ between TPA-groups, whereas prevalence of obesity did. High-TPA boys had a lower prevalence of obesity (2.9%, 99% CI: 1.3 to 6.6), compared to low TPA boys (8.6%, 99% CI: 4.5 to 15.7).
One of the limitations of the BMI is its inability to distinguish body fat from muscle mass. However, in children younger than 13-14 years of age, even intense resistance training does not generally increase muscle mass.

### 6.1.5 Trends over 14 years

To assess trends in prevalence of overweight and obesity, the 1987 sample (S87) was contrasted to the comparable part of 2001 sample (S01T). Prevalence of overweight and obesity combined was higher in S01T than in S87. Using the standard definitions by Cole et al., 7.6% (95% CI: 5.6% to 10.2%) of all subjects in S87 were either overweight or obese. In S01T, the corresponding figure was 20.0% (95% CI: 18.0% to 22.1%), which represents more than a 2.5-fold changed prevalence. In S87, 6.6% (95% CI: 4.8 to 9.1) of the subjects were overweight and 1.0% (95% CI: 0.4 to 2.2) obese. The sample size of S87 (n=516) did not allow meaningful analyses of prevalence of overweight and obesity in age and gender groups separately.

### 6.1.6 Changes in BMI-distribution

BMI-distributions in general are often skew, with a long right tail. This is the case also for the 2001-sample. As show by for example Kautiainen (Kautiainen et al., 2002), this distribution seems to become increasingly skew. This means that the increase in upper extremes (high BMI-values) is not accompanied by increases in lower extremes. The increased prevalence of overweight and obesity seems to come to great extent from a change in the upper extreme and not from a general shift from low to high BMI-values.

| Table 10. Median BMI (95% CI), plus the 10th and 90th percentile of the BMI distribution in each sample. |
|---|---|---|---|---|---|
| | Median (95% CI) | | Difference | | | |
| | (1987/2001) | S87 | S01T | 10th percentile | 90th percentile |
| Girls 10 yr | 17.7 (16.2 to 18.2) | 17.4 (16.9 to 17.7) | 5.0 % | 10.5 % |
| 13 yr | 18.9 (18.1 to 19.7) | 19.2 (18.7 to 19.8) | 1.1 % | 12.3 % |
| 16 yr | 20.2 (19.8 to 20.7) | 21.3 (21.0 to 21.8) | 0.8 % | 11.8 % |
| Boys 10 yr | 16.8 (16.5 to 17.8) | 17.4 (17.0 to 17.7) | -0.2 % | 8.8 % |
| 13 yr | 18.2 (17.0 to 19.5) | 19.0 (18.5 to 19.2) | 6.7 % | 8.5 % |
| 16 yr | 20.3 (19.8 to 21.5) | 21.0 (20.5 to 21.7) | 0.1 % | 7.4 % |
Table 10 shows the median (95% CI) BMI by gender and age in S87 and S01T, respectively. In S01T, the median BMI was higher than in S87, with the 95% CI in S01T not including the S87 median in all groups except girls 10 and 13 years of age. The largest difference was found in the older children, aged 13 and 16 years.

When comparing percentiles of BMI between the two samples it was found that the greatest change in BMI from S87 to S01T was found in the higher percentiles. The 10th percentile was moderately changed from S87 to S01T, with changes ranging from −0.2% to 6.7%. At the median or 50th percentile, BMI was also moderately elevated in most groups, with differences ranging from −1.6 to 5.7%. However, the BMI at the 90th percentile was more increased, with differences ranging from 7.4% to 12.3%. It is apparent that the difference in average BMI between S87 and S01T is mainly due to a change in prevalence of the highest BMI-values.

Figure 3. BMI-percentiles plotted against BMI in percent of the age and gender specific BMI cut-off for overweight in the 1987 and 2001 samples (95% CI).
6.2 PHYSICAL PERFORMANCE

Standard criteria of cut-off values help to discriminate between high and low BMI-values. In the case of physical fitness, there are no agreements on such criteria. Chen et al. (Chen et al., 2002) have proposed BMI cut-off limits for overweight, based on physical performance, in a large sample of Taiwanese adolescents. However, no absolute values to define as “low physical fitness” were given. Such cut-off limits for performance may be difficult to validate, since performance in childhood and adolescence is only moderately related to adult performance. Therefore, it is not possible to judge how many children that are “unfit” in the 2001-sample based on scientific ground. However, in the 2001-sample;
- 15.0% of the children could not support their own body mass in the flexed arm-hang test
- 5.1% cannot perform 10 sit-ups
- 20.0% cannot jump 25 cm, using both legs

These anecdotal results are difficult to interpret per se, which is why data on changes in performance are important.

6.2.1 Variability of results from repeated tests.

(Paper 4) The test-retest variability of the selected test was assessed in Paper 4. This was conducted to assist the planning of future intervention studies. The first aim of Paper 4 was to assess any possible mean differences in results between two repeated anthropometrical assessments and selected tests for physical fitness in children aged 10 to 16 yrs. The second aim was to determine the individual variation around the mean differences for these tests and anthropometrical assessments. Table 11 shows differences between trials.

<table>
<thead>
<tr>
<th>Test/assessment</th>
<th>$\bar{x}_{diff}$</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>0.1</td>
<td>(0.0 to 0.2)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>0.2</td>
<td>(0.1 to 0.3)</td>
</tr>
<tr>
<td>Sit and reach (cm)</td>
<td>1.2</td>
<td>(0.5 to 1.8)</td>
</tr>
<tr>
<td>Quiet stance (ascents)</td>
<td>-0.8</td>
<td>(-1.2 to -0.3)</td>
</tr>
<tr>
<td>Flexed arm hang (kg$^{1/3}$/s)</td>
<td>-7.2</td>
<td>(-14.4 to 0.0)</td>
</tr>
<tr>
<td>Vertical jump (kJ)</td>
<td>1.6</td>
<td>(-1.6 to 4.8)</td>
</tr>
<tr>
<td>Sit-ups (number)</td>
<td>1.5</td>
<td>(0.9 to 2.1)</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>0.0</td>
<td>(-0.6 to 0.5)</td>
</tr>
<tr>
<td>Heart rate response (bpm)</td>
<td>-2.0</td>
<td>(-3.5 to -0.5)</td>
</tr>
</tbody>
</table>

The correlation between the first and the second trial in the fitness tests ranged from 0.59 for the quiet stance test to 0.98 for the vertical jump test. Both body height and body mass assessments had a correlation between trials of 0.99. The distributions of individual differences in the tests and anthropometrical assessments are shown in table 12. These are the intervals containing the central 70, 80 and 95 percentiles, respectively.
Table 12. The intervals containing the central 70, 80, and 95 percentiles, respectively, for the differences in the seven performance tests and the two anthropometrical assessments.

<table>
<thead>
<tr>
<th>Test/assessment</th>
<th>70 percentiles</th>
<th>80 percentiles</th>
<th>95 percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>(-0.4 to 0.6)</td>
<td>(-0.6 to 0.7)</td>
<td>(-1.0 to 1.2)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>(-0.5 to 0.7)</td>
<td>(-0.6 to 0.8)</td>
<td>(-1.5 to 1.3)</td>
</tr>
<tr>
<td>Sit and reach (cm)</td>
<td>(-1.0 to 4.0)</td>
<td>(-3.0 to 5.0)</td>
<td>(-6.0 to 7.0)</td>
</tr>
<tr>
<td>Quiet stance (ascent)</td>
<td>(-2.0 to 1.0)</td>
<td>(-3.0 to 1.0)</td>
<td>(-7.0 to 2.0)</td>
</tr>
<tr>
<td>Flexed arm hang (kg(^{1/3})/s)</td>
<td>(-40.8 to 25.2)</td>
<td>(-64.7 to 31.9)</td>
<td>(-93.0 to 62.1)</td>
</tr>
<tr>
<td>Vertical jump (kJ)</td>
<td>(-13.2 to 17.0)</td>
<td>(-19.5 to 18.8)</td>
<td>(-33.3 to 33.4)</td>
</tr>
<tr>
<td>Sit-ups (number)</td>
<td>(-1.0 to 4.0)</td>
<td>(-2.0 to 6.0)</td>
<td>(-5.0 to 9.0)</td>
</tr>
<tr>
<td>Grip strength (kg)</td>
<td>(-2.0 to 2.0)</td>
<td>(-2.5 to 2.5)</td>
<td>(-7.0 to 4.0)</td>
</tr>
<tr>
<td>Heart rate response (bpm)</td>
<td>(-10.0 to 5.0)</td>
<td>(-13.0 to 6.0)</td>
<td>(-19.0 to 15.0)</td>
</tr>
</tbody>
</table>

The results in *Paper 4* show relatively small mean changes between the trials in most of the tests and the anthropometrical assessments. The findings support the use of the flexed arm hang, the vertical jump and the grip strength test in future intervention studies. The sit and reach, the quiet stance and the cycle ergometer tests may also be used, but it should be mentioned that these tests may show differing group mean values, even without an interspaced intervention. The usefulness of some of these tests is impaired due to large variations of the differences between trials, especially in the sit-ups and the quiet stance tests. The identified changes between trials may serve as indications of limits for the smallest detectable difference using these tests in a repeated measures design, such as in intervention studies.

Direct conclusions from the results in *Paper 4* to the results in *Papers 2 and 3* in the present thesis cannot be drawn. In the two earlier papers, all groups are naïve, meaning that most children met these tests for the first time.

### 6.2.2 Differences between 1987 and 2001

(*Paper 2*) Results from the performance tests in the S87 and S01T were compared in *Paper 2*. Concerning cardio-respiratory performance in girls aged 16 years; only very small differences were found, whereas boys in S01T performed poorer than boys in S87 (46 ml x kg\(^{-1}\) x min\(^{-1}\) vs. 41 ml x kg\(^{-1}\) x min\(^{-1}\) for S87 and S01T, respectively. The median difference was -9.2 %, 95% CI: -16.7 to -2.2).

The neuro-muscular performance testing showed varying results. Generally, performance in the upper body and trunk muscles strength and endurance was lower in S01T compared to S87. Performance in lower body function differed less. Table 13 shows the differences in results (in percent) between S87 and S01T. For girls, and for boys aged 13 years, vertical jump test differed only marginally, while lower values in S01T were found in 10- and 16-year-old boys. Arm-hang test differed widely between the two samples, except for 16-year-old boys. In the sit-ups test, girls aged 13 and 16 and boys aged 10 and 13 in S01T performed worse, compared to S87.
Table 13. Differences in performance between the 1987 and the 2001 samples. Results are median difference and its 95% CI. Negative values denote lower values in the 2001-sample and positive values higher values in the 2001-sample.

<table>
<thead>
<tr>
<th></th>
<th>VO2 (ml·kg⁻¹·min⁻¹)</th>
<th>Jump (kJ)</th>
<th>Armhang (kg¹/³·s)</th>
<th>Situps (number)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Girls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 yr.</td>
<td>4.6% (-5.5 to 14.9)</td>
<td>-32.2% (-57.2 to -11.5)</td>
<td>-6.3% (-12.5 to 6.3)</td>
<td></td>
</tr>
<tr>
<td>13 yr.</td>
<td>-3.0% (-11.5 to 5.8)</td>
<td>-36.1% (-59.0 to -10.7)</td>
<td>-15.0% (-20.0 to -5.0)</td>
<td></td>
</tr>
<tr>
<td>16 yr.</td>
<td>0.7% (-8.9 to 7.0)</td>
<td>-0.2% (-4.0 to 4.6)</td>
<td>-26.2% (-43.7 to -9.3)</td>
<td>-10.0% (-15.0 to -5.0)</td>
</tr>
<tr>
<td><strong>Boys</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 yr.</td>
<td>-9.0% (-18.2 to 0.0)</td>
<td>-45.6% (-67.0 to -25.2)</td>
<td>-11.1% (-22.2 to -5.6)</td>
<td></td>
</tr>
<tr>
<td>13 yr.</td>
<td>0.2% (-8.6 to 9.1)</td>
<td>-31.8% (-52.9 to -10.7)</td>
<td>-4.5% (-13.6 to 0.0)</td>
<td></td>
</tr>
<tr>
<td>16 yr.</td>
<td>-9.2% (-16.7 to -2.2)</td>
<td>-7.4% (-11.3 to -3.3)</td>
<td>-5.2% (-15.5 to 5.2)</td>
<td>0.0% (-4.3 to 4.3)</td>
</tr>
</tbody>
</table>

The large differences in results from the arm hang test do not indicate a proportionately difference in strength. The relation between time to exhaustion and isometric strength is most likely curve-linear. Thus, a large decrease in time to exhaustion may well be dependent on a much smaller difference in strength.

6.2.3 Relation to physical activity

In both health promoting and other health counselling, physical activity is encouraged to improve performance as well as to prevent overweight and obesity. As shown earlier, physical activity and overweight are related in 10 and 13 years old children but not in 16–year-olds. Studies of the relation between activity and performance in cross-sectional samples are few. In the 2001-sample, however, the relation between activity, both total and high intensity physical activity, and different aspects of performance were assessed.

6.2.3.1 Neuro-muscular performance

For both boys and girls, differences in neuro-muscular performance between activity groups increased with age (see table 14). Boys showed only small differences in the strength index between active and less active (both TPA and HiPA) at age 10, but larger at age 13 and 16 years. High-TPA girls aged 10 yrs showed slightly higher SI than low-TPA girls. At age 13 and 16 years, SI differed widely between active and less active girls in both TPA and HiPA.

6.2.3.2 Cardio-respiratory performance (CRP)

At age 10, only small differences were found in CRP between active and less active subjects in both TPA and HiPA. (table 15). At age 13 and 16 years both girls and boys showed large differences in CRP between activity levels. The differences between active and less active children were comparable for TPA and HiPA, except for girls aged 16 years, where CRP differed less in TPA. Although there are several important differences in study design, these data may be compared with results from experimental studies on the effect of training exercise in children and adolescents. Typically, the effect on cardio-respiratory performance from a
training period in pre- or circum-pubertal children is between 5 and 10 % (Baquet et al., 2003). The differences between the two extreme groups in HiPA in this study are −3.5% and 5% at age 10, 15.8% and 7.9% at age 13 and 20.8% and 25.5% at age 16, for boys and girls respectively.
Table 14. Strength index (SI) in relation to total physical activity (TPA) and high-intensity physical activity (HiPA) in boys and girls aged 10, 13 and 16 years. Values are mean (99% CI).

<table>
<thead>
<tr>
<th>Girls</th>
<th>TPA/HiPA*</th>
<th>SI_{HiPA} (mean rank)</th>
<th>SI_{TPA} (mean rank)</th>
<th>Boys</th>
<th>TPA/HiPA*</th>
<th>SI_{HiPA} (mean rank)</th>
<th>SI_{TPA} (mean rank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 yrs Lowest</td>
<td>336.5 (304.7 to 368.5)</td>
<td>292.4 (256.8 to 327.9)</td>
<td>10 yrs Lowest</td>
<td>413.4 (367.9 to 459.0)</td>
<td>396.3 (346.1 to 446.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>352.9 (301.4 to 404.4)</td>
<td>351.9 (320.4 to 383.3)</td>
<td>Middle</td>
<td>397.5 (346.7 to 448.2)</td>
<td>428.9 (394.7 to 463.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>388.3 (320.7 to 455.9)</td>
<td>378.9 (297.1 to 460.6)</td>
<td>Highest</td>
<td>459.2 (398.5 to 519.9)</td>
<td>431.8 (353.7 to 510.0)</td>
<td></td>
</tr>
<tr>
<td>13 yrs Lowest</td>
<td>454.4 (406.5 to 502.2)</td>
<td>441.9 (377.6 to 506.1)</td>
<td>13 yrs Lowest</td>
<td>404.1 (347.8 to 460.3)</td>
<td>413.9 (338.9 to 489.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>469.7 (435.2 to 504.2)</td>
<td>450.3 (418.0 to 482.5)</td>
<td>Middle</td>
<td>492.8 (455.1 to 530.5)</td>
<td>431.1 (392.0 to 471.2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>538.1 (463.1 to 612.6)</td>
<td>512.0 (465.3 to 558.8)</td>
<td>Highest</td>
<td>510.6 (460.6 to 560.7)</td>
<td>525.2 (488.0 to 562.3)</td>
<td></td>
</tr>
<tr>
<td>16 yrs Lowest</td>
<td>423.5 (381.3 to 465.7)</td>
<td>368.5 (316.8 to 420.2)</td>
<td>16 yrs Lowest</td>
<td>348.7 (287.3 to 410.1)</td>
<td>335.1 (279.2 to 390.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>455.8 (413.1 to 498.5)</td>
<td>436.7 (398.4 to 475.1)</td>
<td>Middle</td>
<td>424.3 (387.8 to 460.8)</td>
<td>406.4 (369.4 to 443.3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>588.3 (519.4 to 657.1)</td>
<td>534.9 (487.5 to 582.3)</td>
<td>Highest</td>
<td>506.1 (466.4 to 545.7)</td>
<td>492.2 (454.9 to 529.4)</td>
<td></td>
</tr>
</tbody>
</table>

* For TPA, Lowest, Middle and Highest groups are “Low TPA”, “Moderate TPA” and “High TPA”, respectively. For HiPA Lowest, Middle and Highest are” None / Irregular”, “Once or twice per week” and” More frequent / Daily”, respectively.
Table 15. Cardio-respiratory performance (CRP) in relation to high-intensity physical activity (HiPA) and total physical activity (TPA) in boys and girls aged 10, 13 and 16 years. Values are mean (99% CI).

<table>
<thead>
<tr>
<th>Girls</th>
<th>TPA/HiPA*</th>
<th>CRP&lt;sub&gt;HiPA&lt;/sub&gt; mL x min&lt;sup&gt;-1&lt;/sup&gt; x kg&lt;sup&gt;-2/3&lt;/sup&gt;</th>
<th>CRP&lt;sub&gt;TPA&lt;/sub&gt; mL x min&lt;sup&gt;-1&lt;/sup&gt; x kg&lt;sup&gt;-2/3&lt;/sup&gt;</th>
<th>Boys</th>
<th>TPA/HiPA*</th>
<th>CRP&lt;sub&gt;HiPA&lt;/sub&gt; mL x min&lt;sup&gt;-1&lt;/sup&gt; x kg&lt;sup&gt;-2/3&lt;/sup&gt;</th>
<th>CRP&lt;sub&gt;TPA&lt;/sub&gt; mL x min&lt;sup&gt;-1&lt;/sup&gt; x kg&lt;sup&gt;-2/3&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 yrs</td>
<td>Lowest</td>
<td>165.6 (154.9 to 176.3)</td>
<td>155.5 (146.0 to 165.0)</td>
<td>10 yrs</td>
<td>Lowest</td>
<td>160.6 (149.0 to 172.2)</td>
<td>155.4 (144.7 to 166.2)</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>171.1 (152.8 to 189.5)</td>
<td>166.6 (156.1 to 177.1)</td>
<td>Middle</td>
<td>160.5 (151.7 to 169.3)</td>
<td>164.1 (157.8 to 170.8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>160.6 (142.0 to 179.1)</td>
<td>167.2 (141.3 to 193.2)</td>
<td>Highest</td>
<td>168.6 (159.1 to 178.1)</td>
<td>166.6 (153.6 to 179.6)</td>
<td></td>
</tr>
<tr>
<td>13 yrs</td>
<td>Lowest</td>
<td>145.7 (137.3 to 154.1)</td>
<td>139.8 (130.9 to 148.6)</td>
<td>13 yrs</td>
<td>Lowest</td>
<td>155.0 (146.1 to 163.9)</td>
<td>157.9 (139.6 to 176.3)</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>157.0 (151.2 to 162.8)</td>
<td>151.0 (145.2 to 156.9)</td>
<td>Middle</td>
<td>159.0 (152.0 to 165.9)</td>
<td>156.1 (149.4 to 162.8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>168.1 (155.6 to 180.7)</td>
<td>164.9 (157.5 to 172.2)</td>
<td>Highest</td>
<td>166.9 (159.4 to 174.3)</td>
<td>165.9 (159.8 to 171.9)</td>
<td></td>
</tr>
<tr>
<td>16 yrs</td>
<td>Lowest</td>
<td>139.5 (132.5 to 146.6)</td>
<td>145.6 (135.1 to 156.0)</td>
<td>16 yrs</td>
<td>Lowest</td>
<td>145.3 (135.2 to 155.4)</td>
<td>149.4 (139.6 to 159.1)</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>147.2 (140.8 to 153.5)</td>
<td>143.3 (137.5 to 149.2)</td>
<td>Middle</td>
<td>167.7 (159.4 to 176.0)</td>
<td>160.2 (152.4 to 168.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>168.8 (155.6 to 182.1)</td>
<td>158.2 (149.2 to 167.3)</td>
<td>Highest</td>
<td>182.6 (174.7 to 190.5)</td>
<td>182.0 (174.6 to 189.4)</td>
<td></td>
</tr>
</tbody>
</table>

* For TPA, Lowest, Middle and Highest groups are “Low TPA”, “Moderate TPA” and “High TPA”, respectively. For HiPA, Lowest, Middle and Highest are “None / Irregular”, “Once or twice per week” and “More frequent / Daily”, respectively.
**6.2.4 The impact of normalisation**

Different normalisations have been used in *Paper 2* and *Paper 3*. In *Paper 2*, cardio-respiratory performance was normalised to body mass to the power of 1, and in *Paper 3*, to the power of 2/3. The scaling factor 1 has been used and is used frequently.

Maximal aerobic power or VO₂ max may be expressed as force times distance per time ((F x l)/t), which in turn, according to dimensional analysis is proportional to \((L^2 x L)/L = L^2\) or \(M^{2/3}\). Therefore, oxygen uptake should be normalised to body mass \(^{2/3}\). There are several studies supporting this approach (Taylor *et al.*, 1981, Von Dobeln, 1956). Other studies find the exponent to be around 0.7 (Bergh *et al.*, 1991, Buşesh and Berg, 2002).

In the present thesis, there are two comparisons of maximal oxygen uptake between groups, and where scaling might change the results, one in *Paper 2* (comparisons between S87 and S01T) and one in *Paper 3* (comparisons across activity strata).

In the analysis of differences in CRP between the 1987-sample and the 2001-sample in *Paper 2*, these differences might be of some importance, since body mass differed widely. In table 16, CRP as \(\text{ml} \times \text{kg}^{-1} \times \text{min}^{-1}\) as well as \(\text{ml} \times \text{kg}^{-1} \times \text{min}^{-2/3}\) are presented. The conclusion concerning CRP in *Paper 2* is thus not depending on normalisation.

### Table 16. Differences between the 1987 and the 2001 sample in CRP expressed as predicted maximal aerobic power in subjects aged 16 yrs, expressed in \(\text{ml} \times \text{kg}^{-1} \times \text{min}^{-1}\) and \(\text{ml} \times \text{kg}^{-1} \times \text{min}^{-2/3}\).

<table>
<thead>
<tr>
<th>Measure</th>
<th>S87</th>
<th>S01T</th>
<th>Median difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Girls</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ml.min⁻¹.kg⁻¹</td>
<td>37</td>
<td>38</td>
<td><strong>0.3 (-2.6 to 3.3)</strong></td>
</tr>
<tr>
<td>ml.min⁻¹.kg⁻²/₃</td>
<td>140</td>
<td>145</td>
<td><strong>2.7 (-7.7 to 13.4)</strong></td>
</tr>
<tr>
<td><strong>Boys</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ml.min⁻¹.kg⁻¹</td>
<td>46</td>
<td>41</td>
<td><strong>-4.3 (1.0 to 7.7)</strong></td>
</tr>
<tr>
<td>ml.min⁻¹.kg⁻²/₃</td>
<td>186</td>
<td>165</td>
<td><strong>-15.9 (2.3 to 28.7)</strong></td>
</tr>
</tbody>
</table>

In the comparisons of performance across physical activity strata, the normalisation could potentially play an important part. In table 17, CRP normalised to body mass across TPA-strata is shown. In boys, the pattern was similar to that found in *Paper 3*, when the exponent 2/3 was used to normalise for differences in body mass, with small differences in the youngest children.
and larger with increasing age. In girls however, the difference between active and inactive was smaller at age 16, compared to at age 13. Using the exponent 1 for normalisation, may thus give slightly different results in girls, compared to 2/3. Values for CRP between HiPA-strata are similar.

Table 17. CRP (99% CI) expressed as mL x min⁻¹ x kg⁻¹ in activity strata.

<table>
<thead>
<tr>
<th></th>
<th>TPA</th>
<th>CRP mL x min⁻¹ x kg⁻¹</th>
<th>10 yrs TPA</th>
<th>CRP mL x min⁻¹ x kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 yrs Low</td>
<td>Moderate</td>
<td>47.1 (43.1 to 51.1)</td>
<td>10 yrs Low</td>
<td>45.9 (41.5 to 50.5)</td>
</tr>
<tr>
<td>High</td>
<td>50.9 (46.9 to 54.9)</td>
<td>Moderate</td>
<td>50.1 (47.3 to 52.8)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>51.0 (41.9 to 60.6)</td>
<td>High</td>
<td>51.5 (46.1 to 56.9)</td>
<td></td>
</tr>
<tr>
<td>13 yrs Low</td>
<td>Moderate</td>
<td>37.6 (34.6 to 40.6)</td>
<td>13 yrs Low</td>
<td>43.6 (37.5 to 49.7)</td>
</tr>
<tr>
<td>High</td>
<td>41.4 (39.5 to 43.3)</td>
<td>Moderate</td>
<td>42.8 (40.6 to 45.0)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>45.4 (43.0 to 47.7)</td>
<td>High</td>
<td>45.9 (44.0 to 47.8)</td>
<td></td>
</tr>
<tr>
<td>16 yrs Low</td>
<td>Moderate</td>
<td>37.5 (34.6 to 40.4)</td>
<td>16 yrs Low</td>
<td>37.3 (34.5 to 40.1)</td>
</tr>
<tr>
<td>High</td>
<td>36.9 (35.3 to 38.5)</td>
<td>Moderate</td>
<td>40.0 (37.9 to 42.1)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>40.8 (38.3 to 43.3)</td>
<td>High</td>
<td>45.0 (43.0 to 47.0)</td>
<td></td>
</tr>
</tbody>
</table>
7 GENERAL DISCUSSION

7.1 OVERWEIGHT AND OBESITY

Figure 4. Prevalence of overweight and obesity in the 1987 and 2001-samples, among children aged 10, 13 and 16 years.

In both the 1987 sample and the 2001 sample, prevalence of overweight and obesity, as it has been defined above, was higher in the lower ages, as shown in figure 4.

Hypothetically, this could be due to two reasons. Either the prevalence is higher in lower ages, and has been so at both occasions. This would be expected in a situation where the trend for prevalence is increasing. The younger would then be more overweight. If so, the higher prevalence in the youngest group in the 2001 sample indicates that the increase in the prevalence of overweight and obesity is not yet over, but will continue. A second possibility is that the cut-off limits are too low in the younger ages, which would explain the constantly higher prevalence in 10 years old children.

Reasons for regional differences are not believed to be due to genetic differences, but due to systematic differences in lifestyle. These are either levels of physical activity, diet or both. In the 2001-sample, physical activity levels were somewhat higher in children attending schools in the major cities, but the impact of this on the prevalence of overweight and obesity is not possible to judge. Equally important is the other half of the overweight issue, namely diet. In the present thesis, only limited attention has been devoted to diet. Neither the 1987, nor the 2001-sample contains information of energy intake or type of food consumed. We can therefore not estimate the importance of these factors on regional differences or trends in the prevalence of overweight and obesity.
Data on the levels and type of physical activity in the 2001-sample have been compared to data from a study in 1968 (L-M Engström, personal communication). The data show an increasing proportion of children in sports clubs, but also an increasing proportion of sedentary children. This increased range in physical activity may be compared to the increased range in BMI values found in the 2001-sample. If a larger part of the childhood population becomes more sedentary, then the skew increase in BMI-values might come from this.

Several investigators have studied the importance of genetic factors for the development of overweight and obesity. Studies of monozygotic twins show a striking concordance (within-pair similarities) in the prevalence of overweight and obesity, in elderly (Poulsen et al., 2001) as well as in adolescents (Pietilainen et al., 1999). Several candidate genes have been proposed to be responsible for transferring obesity from generation to generation. It may be questioned whether these genetic factors can explain the increase of overweight and obesity reported worldwide over the last 20 to 30 years.

Many studies on the relation between BMI status in parents and offspring have used other subjects than twins and are often cross-sectional. In these cases, it is very difficult to separate genetic influence from acquired or socialized behaviours. The accuracy of assessments of physical activity and caloric intake in most epidemiological studies does not allow calculation of energy balance with the precision needed. An imbalance of only a few kilocalories will over a few years time result in large changes in adipose tissue. Also, intra-individual variations up to 10% in resting metabolic rate are probably present, although at least one study fails to find any systematic difference in resting metabolic rate between obese and lean children when adjusted for both fat mass and fat-free mass (DeLany et al., 2002). The same study failed to find differences in the thermic effect of food intake between lean and obese.

In this thesis, overweight and obese children and adolescents have been grouped in most analyses. Many of the studies on twins investigate the concordance of obesity, but not for overweight. The extent to which overweight (and not obesity) is inherited is less well studied. The risk of future diseases is higher in obese children, but still elevated in overweight, compared to normal weight children. The prevalence of overweight for example in the present study is almost three times higher, than for obesity. This is an example of the so-called epidemiological paradox, where the most cases of illnesses are generated from the large group of individuals with moderately increased risk, and not from the small group of individuals, with high risk.

### 7.2 PHYSICAL PERFORMANCE

The method used, where heart rate is measured at a given work rate, indicates the size of the subject’s oxygen pulse and therefore stroke volume, since oxygen consumption is reasonably stable at a given work rate. Comparisons of cardio-respiratory performance between age categories should be made with caution, since systematic differences in maximal heart rate may be present. With these limitations at hand, there was an interesting pattern in these data. With increasing age, active boys seem to improve their CRP, whereas the sedentary maintain their levels. In girls, active girls stay on about the same CRP from 10 to 16 years, while the sedentary decrease their CRP.
Paper 2 generally shows moderate median differences in performance, with the exception of upper-body strength and endurance (the flexed-arm hang test). Potentially, this could follow the same pattern as the BMI trends, where median BMI only changed moderately between the 1987 and the 2001-samples, whereas the upper extremes changed more. However, no such pattern could be found when comparing the two samples.

The results from the performance testing might be somewhat hard to translate into other terms. Many activities of daily life require strength as well as aerobic capacity. Hypothetically, being unable to play with friends may affect the child’s self-esteem in general and the confidence of the own capacity for sports in particular.

7.2.1 Combining test results

In the present thesis, two types of indices for combining tests of neuro-muscular fitness have been used. One was a z-value based index and the other was a rank-order based index. There are some differences between the methods used. The most important difference is that extreme values have lesser impact on the rank-order based index. Figure 5 shows the prevalence of overweight and obesity, in performance strata, using the rank order based (left panel) or the z-value based (right panel) index.

![Figure 5. Combined prevalence of overweight and obesity in performance strata, based on rank order (left) or z-values (right).]

7.2.2 Maturation

Level of maturation affects physical performance. For example, peak height velocity age is close to similar to the peak VO\textsubscript{2}max velocity age, i.e. the age at which maximal aerobic power increases most rapidly (Geithner \textit{et al.}, 2004). Systematic differences in maturity are therefore potential confounders. Together with many other signs, body height might be used as an indicator of maturity, since a rapid growth spurt occurs during puberty. In Paper 3, mean height was compared between activity groups to study if any systematic difference in height was present. If level of maturity to any major extent should have been differing between activity strata, height ought to have differed, which it did not.
The subjects in the 2001 sample were retested in 2004, when, among other things, self-reported height and body mass were collected. In 1154 subjects (66.6% of the 2001 sample), a ratio of height in 2001 and 2004 could be formed, and compared across 2001 activity strata. The prevalence of overweight and obesity in 2001 did not differ between participants and non-participants in the 2004 retest in any age or gender groups, except in girls aged 13 years. Using Kruskal-Wallis test (a non-parametric test corresponding to a one-way analysis of variance), no differences in the 2004-to-2001-height ratio were found in any age or gender group across HiPA or TPA-strata. This is another indicator that level of maturity did not differ largely between activity strata in 2001.

A drawback of using fitness as a health measure is the influence of genetic factors on the level of fitness. Within the same physical activity strata, levels of performance may differ widely. Favorable genetic components, together with serious exercise for many years are needed to reach extremely high levels of performance. However, studies show that the protective effect of a good physical fitness (Cheng et al., 2003, Church et al., 2001) and physical activity (Andersen et al., 2000) increases steeply between low and moderate fitness and activity. Beyond that point, smaller increases are generally shown. Therefore, the upper extreme is not in focus from a health perspective, but the lower. It may further be hypothesized that a very limited proportion in a given population has such extremely poor genetic prerequisites that they cannot reach moderate fitness, despite regular physical activity. Bouchard et al (Bouchard et al., 1988) showed that about 5% of a population responded poorly to training (less that 5% increase in aerobic power).

Conversely, with differences in genetics, the lower activity strata will also contain individuals with moderate or even high levels of fitness. An interesting issue is whether “genetically dependent” fitness is as protective as “activity dependent” fitness. A 14-year follow-up study on Danish men (Hein et al., 1992) shows that cardio-respiratory performance, assessed by a maximal cycle ergometer test, was a predictor of ischemic heart disease in active, but not in sedentary men. The same authors also reported that unfit, sedentary men had a higher risk for ischemic heart disease, compared to unfit, but active men (RR: 1.67, 95% CI: 1.06 to 2.64).

The measurements of neuro-muscular fitness should not be validated against an isolated muscle’s maximal power, since many of functional tests involve several muscle groups. Nor is the exact use of specific muscle groups in complex movements fully known (i.e. sit-ups). Besides, the capacity of an isolated muscle may play a limited role in a health related activity perspective. The functional tests include the important factor of motor ability/coodination, which mirrors whether the subject is used to perform this or similar activities. Some of these tests have been validated against other strength measures in a few studies. The arm-hang test has been validated in a study by Pate et al (Pate et al., 1993). The correlations with body mass related bench-press, pull-down and arm-curl were between 0.45 and 0.57. To a large extent however, the validity of the used tests, as described above, is unknown.
7.2.3 Physical activity

As mentioned earlier, studies have shown quiet high mean levels of physical activity among children. This raises questions if there are reasons for concerns over the physical activity in children.

One viewpoint is that there are at least two important reasons why a high mean physical activity level (PAL, i.e. energy expenditure over a period expressed as a multiple of resting metabolic rate) or mean minutes at moderate intensity are not enough to assure a satisfactory level of physical activity in population. Firstly, the mean PAL is not the most important measure; it’s the proportion of children that are under a certain level (“inactive”). Mean PAL may be identical in two groups or unchanged over time, but a changed distribution may yield an increased percentage of inactive individuals. Percentiles are seldom reported in recent papers. Secondly, since the precise level of lowest amount of exercise needed for maintaining a good health is yet to be determined, focus should be more on trends and in the distribution of PAL to be able to state whether the situation is troublesome.

Changes in the prevalence of overweight and obesity are sometimes used as an indication that the levels of total physical activity are decreasing. However, it is not possible to determine whether energy intake has increased or if the physical activity has decreased merely by assessing changes in morphological fitness or trends in prevalence of obesity and overweight. Studies investigating energy intake in different cohorts generally report a decreased or unchanged total energy intake over time (Bergstrom et al., 1993, Nicklas et al., 2001). It may therefore be hypothesized that the increased prevalence of overweight and obesity in youths as reported in many western countries, at least to some extent, is due to a decreased level of activity. This has been pointed out by (Troiano et al., 2000), and others.
8 CONCLUSIONS:

To conclude:

- The combined prevalence of overweight and obesity amongst children and adolescents in 2001 was 20.1%, with large variations between age and gender groups.

- This prevalence has most likely increased more than two-fold over the fourteen years preceding the 2001 study.

- Changes in physical performance are not general. In upper-body and trunk strength and endurance, subjects in the 2001 study performed worse compared to subjects in the 1987 sample. Additionally, cardio-respiratory performance in boys aged 16 was lower in 2001, compared to 1987. Other measured aspects of performance were unchanged.

- Self-reported physical activity was associated with physical performance in older children (16 yrs), but not in younger (10 and 13 yrs).

- Self-reported physical activity was found to be associated with the prevalence of overweight and obesity in younger children (10 and 13 yrs), but not in the older (16 yrs).

- Data on the variations between repeated tests may serve future intervention studies when designing studies and evaluating intervention effects.

These results give possibilities to focus preventive actions and to evaluate the effect of interventions. For example, it seems that overweight and obesity is most prevalent among the younger children (girls in particular). Further, data suggest that evaluation of physical activity-enhancing initiatives should not be performed using performance measures in young children or anthropometrical measures in 16-year-olds.

In my opinion, these data also provide a good platform when analysing and evaluating future studies applying the same methods on similar age groups.
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10 REFERENCES:


