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Physical activity patterns, aerobic fitness and body composition in Norwegian children and adolescents

The Physical Activity among Norwegian Children Study

SUMMARY

Regular physical activity is important for children and adolescent's healthy growth and for their physical, social and mental health. Therefore, comprehensive knowledge is needed on levels and patterns of physical activity, as well as factors influencing physical activity participation.

Purpose: The overall purpose was to increase the knowledge regarding 9- and 15-year-olds physical activity level, aerobic fitness and their body composition. Further, to gain increased insight with regards to changes in 9-year-olds physical activity level and their body composition.

Methods: In 2005–2006, 2299 9- and 15-year-olds were randomly recruited from all regions in Norway (Papers I and II). The participation rate was 89% and 74% among the 9- and 15-year-olds, respectively. In Papers III and IV, data were gathered in two cross-sectional studies conducted in 1999−2000 and 2005. All assessments of physical activity level were performed objectively by accelerometry, and aerobic fitness was assessed directly as peak oxygen uptake (VO_2) during a maximal cycle ergometer test. Measurements of body composition included body mass index (BMI), waist circumference (WC) and skinfold thickness.

Main results: The main findings were: 1) Boys were significantly more physically active than girls at both age 9 and 15 years. Both 9- and 15-year-olds were significantly more active during weekdays than during weekends. Four out of five 9-year-old children met current physical activity recommendations, but only half of the 15-year-olds did. Furthermore, boys had a significantly higher peak VO_2 than girls; 2) In 9-year-olds, substantial differences in physical activity levels and patterns were observed across seasons. The physical activity level was significantly higher in spring than in fall and winter. No seasonal variation was observed in 15-year-olds physical activity level; 3) Nine-year-old children have increased both their mean physical activity level and their activity level during weekends between 1999−2000 and 2005, with the patterns being similar for girls and boys. Interactions were found between change in physical activity and socioeconomic status; 4) In 9-year-old children, there was no significant change in the prevalence of overweight (including obesity) over a five year period; however, it seems clear that a shift has occurred. BMI remained fairly stable over the five year period, however, an increase in WC and skinfold thickness was observed.

Conclusions: In a large nationally representative sample, it was observed that 9-year-olds participate in high volumes of physical activity; however, the activity level decreases substantially by age 15. Boys had a significantly higher peak VO_2 values than girls at both age 9 and 15 years. This knowledge is of importance and should help inform public health policy. This study should be a start of a regular national surveillance system to monitor secular trends in physical activity levels, aerobic fitness and body composition.

Key words: Children, adolescents, physical activity, accelerometers, seasons, aerobic fitness, overweight, obesity, cross-sectional, epidemiology.

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ABBREVIATIONS

ALSPAC: Avon Longitudinal Study of Parents and Children
BMI: Body mass index
CI: Confidence interval
CVD: Cardiovascular disease
DLW: Doubly labeled water
DXA: Dual-energy radiograph absorptiometry
EE: Energy expenditure
EYHS: European Youth Heart Study
HR: Heart rate
IOTF: International Obesity Task Force
METS: Metabolic equivalents
MPO: Maximal power output
MVPA: Moderate-to-vigorous physical activity
PA: Physical activity
PANCS: Physical Activity among Norwegian Children Study
Peak VO_2: Peak oxygen uptake
RER: Respiratory exchange ratio
RMR: Resting metabolic rate
SES: Socioeconomic status
VO_2:   Oxygen uptake
VPA: Vigorous physical activity
WC: Waist circumference
W_{max}: Wattmax

LIST OF PAPERS

The dissertation is based on the following original research papers, which are referred to in the text by their Roman numerals:

I. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Objectively assessed physical activity and aerobic fitness in a population-based sample of Norwegian 9- and 15-year-olds. *Scand J Med Sci Sports*. Published Online: Apr 14 2009. DOI: 10.1111/j.1600-0838.2009.00892.x.

II. Kolle E, Steene-Johannessen J, Andersen LB, Anderssen SA. Seasonal variation in objectively assessed physical activity among children and adolescents in Norway: a cross-sectional study. *Int J Behav Nutr Phys Act*. 2009; 6:36.

III. Kolle E, Steene-Johannessen J, Klasson-Heggebø L, Andersen LB, Anderssen SA. A 5-year change in Norwegian 9-year-olds objectively assessed physical activity level. *Med Sci Sports Exerc*. 2009; 41:1368-1373.

IV. Kolle E, Steene-Johannessen J, Holme I, Andersen LB, Anderssen SA. Five-year changes in body composition among 9-year-olds in Oslo, Norway. Submitted.

CONTENTS

1. INTRODUCTION

1.1 Physical activity and aerobic fitness - definitions and basic principles

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (1). It is a complex behavior that occurs in a variety of forms and contexts including free play, exercise, physical education and organized sports. Physical activity consists of several dimensions including: *duration* (units of time); *frequency* (number of sessions per time unit, bouts or days); and *intensity*. The term metabolic equivalent (MET) is often used to describe physical activity intensity. One MET is equivalent to the energy expenditure of resting metabolic rate (RMR), and for adults, 1 MET is considered equal to a oxygen uptake (VO_2) of 3.5 ml·kg^{-1}·min^{-1} or 1 kcal·kg^{-1}·min^{-1} (2). Compendium values are commonly used to convert subjects' physical activity into an estimation of calorie use (3; 4). The first compendium MET levels were applicable for adults, and recently a compendium of energy expenditures for youth has been published (5). RMR is higher in children than in adults, and somewhat higher in boys than in girls (6). The increased RMR is probably due to a variety of factors, including age, growth, puberty, body mass and body composition. The duration, frequency and intensity of the activity make up the *total volume* of the activity, and yields the energy expenditure associated with total physical activity.

Other important dimensions of physical activity are *type* or *mode* of the activity, which refers to the different specific activities in which subjects are engaged (e.g., running, bicycling, walking, football), and the activity *domain* (the context or reason for the physical activity, e.g., playground, transport, leisure, physical education) (7).

Aerobic fitness is a set of attributes rather than a behavior (1), and it is a result of genetics and stage in the lifespan, as well as physical activity levels. Aerobic fitness, defined as maximal oxygen uptake (VO_2max), is generally considered to be the best marker for the functional capacity of the cardiorespiratory system. VO_2max may be defined as the ability to deliver oxygen to the muscles and to utilize it to generate energy during exercise (8). VO_2max is expressed either as an absolute rate (i.e., l·min^{-1}) or relative to body weight (i.e., ml·min^{-1}·kg^{-1}) (2). Because large persons usually have large absolute VO_2 by virtue of larger muscle mass, the latter allows a more equitable comparison between individuals of different body mass.

An important distinction between physical activity and aerobic fitness is the intra-individual day-to-day variability. Physical activity varies on a daily basis, whereas aerobic fitness will remain relatively static, taking time to change. This variability will impact on the ability to measure these two quantities and consequently influence the ability to demonstrate their relationship with health outcomes.

1.2 Physical activity, fitness and health of children

Physical inactivity is associated with health risks across the lifespan, and the World Health Organization estimates that 1.9 million deaths throughout the world are attributable to physical inactivity (9). Among adults, both physical activity and aerobic fitness are inversely related to mortality (10; 11), and the relationship between regular physical activity and a lower risk of cardiovascular disease (CVD), type 2 diabetes, some cancers and osteoporosis is well-documented (9; 12).

In children and adolescents there is a lack of hard health endpoints. Also, assessing physical activity is a complex task (13), therefore, the relationship between physical activity and health in children appear to be less clear-cut. Nevertheless, physical activity is known to be important for children's healthy growth and development (14). Evidence-based data are also strong for beneficial effects of regular physical activity on musculoskeletal health, adiposity in overweight youth, and blood pressure in mildly hypertensive adolescents (15; 16). Physical activity has also proven to be beneficial for lipid and lipoprotein levels and adiposity in normal weight and overweight children and adolescents, blood pressure in normotensive youth, other cardiovascular variables, self-concept, anxiety, depression symptoms, and academic performance (15; 17-19). It also appears to be an independent association between physical activity and metabolic health in children (20), and physical activity might also be necessary to prevent insulin resistance (17).

Population studies have shown an independent relationship between aerobic fitness and single risk factors for CVD in children (21; 22) while a recent study reported a strong association between aerobic fitness and clustering of CVD risk factors in children and youth independent of age, sex and country (23). A consistent finding is the strong relationship between aerobic fitness and body composition (24; 25). Furthermore, aerobic fitness in childhood is important as it seems to track from childhood to adulthood (26-28).

1.3 Childhood overweight and obesity

Obesity is often defined simply as a condition of abnormal or excessive fat accumulation in adipose tissue, to the extent that health may be impaired (29). The underlying cause is the undesirable positive energy balance and weight gain. Classifying overweight and obesity during childhood or adolescence is complicated by the fact that height is still increasing and body composition is continually changing. A wide variety of methods are available to measure body composition, including laboratory techniques such as *underwater weighing* and *dual-energy radiograph absorptiometry (DXA)*. These methods have high reliability and validity and are therefore considered to be the gold standard for body composition assessment. Underwater weighing and DXA may be used as reference methods (30-32), however, in epidemiological research the use of these methods has been limited because of their complexity and cost.

In public health evaluations, anthropometric-based measures are commonly used, such as skinfold thickness, waist and hip circumference, or various height- and weight-based indices such as weight-for-height, ponderal index (kg/m^3) and body mass index (BMI) (33). *BMI* (in kg/m^2) is usually used to classify underweight, overweight and obesity in adults. In recent years, the use of BMI to classify children and adolescents as overweight or obese is well established (34). However, BMI is only a proxy measure used to estimate degree of body fatness; further, BMI does not distinguish between weight due to muscle and weight due to fat and fails to capture body fat distribution. Body fatness has also been estimated from measurements of *skinfold thicknesses*, which correspond well with various laboratory estimates of body fatness (33). The method is simple with minimal costs; however, it is open to numerous sources of both random and systematic errors. *Waist circumference (WC)* has been recommended as a means of identifying persons at risk of morbidity associated with central adiposity. The method has several advantages by being relatively easy to measure, reliable and inexpensive.

The two most widely recommended indicators of overweight and obesity in children and adolescents are; 1) age- and sex-specific BMI values presented by the International Obesity Task Force (IOTF) that correspond to BMI values of 25 and 30 at 18 years (35); and 2) BMI for age and sex percentile reference data with arbitrary cut-offs, often the 85th and 95th percentiles in a specific population. Both definitions are strong predictors of the development

of CVD risk factors in young adulthood (36). The prevalence of childhood overweight and obesity depends on the criteria used. By using the cut-offs described by IOTF (35), 35% of school-aged children in the US (37), 23% of 2-16-year-olds in Australia (38), 27–36% of 7-11-years-olds in Mediterranean countries (39) and 20% of 4-18-year-olds in the UK (40) are currently classified as overweight or obese. In Scandinavia, 15-25% of Swedish 10-year-olds (41; 42), 16-22% of Norwegian 8-12-year-olds (43-45) and 8-13% of Norwegian 15-year-olds have been defined as overweight or obese (43; 44).

The high prevalence of childhood overweight and obesity is of concern because it has shown to have deleterious health consequences like hypertension, dyslipidaemia, and hyperinsulinemia (46; 47), and social consequences with obese children being stereotyped as unhealthy, socially inept, and lazy (48). Furthermore, obesity in childhood is an independent risk factor for obesity in adulthood (49), and a 32-year follow-up of 227,000 Norwegian girls and boys showed an increasing risk of death by increasing BMI in adolescence (50). Thus, preventing childhood obesity is a public health priority (51).

1.3.1 Secular trends in overweight and obesity

In Norway, there is a lack of anthropometric data measured objectively. Hence, studying secular trends in the prevalence of childhood overweight and obesity is challenging. However, data from Oslo provide evidence that 9-year-old children have increased their mean height, body weight, and BMI from 1920 to 1975 (52). In 1920, an average 9-year-old girl would be 125.3 cm and weigh 24.6 kg, by 1975, she would be 135.0 cm and weigh 29.5 kg. Data from the Norwegian part of the European Youth Heart Study (EYHS) in 1999–2000 (53) and self-report data including 9-year-old children in a nationwide survey (43), show further increases in height and weight. On the whole, there appear to have been secular increases in 9-year-olds height and weight from 1920 to 2000. It is, however, important to emphasize that a shift in height and weight to the right of the whole population might be a healthy sign cause it may reflect a better nutritional status and better health (54). From 1993 to 2000, marked increase in overweight and obesity (based on BMI) has been reported among Norwegian eighth graders (43). Also, data from 1971–74 and 2003–06 have shown increase in both weight-for-height and triceps and subscapular skinfold thickness among 4-15-year-old children living in Bergen, Norway (44). This increase is not caused by increase in height, but is merely a result of increased fatmass. Importantly, earlier maturation affects secular trends in skinfold thickness

(55). In Norway, mean age of menarche has remained unchanged over the last three decades (44; 56). Hence, it is unlikely that the increase in skinfold thickness is caused by earlier maturation.

Recently, some studies have indicated a possible leveling off in the previous steep increase in the prevalence of childhood obesity. From 1997 to 2003, data from Cyprus showed no change in the prevalence of overweight, but an increase in the prevalence of obesity among 11-year-old children (57). From 2000–2001 to 2004–2005, no change in the prevalence of overweight and obesity have been reported among 10-year-old boys in Sweden, whereas a reduction in the prevalence of overweight and obesity was reported in the 10-year-old girls (41). Similar trends have also been observed in the US, where research has shown no increase in childhood obesity between 2003–04 and 2005–06, with a possible fall in prevalence for non-Hispanic white children (58).

1.4 Physical activity

Children have a unique activity pattern that differs substantially from that of adults (59). An observational study reported that children aged 6-10 years had a median bout time of 6 s in light-to-moderate intensity physical activity and 3 s in vigorous-intensity physical activity (60). Ninety-five percent of children spent not more than four continuous minutes at rest, illustrating the intermittent and spontaneous nature of young children's physical activity. Adolescents' physical activity is also likely to differ from adults' physical activity for instance by engaging in higher levels of active transport (e.g., walking or cycling), sports, physical education and physical activities at school (61).

1.4.1 Assessment of physical activity

In children and adolescents, accurate and reliable assessment methods for quantifying physical activity are important for several reasons: to document the frequency and distribution of physical activity in population groups; to determine the amount or dose of physical activity required to influence specific health parameters; to identify correlates; to detect natural changes over time; and to evaluate the efficacy or effectiveness of health promotion programs to alter physical activity (61). Numerous methods for the assessment of physical activity exist, and the methods can broadly be categorized into two groups; subjective (i.e. self-report and

diaries) and objective (i.e. direct observation, accelerometers and pedometers) methods (62). Each method has specific advantages and disadvantages that one must consider when selecting an instrument and these are summarized in Table 1. The variety of methods suggests that no single method can fully reflect a person's activity behavior and the energy cost of activity.

Subjective methods include self-administered recalls, interview administered recalls, diaries, and proxy report from parents or teachers. Data from subjective methods rely on the validity of the reported response by the respondent (14; 63). Among the different subjective methods, self-administered questionnaires are most common in children and adolescents, because diaries are regarded as too demanding, and proxy-reports often provide a very crude measure of children's activity behavior as parents or teachers are unable to observe children all day. Subjective methods have often been used in large epidemiological research or surveillance studies where objective methods have not been feasible. However, the sporadic and intermittent nature of children's activity makes it difficult to capture reliable data via self-report (60). Both the concept of time and the ability to recall accurately are limited by the child's level of cognition, and children under 10 years of age cannot recall activities accurately and are unable to quantify the time frame of the activity (64).

Objective methods of physical activity include indirect calorimetry, doubly labeled water, direct observation, heart rate monitoring, pedometers and accelerometers. Data derived from *indirect calorimetry* offer great precision, however, the expenses and difficulty in implementation of laboratory methods limit their applicability to large population-based studies and free-living activities (65). *Doubly labeled water (DLW)* is considered to be the "golden standard" for the determination of total energy expenditure under free-living conditions. The DLW technique provides no information of the frequency, intensity or duration of activity, but instead accurately assesses energy expenditure over a period of time. The method estimates energy expenditure on a group level within 1-3% measured by respiratory gas analysis in the laboratory (66-68) and the reliability has shown to be about 4-10% (69-71). *Direct observation* is often considered the "golden standard" for physical activity assessment. It involves observing a child at home or school for extended periods of time and use coding forms to recode an instantaneous rating of the child's activity level. The method is particularly relevant if information on children's physical activity in particular

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settings are required. Direct observation has shown to be a valid and reliable tool for assessing physical activity in children (72).

The basic principle when assessing physical activity using *Heart rate (HR)* monitoring is the close relationship between HR and VO_2, hence energy expenditure, during a wide range of exercise intensities. HR is therefore an indirect measure of physical activity as it measures the physiological response to activity and not body movement (73). HR monitoring has shown to be a valid and reliable method, however, other factors than physical activity can influence HR during low intensity physical activity (74; 75). Therefore, HR monitoring should primarily be a tool for the assessment of moderate to vigorous activity, and HR below 120 beats·min^{-1} would not normally be considered to be valid estimates of physical activity (76). The *pedometer* is a devise measuring step frequency by sensing vertical movement of the body. Pedometers provide a daily total of steps taken, and sometimes a calculated distance and energy-expenditure value. Studies have provided evidence for the reliability and validity of pedometers for the quantification of distance walked, number of steps taken (77), and assessment of total daily activity (78). Correlations between VO_2 and step frequency assessed by hip-mounted pedometer reach 0.92 during unregulated play in 9-year-old children (79), whereas another study showed a correlation of 0.59 between pedometer counts and fitness in girls aged 8-10 years (80).

Accelerometers measures body accelerations and are increasingly being used to assess physical activity in children and adolescents. Acceleration is a change in velocity with respect to time (m/s^2), enabling accelerometers to quantify intensity of movement (81). Accelerometers monitor movement in a specific plane. The majority of accelerometers are uniaxial and sensitive to movement in the vertical plane. Sensors measuring acceleration in multiple plans (triaxial) exist, but research has shown that differences between triaxial and uniaxial accelerometers are small, and the correlation between the output are high indicating that they provide similar information (82). To assess accelerations of the body, the monitor is usually placed on the hip or on the back of the body.

Accelerometers capture movement in 'real time' allowing physical activity assessment in specific periods of the day as well as across the whole day. In recent years, accelerometers has shown to be useful for assessing physical activity in large population-based studies (83; 84). Several different models of accelerometers exist, but the Actigraph accelerometer

(Manufacturing Technology Inc., Fort Walton Beach, FL), formerly known as Computer Science and Applications activity monitor, is the most frequently used for physical activity assessment. Intra-instrument reliability has shown to be relatively good (mean CV of 4.4%), although questionable on extreme values of acceleration (85). The Actigraph has been validated in both children and adolescents against a range of methods (86-88). Trost et al (88) reported that activity counts from the Actigraph accelerometer were strongly correlated (r=0.87) with energy cost measured with indirect calorimetry during treadmill walking and running in 10-14-year-old children. Similar findings were revealed in a study by Corder et al (86) who reported a correlation of r=0.71 between physical activity energy expenditure and activity counts during treadmill walking and running in 13-year-old children. Both mentioned studies were laboratory-based taking place in controlled environments. Somewhat lower, but still significant, correlations have been observed between activity counts and physical activity energy expenditure (r=0.54) and physical activity level (r=0.58) measured by DLW in 9-year-old children during free-living activities (87).

Physical activity is a complex behavior and both accelerometers and heart rate monitors are associated with limitations. The relationship between HR and VO_2 is weaker for low-intensity activities compared to more vigorous levels, while high intensity running is underestimated by accelerometry. As the errors associated with these two methods are independent, a combination of the two methods may provide a better measure than either method alone (89). One example of a sensor combining these methods is the Actiheart (Cambridge Neurotechnology, Papworth, UK), a small HR recorder with an integrated accelerometer. Studies in children have indicated that accelerometry combined with HR monitoring gives a greater accuracy in the prediction of children's energy expenditure than either accelerometry or HR alone (86; 90). A downside to the method is the cost of the monitor that prohibits its use in all but small-scale studies.

Table 1. Advantages and disadvantages of various physical activity assessment methods (7; 63; 89; 91; 92).

Measure	Advantages	Disadvantages
Doubly labeled water	• Precision of measure • Assess EE	• High cost • Gives an assessment of total EE • No information about PA intensity, duration or frequency
Direct observation	• Provides detailed quantitative and qualitative PA information • Provide information about PA behavior (e.g. behavioral cues, environmental conditions and the presence of significant others) • Software programs available to enhance data collection and recording	• Labor- and time-intensive data collection • Subject reactivity • Suitable to use with a small amount of participants • Time-intensive training needed to establish between- and within-observer agreement
Heart rate monitor	• Measures physiological response to PA • Good association with EE • Describes PA intensity, duration and frequency	• Changes in HR can be caused by other parameters than PA • Susceptible to poor pick-up during free-living conditions • Useful only for aerobic activities
Pedometers	• Inexpensive • Easy to administer in large groups	• Loss of accuracy when jogging or running is being assessed • Specifically designed to assess walking only • No information about PA intensity, duration or frequency
Accelerometers	• Low subject burden • Can detect intermittent and sporadic PA • Describes PA intensity, duration and frequency • Allows for extended periods of recording	• Inaccurate assessment of a large range of activities (e.g., upper-body movement, incline walking, water-based activities, cycling) • Data entry and reduction is complex • Lack of field-based equations to accurately estimate EE in specific populations • Accelerometer counts plateau or even begins to decline at a running speed greater than 9-10 km/h
Self-report	• Easy to administer in large groups • Inexpensive • Low investigator and respondent burden • Describes PA intensity, duration, frequency and mode • Information available to estimate EE from daily living	• Reliability and validity problems associated with recall of activity • Hard to recall intermittent and sporadic PA • Children tend to overestimate high intensity PA behavior, and underestimate moderate PA

EE, energy expenditure; HR, heart rate; PA, physical activity

1.4.2 Physical activity recommendations

Physical activity recommendations are intended to identify the minimum level of physical activity required for good health. The first physical activity recommendations for young people were introduced by the American College of Sports Medicine in 1988 (93). Their proposal was based on the recommendations for adults and recommended that all children and adolescents should achieve 20 to 30 minutes of vigorous exercise each day. Since then, physical activity recommendations have changed several times. In 1998, the physical activity recommendations were updated by the Health Education Authority in the UK (94). The recommendations suggested that both children and youth should participate in physical activity of at least moderate intensity for 60 minutes each day. Their secondary recommendation was that, at least twice a week, some of these activities should help to enhance and maintain muscular strength, flexibility and bone health. In 2005, Strong et al (15) did a systematic review of the evidence base for health and physical activity in school-age children, and the conclusion of the review was close to the existing recommendations. However, the evidence base mainly consists of intervention studies, where the health effect of an exercise intervention added to normal daily physical activity is measured. The total physical activity level is rarely known.

In 2000, the Norwegian physical activity recommendations for children and youth were presented by the National Council on Nutrition and Physical Activity (95). They stated that all children and youth should participate in sport, physical activity or informal play at least 60 minutes per day. The activities should be comprehensive and aim to develop qualities like aerobic fitness, muscular force, agility, flexibility, speed of movement and coordination.

It is important to emphasize that the evidence is scarce for a particular dose-response relation from which physical activity recommendations for children and adolescents can be obtained. Consequently, the recommendations are continuously being discussed (17; 96).

1.4.3 Levels and patterns of physical activity in youth

In recent years, several studies have assessed physical activity by accelerometry in children and adolescents and some of these studies are summarized in Table 2. Different study protocols and data reduction methods make it difficult to compare results; however, some general conclusions can be drawn. First, boys are more physically active than girls (53; 83;

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84; 97-99). Second, sex differences are particularly pronounced at activities of moderate and vigorous intensities (83; 98). Third, physical activity declines from childhood through adolescence (53; 83; 84; 99-101).

Some studies have been published where physical activity has been assessed objectively in large samples of children (83; 84; 99; 102; 103). As can be seen in Table 2, the mean physical activity level (counts·min^{-1}) is comparable between children of the same age in the European countries (53; 83; 84; 97; 98; 103; 104) and in the US (99). One exception is 12-19-year-olds in the US who appear to be somewhat less active than their European peers (99). When studying compliance to physical activity recommendations the picture is less clear. In EYHS, 97–98% of 9-year-old girls and boys, 62% of 15-year-old girls and 82% of 15-year-old boys fulfilled physical activity recommendations (83). Fairly high compliance to physical activity recommendations was also reported by Van Sluijs et al (103), whereas all children met the recommendations in the study by Dencker et al (97). In the Avon Longitudinal Study of Parents and Children (ALSPAC), quite different results were reported (84). Only 5% of boys and 0.4% of girls met physical activity recommendations. These results illustrates that compliance with physical activity recommendations vary noticeably, depending on the accelerometer cut point used to define moderate-to-vigorous physical activity (MVPA). In the studies by Riddoch et al (83), Dencker et al (97) and van Sluijs et al (103), the cut points used to define MVPA were between 1000 and 2000 counts·min^{-1}. In ALSPAC, the cut point for MVPA was considerably higher, and 3600 counts·min^{-1} was used to define MVPA (84).

Table 2. Display of selected studies that have used Actigraph to assess mean physical activity level (counts·min^{-1}) and the prevalence (%) meeting physical activity recommendations.

Citation	Country	Age (yrs)	Population (n) G − B	PA[a] G − B	PA rec (%) G − B
Eiberg et al (2005) (98)	Denmark	6-7	269 − 291	679 − 743	NA
Dencker et al (2006) (97)	Sweden	8-11	116 − 111	618 − 751	100 − 100
Van Sluijs et al (2008) (103)	England	9-10	1046 − 822	636 − 717	59 − 81
Klasson-Heggebø & Anderssen (2003) (53)	Norway	9 15	165 − 172 82 − 119	714 − 839 520 − 622	80 − 87 50 − 62
Riddoch et al (2004) (83)	Norway Denmark Estonia Portugal	9 15	2185 total	649 − 784 491 − 615	98 − 97 62 − 82
Rizzo et al (2007) (104)	Sweden	9 15	132 − 141 133 − 123	663 − 801 484 − 561	NA
Riddoch et al (2007) (84)	England	11	2933 − 2662	529 − 644	0.4 − 5
Pate et al (2006) (102) [b]	US	11-12	1578	NA	88
Troiano et al (2008) (99)	US	6-11 12-15 16-19	309 − 288 308 − 344 262 − 267	568 − 647 382 − 521 328 − 429	35 − 49 3 − 12 5 −10

G, girls; B, boys; PA, physical activity; PA rec, physical activity recommendations; NA, not available
[a]Results are presented as mean counts·min^{-1}
[b]Included girls only

1.4.4 Secular trends in physical activity

Children today are thought to be less physically active than in previous generations. This perception is, among others, based on the increased prevalence of overweight and obesity seen from an early age (39; 43). There are, however, few reliable physical activity data to support this notion. To study secular trends in physical activity, it has therefore been suggested to summate available evidence in other areas of daily activities and then draw tentative conclusions (105). One area where quantifiable data are available is in children's use of transport. Data from the US shows that 41% of students walked or cycled to school in 1969, by 2001 the proportion was 13% (106). In Denmark, the prevalence of children cycling to school was reduced by 30% from 1993 to 1998–2000 (107). In Norway, there are few data to report trends in walking and cycling among children, however, recent data showed that 62% of Norwegian school children walked or biked to school, whereas 69% commuted by car to get to organized leisure time activities (108). In recent decades, there has also been an

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increase in the time children devote to sedentary activities (109). Norwegian adolescent boys have increased their time spent sitting in front of the computer from 1.4 hours·week^{-1} in 1989 to 30.6 hours·week^{-1} in 2005 (110).

Given the high prevalence of childhood overweight and obesity, the increased use of motorized transportation as well as the increased time spent devoted to sedentary activities it is reason to believe that children and adolescents have decreased their physical activity level. At present, few studies have reported on changes in objectively assessed physical activity. Self-report data actually suggest relatively stable MVPA participation among US adolescents during recent decades (111; 112), whereas Australian adolescents have increased their MVPA participation between 1997 and 2004 (113). Further, a study from Denmark reported no change in 8-10-year-olds physical activity assessed by accelerometry between 1997−98 and 2003−04 (114), whereas Swedish 7-9-year-olds increased their weekday physical activity (steps per day) between 2000 and 2006 (115).

1.4.5 Determinants of physical activity in children and adolescents

Physical activity behavior in children and adolescents is associated with different factors (116). These factors are classified as either physiological (e.g., age, gender, ethnicity), psychological (e.g., self efficacy, perception of physical or sport competence, enjoyment), sociocultural (e.g., parental level of physical activity parental support, parental income), or ecological (e.g., access to play spaces, facilities, availability of equipment, season).

The association between childhood physical activity and socioeconomic status (SES) is unclear, and results remain inconclusive. While some studies report an association between children's physical activity level and SES (84; 117), other studies find no such association (118). Moreover, a study from the US revealed that a lower level of parental education was associated with greater physical activity decline when going from childhood through adolescence (119). The reason for the inconsistencies among studies might be that behaviors may be differently related to SES in different cultures, or the different classifications of SES used in each study (120).

Seasonality has until recently received little attention as a potential environmental determinant of physical activity, and the literature on seasonality in children and youth's physical activity

participation is inconsistent. Some studies have reported a significant association between season and physical activity in children (121-125). When studying the association between physical activity and season in adolescents, studies conducted in Denmark (125) and the US (126) found no association, conversely, studies from Portugal (127) and UK (84) have observed significantly different physical activity levels across seasons. Measurement error, different sample characteristic, different geographic regions, and different analysis strategies all increase the likelihood of inconsistent findings across studies.

Although researchers are becoming interested in seasonality, few studies to date have examined this issue by using accelerometers in climatically diverse countries. Knowledge about seasonal participation in physical activity is important, as it will be useful to interventions and health promotion planning. Identification of a particular season or seasons that are characterized by low physical activity levels would enable these periods to be targeted for promotion of physical activity.

1.5 Aerobic fitness

When measuring aerobic fitness in adults, a maximal test is theoretically defined by the plateau of VO_2 with further increases in workload (128). However, it has been shown that children can complete a maximal test without a leveling-off in VO_2. Also, children who plateau in VO_2 during a maximal test do not have higher VO_2, HR, respiratory exchange ratio (RER) or post-exercise blood lactate values than those without a leveling-off (8). The term VO_2max conventionally implies the existence of a VO_2 plateau, but as this response is not typical of young people it has been common to use the term peak VO_2, the highest VO_2 reached during an exercise test to exhaustion, to describe children and adolescents' aerobic fitness (129). If a child during a maximal test demonstrates signs of intense effort supported by objective criteria (e.g., HR>185 beats·min^{-1} and/or RER>1.0), peak VO_2 can be accepted as equal to VO_2max and a maximal index of aerobic fitness. Notably, the terms VO_2max and peak VO_2 have the same physiological meaning (130), and in the present thesis the term peak VO_2 is used.

1.5.1 Assessment of aerobic fitness

Aerobic fitness can be determined using a variety of tests. Peak VO_2 is often assessed objectively in the laboratory using treadmill or cycle ergometer, and these tests can include *direct measurement* of peak VO_2 or *indirect estimation*. *Direct testing* requires sophisticated equipment to measure the volume and gas concentrations of inspired and expired air. Historically, gas exchange was measured by the Douglas bag method which involved the collection of exhaled air in large, impermeable canvas bags and subsequent measurement of gas fractions and expired volumes. The Douglas bag method is precise and has served as the "gold standard" for gas exchange measurements for over a century (131-133). A downside to the method is its time consuming nature and requirement of trained personnel. The gas volume or flow can also be measured electronically, and as the electronic sensors have become gradually smaller, portable instruments that allow the VO_2 to be measured outside the laboratory have now become available (134). *Indirect testing*, on the other hand, requires little or no expensive equipment. There are many indirect tests used to estimate peak VO_2. Some are more reliable and accurate than others but none are as accurate as direct testing.

The many tests for aerobic fitness can be divided into either *maximal* or *submaximal tests*. *Maximal exercise tests* either measure or predicts peak VO_2, and requires an all-out effort where the individual exercise to exhaustion usually on a treadmill or cycle ergometer. More simply, maximal tests can be performed in the field by maximal running tests (performance tests). For instance the *20m shuttle run test (20mSRT)* has been widely used to assess aerobic fitness in children and adolescents (135). The test has shown to be a reliable and valid field test to estimate peak VO_2 (135-138). Large groups can perform this test all at once for minimal costs. A downside to the method is that environmental differences, clothing and running surfaces, test familiarization and instructions, motivation and pacing, and the purpose and context of testing can affect 20mSRT performance. There is good reason to believe that field tests are reliable and reasonable valid estimators of aerobic fitness (139). All maximal tests have a correlation between test results and directly measured peak VO_2 of around 0.8-0.9 within the same age group and sex (the predictive value is mainly driven by the test result and not background variables).

Direct maximal tests are considered the gold standard for assessing peak VO_2, however, as it relies on stressing the body to exhaustion such testing is limited in people whose performance may be limited because of pain rather than exertion and in cases where maximal exercise

testing is contraindicated (140). In such cases, *submaximal tests* which are less demanding can be used. There are two major categories of submaximal tests; *performance* and *predictive tests*. *Performance tests* involve measuring the responses to standardized physical activities that are typically encountered in everyday life (140). Examples are different walking tests and Timed Up & Go tests, but these are mainly used for people with musculoskeletal limitations and are not frequently used in the pediatric population. *Predictive tests* are submaximal tests used to predict maximal aerobic capacity. Typically, HR or VO_2 at two or more workloads is measured (141), and a predicted VO_2 value is obtained by extrapolating the relationship between HR and VO_2 to age-predicted maximal HR. The Åstrand and Rhyming Cycle Ergometer Test is one of the most frequently used submaximal cycle ergometer tests (142). During the test, steady state HR is determined, and this value can be looked up in a nomogram (published by Åstrand and Rhyming) to estimate peak VO_2. A study by Andersen et al (143) showed that using Åstrand's nomogram gave only 82% and 91% of directly assessed peak VO_2 in adolescent boys and girls, respectively. It has been shown that submaximal tests in general have low reproducibility (143), and probably suffers from systematic bias (54).

1.5.2 Aerobic fitness in children and youth

In normal girls and boys, absolute peak VO_2 increases proportionally to body size and mass (144). When peak VO_2 is expressed relative to body mass, it appears that peak VO_2 remains stable in boys throughout childhood and adolescence while it decreases in girls (130). There are two population based studies where peak VO_2 has been assessed directly in adolescents (143; 145), however, there is a lack of population based studies including children. Studies performed include relatively small study samples, where the subjects often are healthy volunteer recruits who are motivated to exercise, and not necessarily representative for the population. Moreover, use of different test protocols and instruments give limitations to the comparisons. For instance, the use of treadmill or cycle ergometer will influence peak VO_2 values. Treadmill running engages larger muscle mass than cycling, peak VO_2 is therefore likely to be limited by central rather than peripheral factors, and is typically 8-10% higher during treadmill running than cycle ergometry (8).

Some studies that have measured peak VO_2 directly are presented in Table 3. In 6-7-year-old children, Eiberg et al (98) reported mean peak VO_2 values of 45 ml·min^{-1}·kg^{-1} in girls and 49

ml·min^{-1}·kg^{-1} in boys. In 9-year-old girls, mean peak VO$_2$ values of 46–48 ml·min^{-1}·kg^{-1} has been reported, whereas the corresponding values in boys were 49–58 ml·min^{-1}·kg^{-1} (146-148). In 14-19-year olds, mean peak VO$_2$ values of 40–49 and 51–61 ml·min^{-1}·kg^{-1} has been reported in girls and boys, respectively (143; 149). The results indicate that sex differences in aerobic fitness are apparent in early childhood. The study by Dencker et al (150) stands out due to low aerobic fitness. Only 71% of the participants reached 85% of predicted max HR, and even fewer children reached an RER≥1.0. This indicates that the children did not exercise until exhaustion, and the peak VO$_2$ values are likely to be underestimated.

Table 3. Display of studies that have measured peak VO$_2$ directly.

Citation	Ergometer	Age (yrs)	Population (n) G – B	Peak VO$_2$ (ml·min^{-1}·kg^{-1})[a] G – B
Eiberg et al (2005) (98)	Treadmill	6−7	283 − 309	44.8 (5.6) − 48.5 (6.0)
Andersen et al (1980) (146)	-	9	22 − 16[b] 11 − 13[c]	49.9 (7.1)[b] − 52.9 (5.1)[b] 45.7 (4.6)[c] − 49.5 (5.0)[c]
Resaland et al (2009) (147)	Treadmill	9	116 − 111	46.9 (7.2) − 52.8 (6.5)
Dencker et al (2007) (150)	Cycle	8−11	108 − 137	35.8 (6.4) − 41.4 (7.2)
Armstrong et al (1995) (151)	Treadmill	11	53 − 111	45 − 51
Rowland et al (2000) (152)	Cycle	11−12	24 − 25	40.4 (5.8) − 47.2 (6.1)
Fredriksen et al (1999) (148)	Treadmill	8−9 14−15 16−17	14 − 12 16 − 24 13 − 13	47.5 − 57.6 48.9 − 60.8 46.5 − 58.5
Knuttgen (1967) (145)	Cycle	15−18	95 − 95	33.6 (4.4) − 50.3 (6.9)
Andersen et al (1987) (143)	Cycle	16−19	156 − 128	40.0 (5.1) − 51.7 (5.8)

G, girls; B, boys
[a]Peak VO$_2$ values are presented as mean (SD). In the studies by Armstrong et al (151) and Fredriksen et al (149) SDs were not reported.
[b]Children attending central schools
[c]Children attending peripheral schools

1.5.3 Secular trends in aerobic fitness

Based on the lack of large population based studies assessing aerobic fitness directly, little is known about children and adolescents' trend in peak VO$_2$. Aerobic fitness is a modifiable CVD risk factor, consequently it is important to monitor changes in fitness in the population in order to be able to intervene if the levels decline.

Currently, no studies have been published assessing secular trends in aerobic fitness using direct measurements of peak VO_2, but some studies have reported changes in indirect measures of aerobic fitness. Wedderkop et al (153) analyzed secular trends in Danish 9-year-olds, measured 12 years apart. By predicting peak VO_2 from an indirect cycle ergometer test to exhaustion, the authors reported that boys, but not girls, tested in 1997–98 were less fit and fatter than those measured 12 years earlier. Tomkinson and Olds (154) published an extensive review quantifying the global change in pediatric aerobic running test performance in more than 25 million 6- to 19-year-olds from 27 countries between 1958 and 2003. The results revealed a decline in aerobic running performance of –0.36% per annum. The secular change was reported to be consistent across age, sex and geographical groups, but not over time as aerobic fitness improved from the 1950s until about 1970, and then declined at a rate of –0.46% per annum after 1970. Both mentioned studies emphasized the fact that fatness increased over the same time period which may explain the decrease in predicted peak VO_2 and change in running performance as the subjects carry their own body weight. From 1980 to 2002, an 8% decline in aerobic fitness has been reported in Norwegian military recruits (155). This study predicted peak VO_2 from a submaximal cycle ergometer test, which, as previously mentioned, are known to have low reproducibility and may have severe bias related to the ergometers and manual measures of HR (54). Andersen et al (156), on the other hand, found no change in estimated peak VO_2 in adolescent girls and boys from 1983 to 2003. Importantly, the authors showed evidence of the difficulties by studying secular trends in aerobic fitness when peak VO_2 is measured indirectly. While no change was seen in estimated peak VO_2 over the time period, a decrease was seen in maximal power output (MPO). A validation study showed that the decrease in MPO was not caused by a decrease in peak VO_2; however, the authors suggested that the decrease could be caused by differences in the ergometers even if those were calibrated repeatedly.

2. NEED OF NEW INFORMATION

There is a need of population based studies including nationally representative samples of children and adolescents describing their physical activity level and aerobic fitness using objective, reliable and valid methods. The four papers included in this thesis all strive to increase the level of knowledge with regards to 9- and 15-year-olds physical activity level, aerobic fitness and their body composition. Knowledge about the activity patterns, factors related to physical activity, as well as fitness levels can help inform public health policy. Importantly, precise and valid physical activity, aerobic fitness and body composition data can be used to monitor time-dependent trends and help us understand how these factors changes over time.

Specific aims of the separate papers were as follows:

o   To describe current physical activity levels among Norwegian 9- and 15-year-olds using accelerometry, and to determine compliance with physical activity recommendations (**Paper I**).

o   To assess aerobic fitness in children and adolescents using direct assessments of VO_2 during a cycle ergometer test to exhaustion (**Paper I**).

o   To compare physical activity across seasons and to determine compliance with current physical activity recommendations across seasons (**Paper II**).

o   To describe five-year changes in 9-year-olds objectively assessed physical activity (**Paper III**).

o   To describe five-year changes in the prevalence of overweight and obesity among 9-year-olds, and to study changes in fatmass and fat distribution by investigating changes in the children's waist circumference and skinfold thickness (**Paper IV**).

3. MATERIALS AND METHODS

3.1 Study design and sampling

Papers I and **II** were based on the Physical Activity among Norwegian Children Study (PANCS), which is a national, cross-sectional examination of randomly selected 9- and 15-year-old children and adolescents in Norway (children from fourth and tenth grade). **Papers III** and **IV** are based on two cross-sectional studies; EYHS carried out in 1999−2000 (157) and a sub-group of PANCS carried out in 2005, including 9-year-old children living in Oslo.

Study sample

In **Papers I** and **II,** Statistics Norway selected the cohorts by cluster sampling, with schools as the primary unit. In the selection of schools, population density and geography was taken into account. Schools for children with special needs and schools with less than 10 students in either fourth or tenth grade were excluded, leaving 96% of Norwegian fourth and tenth graders in the sampling frame. Figure 1 provides an overview of recruitment of schools and children. Children and adolescents from 63 of 68 invited schools participated in the study. When a school consented to participate, all children in fourth or tenth grade were invited to participate in the study. A total of 2299 9- and 15-year-olds participated, yielding a participation rate of 82%.
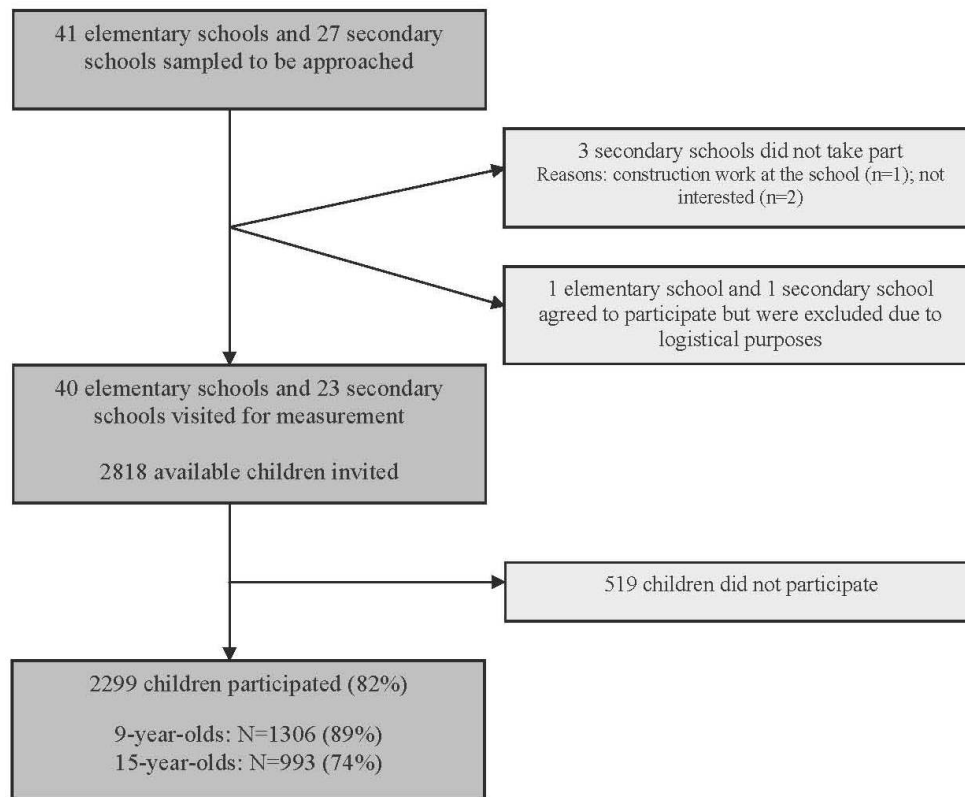
Figure 1. Flowchart of recruitment of schools and participants into **Papers I** and **II**.

In 1999, all elementary schools in Oslo were stratified according to the socioeconomic character of their local area (**Papers III** and **IV**). A proportional sample of schools was randomly selected from each of three socioeconomic strata (low, middle and high) based on the number of students attending each school. In 1999−2000, fourth graders were recruited from nine elementary schools in Oslo. The same schools were included in the 2005 study, and the flowchart of the study population is presented in Figure 2. In 1999−2000, 410 of 578 invited fourth graders participated in the study, giving a participation rate of 70.9%. In 2005, 449 of 491 invited children were included in the study, giving a participation rate of 91.4%.

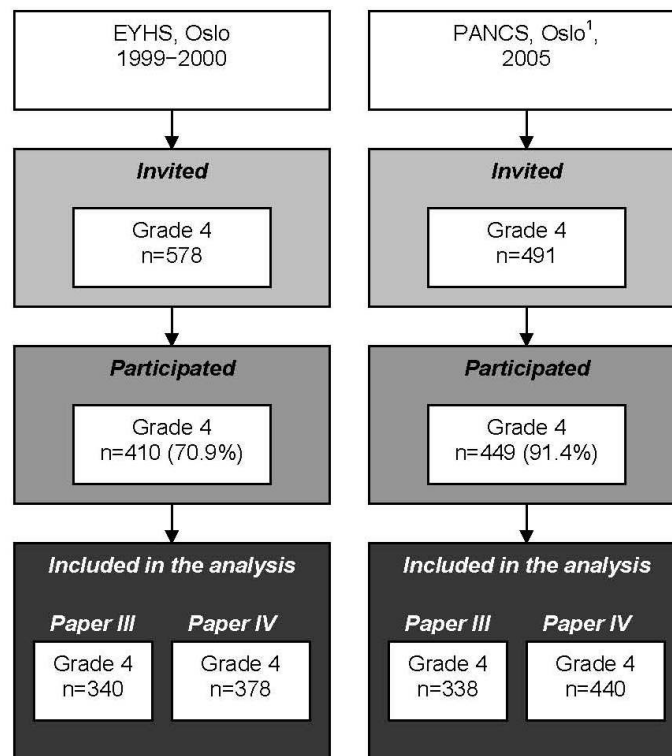**Figure 2.** Flow chart of the study populations in **Papers III** and **IV**.
[1]This population is a part of the total sample included in the Physical Activity among Norwegian Children Study (**Papers I** and **II**).

Measurements and tests were performed at the respective schools, and 10 to 15 children were examined per day. The data collection in **Papers I** and **II** started March 2005 and finished October 2006. In EYHS, the data collection started in October 1999 and finished in June 2000, while the data collection in the Oslo part of PANCS started in March 2005 and finished in June 2005 (**Papers III** and **IV**). All participants were sent an information sheet outlining the aims of the study, its possible hazards, discomfort, and inconvenience. Written, informed consent from the child's parent or legal guardian was required for participation in the study (Appendix 1). Both studies were approved by the Regional Committees for Medical Research Ethics and Norwegian Social Science Data Services (Appendixes 2 and 3), and performed by the rules stipulated by the Helsinki declaration.

3.2 Sample size

In the sample size calculations in **Papers I** and **II**, physical activity and aerobic fitness were the primary outcome variables. The sample size calculations for differences between groups were based on numbers required per cell to detect a difference of 4% in aerobic fitness ($ml \cdot min^{-1} \cdot kg^{-1}$) and 7% in physical activity level ($counts \cdot minute^{-1}$). Calculations were made using a two-tailed test assuming Type I error rate=0.05; and statistical power=0.8. Calculations indicated that the study would require 444 subjects per gender and age group, which gave a total of 1776 9- and 15 year-olds (444 x 4). Because cluster sampling was used, a design effect of 1.1 was incorporated, giving a final target sample size of 500 subjects per age and gender group.

In **Paper III**, the 1999−2000 study comprised 340 children and the 2005 study comprised 378 children with valid physical activity assessments. With physical activity ($counts \cdot min^{-1}$) as the primary outcome variable, the variability known from the baseline population (SD=286) was used to calculate the minimum size of differences that could be distinguish between subgroups. With respect to this, 340 children in each group gave the ability to detect sub-group physical activity differences of 30 $counts \cdot min^{-1}$ (4%) (α=0.05), using a two-tailed test (1-β=0.80).

3.3 Measures

3.3.1 Anthropometry

Trained research assistants performed all anthropometric measures (**Papers I–IV**). Body weight and height were measured while the children were in light clothing and without shoes. Weight was measured to the nearest 0.1 kg with a digital Seca 770 scale (SECA GmbH, Hamburg, Germany). Height was measured to the nearest 0.1 cm, using wall mounted tapes, with the child standing upright against the wall. BMI was calculated as weight (kg) divided by the height squared (m^2).

In Paper IV WC was measured with a metal anthropometric tape midway between the lower rib and the iliac crest at the end of a gentle expiration. Four skinfold thickness measurements (triceps, biceps, subscapular and suprailiac) were taken on the left side of the body using Harpenden skinfold caliper (John Bull; British Indicators Ltd., West Sussex, England)

according to the criteria described by Lohman et al (158). Duplicate measurements were taken for each skinfold, with a third measure taken if the difference between the two measurements differed by ≥ 2 mm. The two closest measurements were the averaged. No data on reliability and accuracy of anthropometric measures were reported in EYHS, Oslo. In PANCS, the intra-class (within-observer) correlation coefficients were ≥ 0.95 for skinfold measurements and 0.93 for WC, while the inter-class (between observers) correlation coefficients were ≥ 0.84 for skinfold measurements and 0.94 for WC.

Sexual maturity was assessed using Tanners five stages (159). The assessment was performed by a researcher of the same gender as the child, using brief observation. Sexual maturity was identified using a 5-point scale of pictures, according to breast development and pubic hair in girls and genitalia and pubic hair in boys. In **Paper IV**, the 9-year-olds sexual maturity was based on breast development in girls and pubic hair in boys.

3.3.2 Physical activity assessment

The uniaxial MTI Actigraph accelerometer (model 7164; Manufacturing Technology Inc., Fort Walton Beach, FL) was used to assess physical activity. This is a small (4.5 × 3.5 × 1.0 cm), lightweight (43 g) monitor that measures acceleration in the vertical plane. The monitor samples voltage signals in proportion to detected accelerations (range: 0.05-2.0 g with a frequency rate of 0.25-2.5 Hz) with a sample rate of 10 measures per second. These settings capture normal human movement but filter out high frequency vibrations. The analog acceleration is filtered and converted to a digital signal and this value (count) is stored in user-specific time intervals. To minimize inter-instrumental variation, all accelerometers were calibrated regularly against a standardized vertical movement.

The participants visited at their school, and each child and adolescent was fitted with an accelerometer in an elastic belt around their waist, worn for four consecutive days (two weekdays and two weekend days). Children and adolescents were asked to wear their accelerometers during waking hours and to take it off only for showering, bathing or water sports. In **Papers I** and **II**, the physical activity assessments were undertaken during all months except July and August. In **Paper III**, the physical activity assessments in both studies were undertaken during the same months of the year (February to June), with the exception of one school in 1999 where data were collected in October and November.

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3.3.3 Aerobic fitness assessment

In **Paper I**, aerobic fitness was assessed through a maximum exercise test on an electronically braked cycle ergometer (Monark Ergomedic 839E; Varberg, Sweden). Initial and incremental work rates were 20 watts for 9-year-olds weighing <30 kg, 25 watts for 9-year-olds weighing ≥30 kg, 40 watts for 15-year-old girls and 50 watts for 15-year-old boys. The workload increased every third minute until exhaustion. The pedal frequency was set at 60-70 revolutions per minute. HR was recorded throughout the test using a heart rate monitor (Polar Electro Yo, Kempele, Finland) and VO_2, RER and ventilation was measured every 10s during the last minutes of the test using a portable MetaMax III X oxygen analyzer (Cortex Biophysics, Leipzig, Germany). Peak VO_2 was defined as the mean of the three highest consecutive measurements. Every morning the analyzer was calibrated against known gas mixtures, and barometric pressure against values from the local weather station. Before each test the analyzer controlled the ambient air and temperature in addition to a volume calibration to take into consideration possible variations in test environment.

If RER was ≥0.99 or max HR was ≥185 beats·minute^{-1} and the test leader judged the subject to show signs of intense effort (e.g. facial flushing or difficulties in keeping up the pedal frequency) the test was accepted as maximal. Eight percent of the girls and boys failed to meet these criteria, while 4% were absent on the test day. Hence, 2,027 (88%) children and adolescents had valid tests and were included in the analyses.

Peak VO_2 was missing in 159 individuals due to failure of the VO_2 analyzer. Based on data from the present study, values were imputed for the missing individuals using the following equation:

9-year-olds: Peak VO_2 (l·min^{-1}) = 0.452 + (0.0108 × W_{max}) + (0.033 × sex)
15-year-olds: Peak VO_2 (l·min^{-1}) = 0.465 + (0.0112 × W_{max}) + (0.172 × sex),
where sex=0 for girls and sex=1 for boys.

Wattmax (W_{max}) was calculated according to the following formula (160):
W1 + (W2 × t/180), where W1 = workload (W) at each fully completed stage, W2 = workload increment at the final incomplete stage and t = duration (s) of final incomplete stage.

A validation study of the MetaMax III X oxygen analyzer showed that the analyzer was stable (<2% variation) at repetitive measurements over a 30-minute period. Repetitive measurements over 12 days also showed less than 2% day-to-day variation at different work rates (4 km/h, 8 km/h and 12 km/h). Additionally, the MetaMax III X oxygen analyzer was validated against the Douglas bag method. At all work rates the analyses showed a systematic 8% overestimation of the oxygen consumption measured by MetaMax III X; consequently all peak VO_2 measurements were corrected downwards by a factor of 1.08.

3.3.4 Socioeconomic status (SES)

In **Paper III**, the classification of SES was based on the economic profile of the catchment area of the schools the children attended. On the basis of the average gross income per inhabitant aged between 30 and 66 years liable to pay taxes within the different school catchment areas, the local authorities calculated the percentage inhabitants who had a gross income considered as high (in 1997 defined as > US $50,000). This calculation was used to divide the catchment areas into three gross income groups: low-, middle-, and high-SES areas. From these three subgroups four schools from low-SES areas, two schools from middle-SES areas and three schools from high-SES areas were included. The clustered SES code was assigned to each child within the dataset.

3.3.5 Ethnicity

In **Paper IV**, the child's parent or legal guardian was asked to select the child's most appropriate ethnic group from the categories: White (Caucasian), Black-African, Black-other, Pakistani, Vietnamese, Chinese, Indian, Arabic and Other (Appendix 4). In both study periods the majority of children were Caucasian (1999−2000: 84%; 2005: 77%). As the other ethnic subgroups were small, these groups were merged in the analyses resulting in two ethnic groups called "western origin" and "non-western origin".

3.4 Physical activity data reduction and analysis

The Actigraphs were initialized to start recording at 6 am on the day following distribution. In **Papers I** and **II** an epoch time of 10 seconds was used. In **Paper III**, the epoch time was set to 60 s in 1999–2000 and 10 s in 2005, but the latter were subsequently summed to 60 s

intervals before further analyses. The Actigraphs were initialized using an Actigraph Reader Interface Unit with RIU software (K64, Computer Science & Applications Inc, Shalimar, FL) connected to a PC. After data collection, each monitor was downloaded to a computer by the RIU software for subsequent data reduction and analysis. A SAS-based software program (SAS Institute Inc., Cary, North Carolina, USA) called CSA-analyzer (http://csa.svenssonsport.dk) was used to analyze accelerometer data. In the analyses of accelerometer data, all night activity (12−6 AM) was excluded. Also, time periods of at least 10 consecutive minutes of zero counts were deemed to represent periods when the monitor was not worn and were thus disregarded before analysis. A newly published study (161) reported that the single-day intraclass correlation coefficient (ICC) for 600 minutes of assessment was 0.45, while the ICC for 480 minutes of assessment was 0.44. To avoid loosing statistical power, 480 minutes was chosen to identify a valid day. In **Papers I** and **II**, data were considered valid if a child had at least two days of at least 480 minutes per day recorded. In **Paper III**, data were considered valid if a child had at least three days of at least 480 minutes per day recorded.

To establish whether there were differences in activity levels between children with different numbers of days with measurement, mean activity level (counts·min^{-1}) was calculated separately for participants with 2, 3 and 4 days of valid activity measurement (**Papers I** and **II**). Using analysis of variance (ANOVA), no difference in physical activity level was detected for the subjects with 2, 3 and 4 days. Furthermore, although a weekend day was not specified in order to fulfill valid activity criteria, 93% of the participants had at least one weekend day of recording.

In Papers I−III, the total amount of physical activity from the activity monitor was expressed as the average of total counts per minute of registered time (counts·min^{-1}). MVPA was defined as all activity above 2000 counts·min^{-1}. This threshold corresponds to a walking pace of about 4 km/h in children (3 metabolic equivalents) (88; 162), and has been applied in previous studies (17; 103; 163). Vigorous physical activity (VPA) was defined as >3000 counts·min^{-1}. The proportion of children and adolescents who achieved the recommended 60 minutes of daily MVPA was established by dividing total time in MVPA (min) by the number of valid days of recording, giving an average (min·day^{-1}) across the assessment period.

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3.5 Statistics

In **Papers I-IV** demographic variables were given as mean values and SD. Differences in physical activity level between sex and age groups were tested by ANOVA (**Papers I** and **III**). In **Paper III** ANOVA with a Bonferroni correction for multiple comparisons was also used to compare physical activity level across SES groups. In **Papers I** and **III** differences of proportions meeting physical activity recommendations was assessed using chi-square analysis.

In **Paper II**, general linear models were used to study the association between sex, age group, mean physical activity and season. Logistic regression analysis was applied to study the percentage meeting the physical activity recommendations in relation to sex, age group and season. The results were presented as odds ratios (ORs) with 95% confidence intervals (CI).

In **Paper III** analysis of covariance (ANCOVA) was performed to test for the effect of study period on physical activity with sex and school as covariates. In separate analysis for girls and boys, ANCOVA was also used to test for the effect of SES and study period, with BMI as a covariate on mean physical activity and MVPA. The patterns of associations were compared among different SES groups by testing interaction terms (study period*SES).

Logistic regression was applied to study five year changes in overweight (including obesity) in **Paper IV**. School and sexual maturity were included as covariates and the results were presented as adjusted ORs with 95% CIs. Changes in anthropometric variables between 1999–2000 and 2005 were tested by using ANCOVA. The anthropometric variable was defined as the dependent variable, study period was the fixed factor, while age, sexual maturity and school were covariates. Standardized change was assessed by investigating changes in Z-scores for BMI, WC and sum of 4 skinfold thicknesses ([mean 2005 – mean 1999–2000] / SD 1999–2000). Shift in BMI, distribution was assessed by using general linear model. BMI was defined as the dependent variable in the model, and study period and deciles of BMI were the main predictors. Shift in BMI distribution was investigated by testing interaction terms (study period*deciles of BMI). The same procedure was performed to test for shift in WC and sum of 4 skinfold thickness.

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 15.0.

4. RESULTS

This chapter presents the main results from each of the four papers. Some additional analyses have been included to investigate some topics more comprehensively.

4.1 Characteristics of the subjects (Papers I-IV)

Four groups of subjects participated in **Papers I** to **IV**. The subjects' anthropometric and physical activity data are shown in Table 4. The standard deviations for some of the variables are high which indicates diversity in the population.

Table 4. Characteristics of the participants in **Papers I-IV**. Values are mean (SD).

Paper	Grade	Subjects (n)	Age (yrs)	Weight (kg)	Height (cm)	BMI (kg/m^2)	PA (counts·min^{-1})
I [a]	4	583 G	9.6 (0.4)	33.8 (7.1)	138.3 (6.8)	17.6 (2.7)	693 (251)
		684 B	9.6 (0.4)	34.0 (6.4)	139.9 (6.2)	17.3 (2.4)	796 (281)
	10	447 G	15.5 (0.4)	58.1 (8.7)	165.9 (6.2)	21.1 (2.8)	487 (167)
		486 B	15.6 (0.4)	64.7 (12.1)	175.8 (7.2)	20.9 (3.5)	542 (199)
II	4	525 G	9.6 (0.4)	34.0 (7.1)	138.4 (7.0)	17.6 (2.7)	693 (251)
		602 B	9.6 (0.4)	33.9 (6.3)	139.9 (6.2)	17.2 (2.4)	796 (281)
	10	359 G	15.5 (0.4)	57.9 (8.7)	165.6 (6.5)	21.1 (2.8)	487 (167)
		338 B	15.6 (0.4)	65.2 (12.8)	175.7 (7.1)	21.1 (3.7)	542 (199)
III	4 [b]	167 G	9.7 (0.3)	33.1 (6.1)	138.6 (6.3)	17.2 (2.4)	713 (195)
		173 B	9.7 (0.3)	33.3 (5.7)	139.8 (6.4)	17.0 (2.0)	842 (288)
	4 [c]	169 G	9.8 (0.3)	34.9 (7.1)	139.6 (6.8)	17.8 (2.7)	786 (319)
		209 B	9.9 (0.3)	34.6 (6.2)	141.4 (5.9)	17.2 (2.4)	872 (319)
IV	4 [b]	174 G	9.7 (0.3)	33.3 (6.1)	138.7 (6.2)	17.2 (2.4)	708 (195) [d]
		174 B	9.7 (0.3)	33.3 (5.5)	139.5 (6.1)	17.0 (2.0)	862 (297) [d]
	4 [c]	193 G	9.8 (0.3)	34.8 (7.3)	139.6 (6.8)	17.7 (2.7)	782 (319) [d]
		247 B	9.9 (0.3)	34.6 (6.3)	141.5 (6.0)	17.2 (2.4)	874 (322) [d]

BMI, body mass index; PA, physical activity; G, girls; B, boys
[a]Includes subjects with valid assessment of physical activity and/or aerobic fitness
[b]Subjects included in 1999-2000
[c]Subjects included in 2005
[d]Includes subjects with valid assessment of anthropometry and physical activity

4.2 Physical activity (Paper I)

In **Paper I** and **II**, a total of 1824 participants provided valid physical activity measurements that met all inclusion criteria. Reasons for exclusion (n=475) were failing to achieve at least two days of assessment (25%), not wearing the accelerometer (36%), and instrument malfunction (39%).

Mean (SD) accelerometer wear time was 764 (60) min·day^{-1} among the 9-year-olds and 778 (78) min·day^{-1} among the 15-year-olds. The results revealed that 9-year-old boys were 14.9% (95% CI: 12.8, 16.9) more physically active than 9-year-old girls, while 15-year-old boys were 11.3% (95% CI: 8.9, 13.6) more physically active than 15-year-old girls. Physical activity decreased significantly with increasing age as 9-year-olds were 45.5% (95% CI: 43.2, 47.8) more physically active than 15-year-olds.

In all age and sex groups a significantly higher physical activity level was seen during weekdays than during weekends. Nine-year-old boys were 14.9% (95% CI: 12.8, 17.0) and 11.9% (95% CI: 9.9, 13.8) more physically active than the girls during the weekdays and weekends, respectively. Fifteen-year-old boys were 16.0% (95% CI: 13.1, 18.9) more physically active than 15-year-old girls during weekdays, however, no sex difference was observed in weekend physical activity (*P*=0.86). Further, a significant association was observed between physical activity level and season among 9-year-olds but not among 15-year-olds. Nine-year-olds were most active during spring.

Overall, on a daily basis, 9-year-olds spent 86.5 minutes in MVPA and 50.5 minutes in VPA, whilst 15-year-olds spent 64.9 and 42.7 minutes in MVPA and VPA, respectively. Nine-year-old boys were involved in more time MVPA (*P*<0.001) and VPA (*P*<0.001) than 9-year-old girls. The sex difference was smaller among 15-year-olds (*P*=0.007 for MVPA, and *P*=0.002 for VPA). Among 9-year-olds, 75.2% of the girls and 90.5% of the boys met the Norwegian physical activity recommendations of 60 minutes of MVPA daily, while the corresponding values among the 15-year-olds were 49.9% of the girls and 54.1% of the boys.

Activity patterns varied in characteristic ways across the day. The patterns were very different at weekdays and weekend days. On weekdays there were strong spikes of activity before

school, at lunch, immediately after school and in the afternoon. On weekend days, activity peaked between 1pm and 5pm.

4.3 Aerobic fitness (Paper I)

Mean (SD) values for peak VO_2 were the following: 9-year-old girls, 42.9 (6.7) ml·min^{-1}·kg^{-1}; 9-year-old boys, 48.2 (7.1) ml·min^{-1}·kg^{-1}; (12.4% sex difference, $P<0.001$); 15-year-old girls, 41.1 (6.0) ml·min^{-1}·kg^{-1}; 15-year-old boys, 51.9 (8.0) ml·min^{-1}·kg^{-1} (26.3% sex difference; $P<0.001$). Fifteen-year-old boys had 3.7 ml·min^{-1}·kg^{-1} higher peak VO_2 than 9-year-old boys ($P<0.001$), whereas 9-year-old girls had 1.8 ml·min^{-1}·kg^{-1} higher peak VO_2 than 15-year-old girls ($P<0.001$).

Deciles in peak VO_2 by sex and age group are presented in Figure 3. In both age groups differences were found within sexes, showing a larger difference with increasing level of aerobic fitness ($P<0.001$ for interaction between sex and deciles). In each sex and age group, the girls and boys in decile 10 had approximately two times higher peak VO_2 compared to the girls and boys in decile 1.
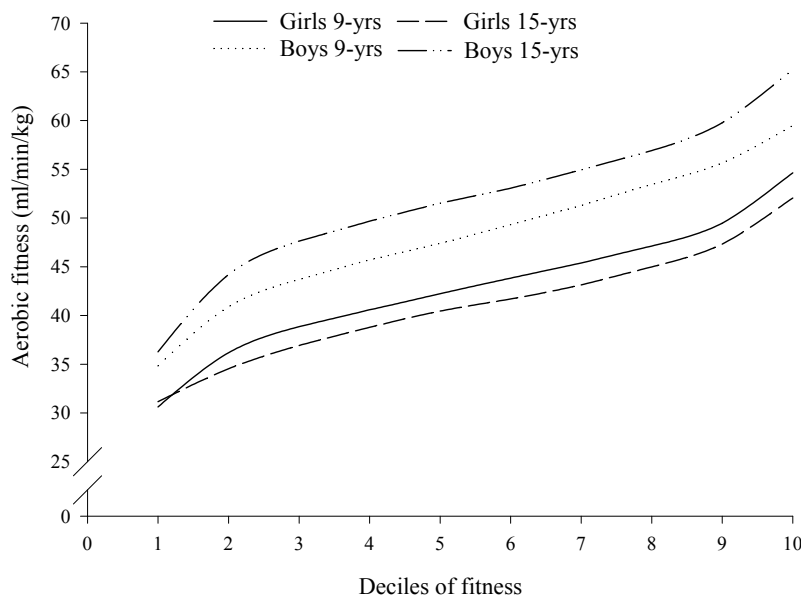

Figure 3. Deciles of aerobic fitness (ml·min^{-1}·kg^{-1}) by sex and age group. The subjects in decile 1 represent the 10% with lowest aerobic fitness, whereas the subjects in decile 10 represent the 10% with highest aerobic fitness.

Changes in aerobic fitness, 1999–2000 to 2005

Aerobic fitness was also assessed in the children participating in EYHS. It was therefore possible to study five year changes in aerobic fitness among the children in Oslo. Identical cycle protocol was used in both EYHS and PANCS; however, the gas exchange was not measured in EYHS. Therefore, peak VO_2 was estimated from W_{max} using the equation calculated in PANCS.

Overall, the 9-year-olds mean (SD) maximal HR during the peak VO_2 test was 197 (7) beats·min^{-1} in 1999–2000 and 198 (7) beats·min^{-1} in 2005. In girls, estimated mean (SE) peak VO_2 was 42.6 (0.5) ml·min^{-1}·kg^{-1} in 1999–2000 and 41.1 (0.5) ml·min^{-1}·kg^{-1} in 2005. In boys, estimated mean (SE) peak VO_2 was 48.6 (0.6) ml·min^{-1}·kg^{-1} in 1999–2000 and 46.9 (0.5) ml·min^{-1}·kg^{-1} in 2005. The decrease in aerobic fitness was significant in both girls (P=0.043) and boys (P=0.019).

Figure 4 shows the aerobic fitness (estimated ml·min^{-1}·kg^{-1}) in deciles for each study period. Of note is that girls and boys in 2005 had lower estimated peak VO_2 than their peers in 1999–2000 in all deciles of aerobic fitness.
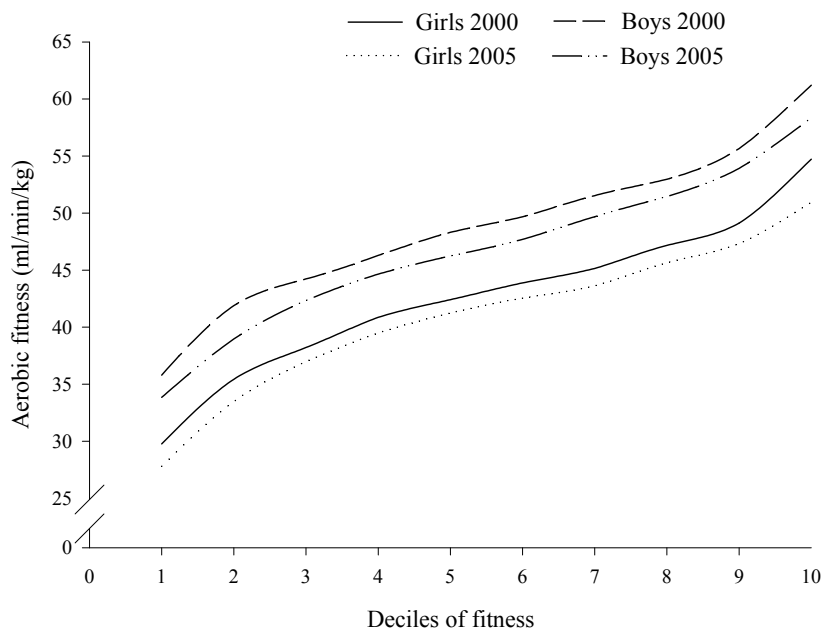

Figure 4. Deciles of aerobic fitness (ml·min^{-1}·kg^{-1}) by sex and study period.

4.4 Seasonal variations in physical activity (Paper II)

In **Paper II**, seasons were defined as periods which fluctuate by weather conditions, daylight hours and temperature, as: "Winter", 1 December – 28 February; "Spring"[1], 1 March – 15 June; and "Fall", 1 September – 30 November.

No significant differences in mean number of valid assessment days or mean number of valid physical activity recordings per day were detected between children assessed in different seasons. Both 9-year-old girls and boys were significantly more active during spring than during winter (girls: mean difference: 188 counts·min^{-1}, 95% CI: 112, 265, $P<0.001$; boys: mean difference 121 counts·min^{-1}, 95% CI: 41, 201, $P=0.001$) and fall (girls: mean difference: 112 counts·min^{-1}, 95% CI: 57, 167, $P<0.001$; boys: mean difference: 113 counts·min^{-1}, 95% CI: 53, 172, $P<0.001$). The physical activity level of 15-year-olds did not differ significantly across seasons.

Among 9-year-olds, the seasonal variation in mean physical activity level was particularly large during weekends. Among girls, the spring-winter difference in weekend physical activity was 240 counts·min^{-1} (95% CI: 120, 361; $P <0.001$) while the spring-fall difference was 174 counts·min^{-1} (95% CI: 87, 260; $P<0.001$). Among boys, the spring-winter difference in weekend physical activity was 204 counts·min^{-1} (95% CI: 99, 309; $P<0.001$) while the spring-fall difference was 159 counts·min^{-1} (95% CI: 82, 237; $P<0.001$). Smaller, but statistically significant differences were also found in 9-year-olds' weekday physical activity. Among girls, the spring-winter difference in weekday physical activity was 158 counts·min^{-1} (95% CI: 80, 236; $P<0.001$) while the spring-fall difference was 73 counts·min^{-1} (95% CI: 17, 129; $P=0.005$). Among boys, the only significant difference in weekday physical activity was found between spring and fall where the difference was 74 counts·min^{-1} (95% CI: 12, 135; $P=0.01$). The results revealed no significant association between season and mean physical activity level during weekdays or weekends among the 15-year-old girls and boys.

For the 9-year-olds, marked differences in the daily activity patterns were observed between the three seasons, particularly in the period between end of school and bedtime. Activity

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[1] Assessments taken in June (summer) (n=121) were categorized as "Spring".

levels were especially high during spring and low during winter. For the 15-year-olds, the daily activity patterns during the three seasons were remarkably similar.

Nine-year-old children had 3.28 times higher odds of meeting physical activity recommendations during spring than during winter. The same pattern was also seen among 15-year-olds who had 1.56 times higher odds of meeting recommendations during spring than during fall and winter.

Additional analyses showed no significant associations between peak VO_2 ($ml \cdot min^{-1} \cdot kg^{-1}$) and season neither in 9-year-old girls ($P=0.19$) or boys ($p = 0.88$) nor in 15-year-old girls ($P=0.72$) or boys ($P=0.99$). Moreover, there were no seasonal differences in mean BMI neither in 9-year-old girls ($P=0.19$) or boys ($P= 0.91$) nor in 15-year-old girls ($P=0.95$) or boys ($P= 0.07$).

4.5 Five-year changes in physical activity (Paper III)

A significant increase in mean physical activity was observed over a five year period ($P=0.02$). The difference in mean physical activity between the children in 1999−2000 and 2005 was 49 counts·min^{-1}, which translates into a 6.2% (95% CI: 4.5, 8.0) difference. Further, physical activity during weekdays showed no change over time ($P=0.4$). However, an increase in physical activity during weekends was observed between the study periods ($P<0.001$). Children in 2005 were 20.8% (95% CI: 17.8, 23.8) more physically active during weekends than children in 1999−2000.

Between study periods, no difference was seen for mean time spent in MVPA or VPA. In 1999−2000, 75.4% of girls and 86.7% of boys met the Norwegian physical activity recommendations of 60 minutes of daily MVPA. In 2005, 79.3% of the girls and 92.8% of the boys met the recommendations, the increase was borderline significant among boys ($P=0.05$).

Physical activity and SES
In 1999−2000, boys from middle-SES groups had significantly lower mean physical activity level than boys from low- and high-SES groups ($P=0.001$ and <0.001, respectively). In 2005, girls from high-SES groups were significantly more active than girls from low-SES groups ($P=0.003$). A significant interaction was found between study period and SES for mean

physical activity for both girls (*P*=0.02) and boys (*P*=0.05). Between studies, the physical activity level among girls from low-SES groups remained relatively stable, whereas an increase in mean physical activity was seen among girls from middle- and high-SES groups. The mean physical activity level among boys from low- and high-SES areas remained fairly stable; however an increase was seen among boys from middle-SES groups.

In 1999−2000, children from low-SES groups participated in more MVPA than children from middle- and high-SES groups (*P*<0.001 and =0.007, respectively). In 2005, there was no association between time spent in MVPA and SES. A significant interaction was found between study period and SES for time spent in MVPA (*P*=0.02). Between studies, the MVPA participation among children from low-SES and high-SES groups remained fairly stable, whereas participation in MVPA increased in children from middle-SES groups.

4.6 Five-year changes in body composition (Paper IV)

In both 1999−2000 and 2005, 83% of the participants were prepubertal (Tanner stage I), and 17% were early pubertal (Tanner stage 2). The IOTF recommended cut-offs based on the age and sex specific values of BMI were used for the definition of overweight and obese children, respectively (35). In 1999−2000, 12.6% of girls and 10.9% of boys were classified as overweight, while an additional 1.1% of girls and 0.6% of boys were obese. By 2005, 15.5% of girls and 15.4% of boys were classified as overweight, and an additional 4.7% of girls and 1.6% of boys were classified as obese. The differences between the two study periods were not statistically significant. In both study periods, logistic regression analyses revealed that children of non-Western origin had higher odds of being overweight than those of Western origin (1999−2000: OR = 2.3, 95% CI: 1.04, 5.00; 2005: OR = 2.0, 95% CI 1.1, 3.59). However, neither the children of Western origin nor the children of non-Western origin showed a significant increase in the prevalence of overweight over the five-year period.

Between the periods of 1999−2000 and 2005, no change was seen for mean BMI, however, the age-adjusted mean WC increased from 60.1 cm to 65.8 cm among girls (*P*<0.001), and from 61.5 cm to 63.4 cm among boys (*P*<0.001). In girls, significant increase was observed for all skinfold measurements. The differences ranged from 2.3 to 3.0 mm at the four sites, while the sum of 4 skinfold thicknesses increased by 10.5 mm which translates into a 25.7% difference (95% CI: 21.2, 30.2). In boys, increase in triceps and supra iliac skinfold

thicknesses were borderline significant (*P*=0.05), while no changes were observed for the other skinfold measurements. When studying the distribution of BMI, WC and sum of 4 skinfold thickness data in the two study periods, there appeared to be a shift to higher values at the upper end of the population distribution (*P*<0.001 for interaction between study period and deciles of BMI, WC and sum of four skinfolds). Among girls, the standardized change (change in Z-score) was 0.21 for BMI, 1.0 for WC and 0.61 for sum of 4 skinfold thicknesses. The corresponding values for boys were 0.09, 0.47 and 0.27.

5. GENERAL DISCUSSION

This thesis presents data from the first large epidemiological investigation on objectively assessed physical activity and directly measured aerobic fitness in a population-based sample of Norwegian children aged 9- and 15-years. The following general discussion will primarily focus on the main results, study populations, and study strengths and limitations.

5.1 Physical activity level

The results from **Paper I** provide novel information of the pattern and intensity of physical activity, as well as the total accumulated physical activity of Norwegian 9- and 15-year-olds. The accelerometer data are in some ways consistent with findings based on self-report (164) and studies using objective assessment (53; 83; 84; 99). The results showed that boys are significantly more active than girls, 9-year-olds are substantially more active than 15-year-olds, and both 9-and 15-year-olds are significantly more active during weekdays than during weekends.

Although these data are cross-sectional, it seems clear that physical activity declines substantially when going from childhood through adolescence. Nine-year-old children were 46% more active than 15-year-olds. The same pattern was observed when investigating activities of higher intensities; 9-year-old children engaged in 76–95 minutes of MVPA daily, while 15-year-old girls and boys accumulated approximately 60 minutes of MVPA every day. It should be noted that physical activity showed high interindividual variability, as the standard deviations for daily minutes of MVPA varied from 23 to 31 minutes in the different sex and age groups. For instance, in 15-year-old girls, 95% of the girls accumulated from 11 to 113 minutes of MVPA daily (±2 SD of the mean).

Several expert panels have recommended that children and youth should participate in at least 60 minutes of MVPA each day (94; 95). The findings of this study suggest that the majority of the 9-year-olds met physical activity recommendations, but only half of the 15-year-olds did. Comparing the prevalence of Norwegian 9- and 15-year-olds meeting recommended levels of physical activity with prevalence data from other countries is challenging. In various studies, the prevalence of children meeting physical activity recommendations differs from 0 to 100% (83; 84; 99; 102). The differences does not necessary reflect true differences in

physical activity in different populations, but is merely a question of accelerometer cut points used to define activity intensities. Usually, moderate-intensity activity is described as equivalent to a brisk walk or activity that noticeably accelerates the heart rate. This relatively loose definition leaves room for different interpretations.

In the present study, the term MVPA refers to activity requiring energy expenditure at least three times greater than RMR. There is reasonable consensus that 3 METs is an appropriate cut point for moderate-intensity physical activity in adults, however, there is no such consensus in youth. In children, RMR is higher than the assumed value of 3.5 ml·kg^{-1}·min^{-1} for adults, so it has been suggested that a value of 3 METs represents a lower relative activity level for youth (84; 102). Therefore, some studies have selected 4 METs as cut point for MVPA (84; 99; 165), resulting in considerably higher accelerometer cut points to define this intensity threshold. For instance, 2000 counts·min^{-1} was used as the threshold for MVPA in the present study, whereas activity above 3600 counts·min^{-1} was defined as moderate in ALSPAC (84). Importantly, the selection of 3 or 4 METs as appropriate intensity cut points for health is arbitrary. To provide an indication of how MVPA cut points can influence compliance with physical activity recommendations, data from the current study were also analyzed using both 2500 and 3000 counts·min^{-1} as cut points for MVPA. A total of 44% and 66% of 9-year-old girls and boys, and 30% and 32% of 15-year-old girls and boys met physical activity recommendations when applying the 2500 counts·min^{-1} cut point. A further reduction in the proportion meeting activity recommendations were observed when applying the 3000 counts·min^{-1} cut point; 15% of 9-year-old girls, 37% of 9-year-old boys, 15% of 15-year-old girls and 21% of 15-year-old boys. Misclassification is always a concern when attempting to determine compliance with physical activity recommendations, and the striking differences demonstrate the need to develop consensus recommendations for reducing and reporting accelerometer data. The chosen MVPA threshold (i.e. 2000 counts·min^{-1}) in the present study might be at the low end of moderate intensity, however, it lies approximately mid-way between the various intensity thresholds derived in children and adolescents, which range from 615 (166) to 3600 counts·min^{-1} (84).

On the whole, data processing decision, such as definition of MVPA will influence adherence to physical activity recommendations. Physical activity is known to have several health benefits, and it is concerning that 50% of Norwegian 15-year-olds are not fulfilling the physical activity recommendations when applying a rather liberal cut point for MVPA.

5.2 Aerobic fitness

The results in **Paper I** are unique because aerobic fitness was measured directly during a maximal cycle test to exhaustion in a large, nationally representative cohort of children and adolescents. The peak VO_2 values are comparable with results from previous studies among children in the same age range using cycle ergometers (143; 152), and as expected, somewhat lower than studies using treadmill test to determine aerobic fitness (147; 148; 151).

Significant sex differences in peak VO_2 values were observed in both 9- and 15-year-olds. Sex differences in peak VO_2 among 15-year-olds are attributed to a number of factors, like lean body mass, hemoglobin concentration and testosterone production (14). During puberty, boys experience increase in muscle mass that is higher than in girls, and the greater muscle mass facilitates the use of oxygen during exercise, and also supplements the venous return to the heart and therefore augments exercise stroke volume. Further, boys' higher hemoglobin concentration is significantly correlated with peak VO_2 and the boys' enhanced O_2-carrying potential is likely to be a contributory factor to the sex difference in peak VO_2. Prior to puberty, sex differences in body composition are minimal. Recent data suggest that sex differences in peak VO_2 in 9-year-olds are due to boys having higher maximal stroke indices than girls (8). Some studies also suggest that physical activity might affect aerobic fitness. A study by Sundberg et al (167) revealed that blind children had significantly lower aerobic fitness than normal children. This was likely to be caused by lower physical activity and especially limited participation in vigorous physical in blind children. It has earlier been thought that physical activity should be of high intensity and of considerable duration in order to improve fitness, but Sundberg's data may indicate that free-living moderate activity may be important to preserve fitness. In the present study, boys had higher mean physical activity level and spent more time in MVPA than girls which might result in a training effect and hence increase the aerobic fitness.

Deciles in aerobic fitness show the diversity in the population. Whereas the fittest children and adolescents showed high peak VO_2 values, the ones in the lowest decile showed a peak VO_2 of 30-36 ml·min^{-1}·kg^{-1}. These values are similar to what has been reported in inactive adults and lower than what has been observed in blind children (167), hence indicating that the physical activity level in this group is low.

In the present study, a significant decline in estimated peak VO_2 was reported from 1999–2000 to 2005, and analyses showed that the whole population had shifted to the left. The latter findings are questionable as it is doubtful that the fit children of today have lower peak VO_2 values than children five years ago. This assumption is reinforced by the increase in physical activity level in the same time period. As identical test protocol was used in both studies, one might speculate if the observed decrease in aerobic fitness were due to differences in cycle ergometers rather than decreased peak VO_2. Previous studies have shown a decline in pediatric aerobic performance over time (139; 154). However, factors like mechanical efficiency, anaerobic capacity and psychosocial factors (e.g. pacing skills, motivation and self-efficacy) contribute to aerobic fitness test performance. Hence, decline in aerobic performance is not necessarily due to decline in peak VO_2. There are no solid data indicating if peak VO_2 is changing over time. Also, it should be emphasized that data on secular trends in peak VO_2 are confounded by the use of the ratio standard to express peak VO_2 (168). If body mass increases, secular declines in peak VO_2 expressed in $ml \cdot min^{-1} \cdot kg^{-1}$ may be observed despite stability in peak VO_2 in $liters \cdot min^{-1}$ (154).

5.3 Seasonal variation in physical activity

The results in **Paper II** showed that Norwegian 9-year-olds had significantly higher physical activity levels in spring than in fall and winter. In the two latter seasons, activity levels were particularly low after school hours and on weekends. No seasonal differences in physical activity were observed among the 15-year-olds. However, both 9- and 15-year-olds had higher odds of meeting recommended levels of physical activity during spring than during winter.

As was the case in the present study, studies from different countries, using different methods to assess physical activity have shown that younger children's physical activity levels are higher in spring than at other times of the year (123-125; 169). It is therefore possible that season have some effect on children's activity. The higher physical activity level during spring might be caused by more time spent outdoors, as studies have shown time spent outdoors to significantly predict children's physical activity (121; 170). The reason for reduced physical activity level during fall and winter remains unclear; however, weather and daylight availability might be the key determinants for low physical activity levels during the cold seasons. In Oslo, the hours of daylight differ from approximately six hours in December

to 19 hours in June, while the areas above the Arctic Circle experience both months with no daylight (winter) and months where the sun never sets (summer). In addition, the months of fall and winter are often characterized by periods of continuous poor and harsh weather (rain, snow and wind), which have shown to be strong deterrents to daily physical activity (171). A combination of low daylight availability and continuous harsh weather might lead to children spending more time indoors. As time spent outdoors is a significant predictor of children's physical activity (121; 170), the consequence might be reduced physical activity level during fall and winter, and lower odds of meeting recommended levels of physical activity .

The present study suggests that seasonality plays only a limited role in physical activity in adolescents. Fifteen-year-old adolescents are more likely to participate in organized sports than free play outside. Consequently, their physical activity level might be less influenced by fluctuation in daylight and weather. With the low physical activity levels during all three seasons, seasonality in 15-year-old's physical activity is of little importance, with interventions needed during all seasons.

There was no seasonal variation in either aerobic fitness or BMI, neither in 9- nor 15-year-olds. Similar findings were reported by Fisher et al (122) who found no significant differences in overweight and obesity across seasons in young children. Physical activity is a behavior, and the activity level is highly variable on a day to day basis. Aerobic fitness and BMI are, on the other hand, stable, robust variables. They will not be affected by day-to-day fluctuations in the daylight and weather in the same way as physical activity, and therefore takes longer time to change.

5.4 Five-year changes in physical activity

The results of **Paper III** revealed that 9-year-old children living in Oslo have increased both their mean physical activity level and their activity level during weekends between 1999−2000 and 2005, with the patterns being similar for girls and boys. This study brakes new ground by being one of the first studies using objective assessment of physical activity to study changes and secular (time) trends in children's physical activity level. This higher level of physical activity after a five-year period is in contrast to the general belief and a report suggesting decline of physical activity among children (105). However, similar results has

been observed in Swedish (115) and Danish children where changes in objectively assessed physical activity have been studied (114).

It is important to address the question whether the observed increase in physical activity is due to real differences in physical activity between groups, or if it can be caused by other factors for instance differences in the methodology used, or to seasonal differences during the data collection. In both studies, the same ActiGraph accelerometers were used. Intra-instrument reliability has shown to be relatively good (mean CV of 4.4%), although questionable on extreme values of acceleration (<1 m·sec^{-2} and >16 m·sec^{-2}) (85). Furthermore, in both studies all accelerometers were calibrated regularly against a standardized vertical movement to minimize inter-instrumental variation. Finally, in both studies, identical data reduction methods were used, which should exclude any systematic differences among studies.

To account for seasonal differences in physical activity, the data collection in 2005 was matched to the time of the year when data was collected in 1999-2000. With the exception of one school in 1999 (tested in Oct-Nov), all data were collected from February through June. As both studies were conducted during the same months of the year, it seems unlikely that seasonal variation in physical activity would influence the study results. Moreover, the results from 2005 revealed that the two schools with highest mean physical activity levels as well as the two schools with the lowest mean physical activity level were assessed in the same month (April). In conclusion, there is no reason to believe that the observed increases in physical activity level were due to seasonal variation in physical activity.

Interactions were revealed between change in physical activity and SES. The association between SES and children and adolescent's participation in physical activity is unclear across studies. Inconsistencies might be caused by the complexity of SES, which is described by multiple indices and also confounded by race/ethnicity (172). In **Paper III,** SES was defined on area-level, which may be biased on the individual level. However, it has been argued that household and neighborhood factors could be important modifiers of physical activity (173). In Oslo, there are strong regional links between socioeconomic background factors and disability and mortality (174), and life expectancy differ by 12 years in low-SES and high-SES areas of the city (175). As the results from the present study revealed associations

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between physical activity and SES in 9-year-old children, our study add to the knowledge of whether neighborhood context affect childhood behavior.

When looking at mean physical activity level in 2005, girls from high-SES areas were significantly more active than girls from low-SES areas. In 1999−2000, 97% of the children in the high-SES group were of Western origin, compared with 78% in the low-SES groups. In 2005, the corresponding numbers were 96% and 68%. In 2005, analyses revealed that girls of Western origin were significantly more active than girls of non-Western origin (mean difference 116 counts·min^{-1}, P=0.029). It might be that ethnic minority girls experience less encouragement from parents and friends to be physically active, and may also have fewer opportunities to be physically active than ethnic Norwegian girls, as the increase in mean physical activity was particularly large among high-SES girls.

5.5 Five-year changes in body composition

In **Paper IV**, there was no statistically significant change in the prevalence of overweight (including obesity) among 9-year-olds over a five year period. However, the prevalence of overweight (including obesity) was 5-7% higher in 2005 than in 1999−2000. Also, the proportion of obese girls increased fourfold in the present study, indicating that a shift has occurred. Further, the results revealed that, while there was no change in mean BMI, there was an increase in WC and sum of four skinfolds (girls only) indicating a change in body shape and body composition. In particular, girls increased their WC by 5.7 cm in five years (9.4%), while the sum of four skinfold thicknesses increased by 25.7%. This is of concern, as both factors are associated with higher disease risk (19). Our results are in line with several investigators showing increases in WC (176-178) and skinfold thickness (44; 179) that are greater than increases in BMI.

The results add to the knowledge regarding changes in distribution of the variables. By studying the percentile distribution, it can be shown whether the heavy children became heavier. Among boys, the patterns of shift (increase) of BMI, WC and sum of 4 skinfold thickness did not appear until approximately the 50th percentile. In contrast, shifts in the girls' values were observed in all percentiles, but BMI, WC, and sum of 4 skinfolds appeared to increase faster in the upper end of the population distribution. This means that the heavier children became heavier, and the fat children became fatter.

Obesity is recognized as a condition of multifactorial origin, but simply put, obesity is caused by long-term positive energy balance (180). In the present study, an increase in skinfold thickness and WC was observed despite the increase in mean physical activity level reported in **Paper III**. Time spent in sedentary pursuits was not investigated. It is still unknown whether sedentary behavior displaces physical activity (109); consequently one might speculate that even though children increased their mean physical activity they might also have increased their sedentary time which again is associated with obesity. The increase in fatmass might also be caused by a change in energy intake. However, data on secular trends in energy intake are sparse and inconsistent, largely due to sampling and methodological variation. Few data are available on specific trends in the energy intake of children adolescents, and on changes in saturated fat consumption as part of total intake. What is known is that over the last few decades, there has been a radical change in how people obtain their food as well as in the composition of the food itself. In Norway, children and adolescents are getting a high percentage of their energy from sugar, and it has increased over the last decades (181). The high sugar intake of sugar is mainly caused by increased consumption of soft drinks and sweets. A prospective study has reported a positive association between intake of soft drinks and BMI (182), whereas another study found that reduction in number of carbonated drinks consumed was associated with a reduction in number of overweight and obese children (183).

5.6 Study design, selection bias and generalization

Papers I–IV are all based on cross-sectional design, where the study subjects are assessed at a single time point. This type of data can be used to assess mean physical activity level and aerobic fitness in a large population, and also to evaluate the relationship between different variables. However, since all data are measured at the same time point causality between variables cannot be concluded (184). Further, it is possible that unmeasured confounding factors other than age group, sex, sexual maturity, school, season and SES may affect the observed relations between determinants and physical activity.

The cohorts included in **Papers I** and **II** were stratified on schools and randomly selected for participation in the study. The headmaster of 63 out of 66 sampled schools were willing to participate, further, 89% of the invited 9-year-olds and 74% of the invited 15-year-olds participated in the study. These rates are satisfactory, and higher than in most studies (53; 83;

44

97; 103; 185; 186). It is therefore safe to assume that the samples studied in **Paper I** and **II** are representative of children of that age and time period, and the results can be generalized to 9- and 15-year-olds in all regions of Norway.

In **Papers III** and **IV,** the cohorts were randomly selected from each of three socioeconomic strata (low, middle and high) in Oslo. The participation was 70.9% in the first cohort (1999−2000) and 91.4% in the last cohort (2005). There is no information on the children who chose not to participate in the study. As the aim of the studies were, among others, to assess physical activity level, aerobic fitness, and body composition, it is likely that the heaviest and least physically active children chose not to participate. Even though the participation rate in both 1999−2000 and 2005 are acceptable, the higher nonparticipating rate in 1999−2000 must be considered a potential source of bias in observed secular changes. The latter indicates that the change in physical activity over the two time points may be somewhat underestimated (**Paper III**) while the changes observed in body composition may be somewhat overestimated (**Paper IV**).

5.7 Strengths and limitations

5.7.1 Strengths of the studies

A major strength of **Papers I−III** was the use of an objective assessment of physical activity in a large population-based sample. Accelerometers are regarded as optimal for quantification of the amount and intensity of physical activity (187), and the use of the device has shown to be both valid and reliable (88). Furthermore, epoch length is a key issue that specifically affects interpretation of children's accelerometer-based physical activity assessment. As accelerometer counts are summed over an epoch, longer epochs (e.g., 1 minute) requires a longer and relatively continuous activity bout to be counted as MVPA (188), resulting in lower overall estimates of MVPA participation. The use of a short epoch time of 10 s which allow the recording of more of the sporadic activity common in children and adolescents is therefore considered as a strength of the present studies. When studying five-year changes in physical activity in **Paper III**, identical data reduction methods were used which should exclude any systematic differences among studies (for instance the 10 s epochs used in 2005 were collapsed to 1 min before analysis).

Direct measurement of VO_2 during a maximal exercise test to exhaustion, as used in **Paper I**, is regarded as the golden standard in exercise testing. The method is precise, valid and has high reproducibility and superior to submaximal testing and indirect exercise protocols used to estimate peak VO_2. A weakness of the used method is the arbitrary criteria used to define a maximum effort. In the present study, the primary consideration for an acceptable test was that the children and adolescents demonstrated signs of intense effort and clear symptoms of fatigue. Test leaders discussed several subjective criteria after each test; hyperpnoea, facial flushing, difficulties in keeping up the pedal frequency, and verbal and body language clearly indicating that the child wanted to stop testing, despite repeated strong oral encouragement. In addition, one objective criteria (HR≥185 beats·min^{-1} or RER≥0.99) was needed to accept the test. These objective values might seem low, however, as mean maximal HR during the peak VO_2 test was 199 beats·min^{-1} and mean RER was 1.07, the subjects in the present study were likely to be exhausted, and hence reached their peak VO_2.

5.7.2 Limitations of the studies

There are limitations in the present studies that need to be addressed. First, use of accelerometers is limited by their inability to capture cycling, swimming, and load-bearing activities (**Papers I-III**). Second, the accumulation of physical activity over two to four days gives a snapshot of the child's physical activity level and may not represent the true physical activity level of the individual (**Papers I** and **II**). The inclusions of individuals who had minimum two valid days of physical activity recordings might affect the study results. Since no difference in mean physical activity was found for the individuals with different number of valid assessment days, no major errors are likely to be introduced by including these individuals. Third, despite the high participation rate**,** in the end only 79% of the participating boys and girls in **Papers I** and **II** had valid physical activity data, while 88% of the participants in **Paper I** had valid aerobic fitness data. However, approximately 40% of the subjects who were not included in the physical activity analyses were explained by instrument breakage, which must be expected to be random across the range of physical activity level.

Fourth, SES was defined on an area-level (**Paper III**). Even though the same nine elementary schools were included in both studies, misclassification could occur if a given area experiences major socio-economic changes between the two study periods. However, there is no evidence that any such changes occurred in Oslo during these five years. Finally, only the

group of 9-year-olds was included (**Papers III** and **IV)**. It would be useful to know if the reported changes in physical activity and body composition are true for children of all age-groups.

5.8 Implications and recommendations

Recommendation 1:

Four out of five 9-year-olds and one out of two 15-year-olds met current physical activity recommendations of at least 60 minutes of daily MVPA. Boys were significantly more active than girls, physical activity declined substantially with increasing age, and both 9- and 15-year-olds had a higher physical activity level in weekdays than in weekends.

- As physical activity have positive health benefits, efforts to increase children's physical activity level should be a high priority.
- Greater attempts should be made to promote physical activity among girls and in weekends.
- Importantly, efforts must be made to avoid the decline in physical activity level when going from childhood through adolescence. Attempts should be made to avoid the decline in organized activities during the adolescent period. By reflecting girls' but also the boys' perspectives and interests, offering a broader array of sports and exercises could both recruit more children and adolescents to organized activities and reduce the drop out of sport seen currently.
- Campaigns are likely to be needed to help parents understand the importance of activity for their children, and to provide parenting strategies to reduce time spent in sedentary pursuits and increase activity time.

Recommendation 2:

Nine-year-old children had significantly higher mean physical activity levels in spring than in winter and fall. In the two latter seasons, physical activity levels were especially low after school hours and on weekends. No seasonal differences in mean physical activity were observed among the 15-year-olds.

- Interventions to increase physical activity during winter and fall should be encouraged, especially for young children.

- The after-school program is an ideal setting to promote physical activity in these periods. Attempts should be made to improve the physical activity opportunities children have in these programs (especially in sedentary children).

Recommendation 3:

From 1999−2000 to 2005, 9-year-old children living in Oslo have increased both their mean physical activity level and their activity level during weekends, with the patterns being similar for girls and boys. However, interactions were found between change in physical activity and SES.

- The Norwegian Government's investment in promotion of physical activity must be sustained in order to capitalize on this improvement and to make further gains to achieve better health for our children and young people throughout their life.
- Efforts should be made to increase access to physical activity opportunities and programs at schools and in community settings, especially for girls and for children from low-SES groups.
- Schools should implement interventions that promote physical activity as the school environment is a good setting to achieve positive health outcomes. This would give children from all SES groups the opportunity to be physically active. Greater efforts should be made to make 60 minutes of daily physical activity mandatory in school curricula. This can be achieved in a cumulative manner during physical education, recess, and before and after school programs.
- Importantly, enhancing teachers' awareness of the importance of adequate physical activity, as well as their skills in physical activity instruction and programming is essential.

Recommendation 4:

The results revealed that where there was no significant increase in prevalence of overweight (including obesity) and mean BMI, there was an increase in WC and skinfold thickness indicating a change in body composition.

- Interventions to promote physical activity, nutrition and healthy weight gain must begin early in life to assist parents to raise healthy children and adolescents.

- As physical inactivity may be an important determinant of weight gain in children, recommendations on sedentary behavior should be developed.
- Further, in addition to measures of body weight and height, measures of WC should be standardized, and routinely incorporated in clinical and epidemiological settings, as well as in school health examinations.

Recommendation 5:

The results of the present studies are a valuable tool to form policy and practice.

- There is a need for ongoing surveillance and monitoring of physical activity, aerobic fitness and body composition in the population of children and adolescents. Hence, PANCS should be repeated every five to ten years.
- Such surveillance would also be an important tool to help evaluate the impact of the Norwegian Government initiatives to promote physical activity.

5.9 Future research

Several questions can be gleaned from the current studies and should lead to future research. First, many cut points or thresholds are available for determining activity intensity, but these are dependent on the type of activity that take place during the measurement period, the type of activity used to calibrate the accelerometer and the data reduction process used to create the threshold. More research is needed here as there is a need for an international consensus on accelerometry in order to standardize methods and the cut points used to define physical activity intensities. Further, validation studies that include habitual physical activity to be able to more accurately convert accelerometer cut points into physiological intensity are warranted. Second, studies should incorporate multiple methodologies such as accelerometers and self-report or global positioning system (GPS) to obtain a better picture of the total physical activity performed and also the context in which it is performed. Third, more research should be conducted with regards to determinants of physical activity to identify why some children are not sufficiently active. Specifically, studies examining the relationship between hours of daylight, temperature and seasonality are necessary. Better knowledge of determinants of physical activity is essential to be able to further develop effective interventions that stimulate children and adolescents' physical activity. Fourth, as physical activity and dietary intake are the key components of energy balance, more attention should

be paid to incorporate both domains in research studies to better understand the recent increases in children's fat mass. Moreover, in addition to study physical activity levels more research is needed to quantify the amount of time children and adolescents devote to sedentary pursuits. Finally, as regular physical activity and aerobic fitness are important and modifiable variables for good health, research is needed to monitor changes in these variables in order to be able to intervene if the levels decline.

7. CONCLUSIONS

Based on the previous chapters the following conclusions can be drawn:

o   Nine-year-old children participate in high volumes of physical activity; however, the activity level decreases substantially by age 15. Boys were significantly more physically active than girls.

o   Whereas four out of five 9-year-olds fulfilled the physical activity recommendations of 60 minutes of MVPA daily, only half of the 15-year-olds did.

o   Boys had a significantly higher peak VO_2 values than girls at both age 9 and 15 years. Fifteen-year-old boys had significantly higher peak VO_2 than 9-year-old boys, whereas 9-year-old girls had significantly higher peak VO_2 than 15-year-old girls.

o   Physical activity levels and patterns among 9-year-olds varied substantially across the seasons, and highest physical activity level was observed during spring. No association was observed between season and mean physical activity in 15-year-olds.

o   From 1999−2000 to 2005, 9-year-old children living in Oslo increased their mean physical activity level as well as their activity level during weekends. The increase in physical activity was not equal across SES groups.

o   Over a five year period, there was no significant increase in the prevalence of overweight and obesity among Norwegian 9-years-olds, although it seems clear that a shift has occurred. No changes were observed for mean BMI, whereas a significant increase in WC and skinfold measurement (girls only) was observed.indicating a change of body composition.

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ERRATA

Paper II

Paper II was published in June in its original form.

Paper IV

Since submission to the doctoral committee, Paper IV has been accepted for publication in BMC Public Health. Corrections have been done in each chapter of the paper. The title of the paper has been changed, and the paper is now entitled "Secular trends in adiposity in Norwegian 9-year-olds from 1999-2000 to 2005".

The following changes have been made:

Page 38: "…15% of 9-year-old girls, 37**%** of 9-year-old boys, 15**%** of 15-year-old girls and 21**%** of 15-year-old boys."

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147. Resaland G, Mamen A, Anderssen S and Andersen L. Cardiorespiratory fitness and body mass index values in 9-year-old rural Norwegian children. *Acta Paediatr*. 2009; **98:687-692.**

156. Andersen LB, Froberg K, Kristensen PL, Moller NC, Resaland G and Anderssen SA. Secular trends in physical fitness in Danish adolescents. *Scand J Med Sci Sports*. 2009; **Published Online: Oct 4 2009. DOI: 10.1111/j.1600-0838.2009.00936.x**

PAPER I

SCANDINAVIAN JOURNAL OF
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IN SPORTS

Objectively assessed physical activity and aerobic fitness in a population-based sample of Norwegian 9- and 15-year-olds

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The present study described current physical activity, determined compliance with physical activity guidelines and assessed aerobic fitness in a nationally representative sample of 9- and 15-year-olds in Norway. In 2005–2006, 2299 children and adolescents were randomly recruited. The participation rate was 89% and 74% among the 9- and 15-year-olds, respectively. Physical activity was assessed objectively by accelerometry, and aerobic fitness was measured directly as peak oxygen uptake during a cycle ergometry test. Boys were more physically active than girls, and 9-year-olds were substantially more active than 15-year-olds. Physical activity was higher during weekdays than weekends, and 9-year-olds were most active during spring. While four out of five children met current physical activity guidelines, only half of the adolescents did. The mean (SD) values for peak VO_2 were: 9-year-old boys, 48.2 (7.1) mL/min/kg; 9-year-old girls, 42.9 (6.7) mL/min/kg; and 15-year-old girls 41.1 (6.0) mL/min/kg and 15-year-old boys 51.9 (8.0) mL/min/kg. Because of the high participation rate, this study provides a good description of the physical activity and aerobic fitness in the young population. Finally, girls and adolescents seem appropriate targets when promoting physical activity in order to increase the proportion meeting the recommendations.

Physical activity is a behavior that occurs in a variety of forms and contexts (Caspersen et al., 1985). Therefore, assessing physical activity is a complex task, especially among children who rarely engage in lengthy sustained bouts of activity, but whose participation typically is intermittent and spontaneous (Bailey et al., 1995). However, objective assessment of physical activity is possible using accelerometers, which are capable of capturing the duration, intensity and frequency of the activity.

Aerobic fitness is a set of attributes rather than a behavior (Caspersen et al., 1985), and it is a result of the genetics and stage in the lifespan, as well as physical activity levels. Even though direct measurement of maximal oxygen uptake is the preferred method to assess aerobic fitness, it is rarely used in large epidemiologic studies because it requires expensive equipment and is time consuming.

We are aware of only three large population-based studies where physical activity has been assessed objectively in children and youth (Riddoch et al., 2004, 2007; Pate et al., 2006); furthermore, population-based studies where oxygen uptake has been measured directly are scarce. Hence, representative data for these variables are lacking in the literature.

Norway is a country that stretches over 2650 km with parts of the country situated above the Arctic Circle and weather conditions differ significantly throughout the year. We assessed physical activity levels and aerobic fitness in a cross-sectional population-based sample, which included approximately 2300 children and adolescents. This was intended as the initial survey in a regular national surveillance system to monitor secular trends in physical activity levels and aerobic fitness. The purpose of the study was to describe current physical activity among Norwegian children and adolescents using accelerometry, and to determine compliance with current physical activity guidelines. We also wanted to assess their aerobic fitness using direct measurements of oxygen uptake during an exhaustive cycle ergometry test.

Material and methods

Study sample

Children and adolescents selected for participation in the study were girls and boys aged 9 and 15 years old. Statistics Norway selected the cohort by cluster sampling with schools as the primary unit. When a school agreed to participate, we invited all children in grade 4 (elementary schools) and grade 10 (high schools) to participate. We recruited girls and boys from 40 elementary schools and 23 high schools in Norway. In Oslo, however, we oversampled elementary schools to be able to compare the results with previous research (Klasson-Heggebo & Anderssen, 2003). We invited a total of 2818 children

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and adolescents and 2299 accepted, yielding a participation rate of 89% and 74% among the 9- and 15-year-olds, respectively. Data were collected in 2005–2006 and analyzed in 2007–2008. Before participation in the study, written informed consent was obtained from each subject and his or her primary guardian. The Regional Committee for Medical Research Ethics and Norwegian Social Science Data Services approved the study.

Measures

We measured weight to the nearest 0.1 kg with a digital scale (Seca 770, SECA GmbH, Hamburg, Germany), and height to the nearest 1 mm. The children and adolescents were in their underwear and without shoes. Body mass index (BMI) was calculated as weight (kg) divided by the height squared (m^2).

We used Actigraph accelerometers (MTI model 7164, Manufacturing Technology Inc., Fort Walton Beach, Florida, USA) for objective assessment of physical activity. The girls and boys wore the accelerometer on their right hip for four consecutive days, including two weekdays and two weekend days. We instructed them in wearing the accelerometer during all waking hours, except during swimming and bathing. Accelerometers were initialized to start recording at 6:00 hours on the day after they were distributed. The epoch length was set to 10 s. The physical activity assessments were undertaken during all months except July and August. In the analyses we defined winter from December through February, spring from March through June and fall from September through November. To minimize inter-instrumental variation, we calibrated all accelerometers regularly against a standardized vertical movement.

In the analyses of accelerometer data, all night activity (24:00–6:00 hours), and all sequences of 10 min or more of consecutive zero counts were excluded from each individual's recording. Physical activity data were included for further analyses if the child had accumulated a minimum of 8-h activity data per day for at least 2 days. A total of 1824 (79%) children and adolescents provided valid physical activity recordings. The reasons for exclusion ($N = 475$) were failing to achieve at least 2 days of assessment (25%), not wearing the accelerometer (36%) and instrument malfunction (39%).

The primary physical activity variable was the mean number of counts per minute (counts/min), and additional outcomes were time spent at different activity intensities. We defined moderate-to-vigorous physical activity (MVPA) as all activity above 2000 counts/min (equivalent to three metabolic equivalents and a walking pace at 4 km/h), and vigorous physical activity (VPA) as all activity above 3000 counts/min. These cutoff points have also been used previously (Ekelund et al., 2004; Andersen et al., 2006).

We assessed aerobic fitness through a maximum exercise test on an electronically braked cycle ergometer (Ergomedic 839E, Monark, Varberg, Sweden). Initial and incremental work rates were 20 W for 9-year-olds weighing < 30 kg, 25 W for 9-year-olds weighing ≥ 30 kg, 40 W for 15-year-old girls and 50 W for 15-year-old boys. We set pedal frequency at 60–70 rpm and increased work rate every third minute until exhaustion. We recorded heart rate (HR) throughout the test using a HR monitor (Polar Vantage, Polar electro YO, Kempele, Finland) and measured oxygen uptake (VO$_2$), respiratory exchange ratio (RER) and ventilation every 10 s during the last minutes of the test using a portable MetaMax III X oxygen analyzer (Cortex Biophysics, Leipzig, Germany). We defined peak VO$_2$ as the mean of the three highest consecutive measurements. Every morning we calibrated the analyzer against known gas mixtures, and barometric pressure against values from the local weather station.

If RER was ≥ 0.99 or max HR was ≥ 185 beats/min and the test leader judged the subject to show signs of intense effort (e.g. facial flushing or difficulties in keeping up the pedal frequency), the test was accepted as maximal. Eight percent of the girls and boys failed to meet these criteria, while 4% were absent on the test day. Hence, 2027 (88%) children and adolescents had valid tests and were included in the analyses.

Peak VO$_2$ was missing in 159 individuals due to failure of the VO$_2$ analyzer. Based on data from the present study, values were imputed for the missing individuals using the following equation:

$$9\text{-year-olds}: \text{VO}_2 \text{ peak (L/min)} = 0.452 + (0.0108 \times W_{max}) + (0.033 \times \text{sex})$$

$$15\text{-year-olds}: \text{VO}_2 \text{ peak (L/min)} = 0.465 + (0.0112 \times W_{max}) + (0.172 \times \text{sex}),$$

where sex = 0 for girls and sex = 1 for boys.

We calculated W_{max} according to the following formula (Hansen et al., 1989):

$$W1 + (W2 \times t/180),$$

where $W1$ = workload (W) at each fully completed stage, $W2$ = workload increment at the final incomplete stage and t = duration (s) of the final incomplete stage.

A validation study of the MetaMax III X oxygen analyzer showed that the analyzer was stable (< 2% variation) at repetitive measurements over a 30-min period. Repetitive measurements over 12 days also showed < 2% day-to-day variation at different work rates (4, 8 and 12 km/h). Additionally, the MetaMax III X oxygen analyzer was validated against the Douglas bag method. At all work rates, the analyses showed a systematic 8% overestimation of the oxygen consumption measured by MetaMax III X; consequently, all peak VO$_2$ measurements were corrected downwards by a factor of 1.08.

Sample size calculation

In the sample size calculation, we used physical activity and aerobic fitness as the primary outcome variables. With respect to this, 444 individuals in each age and sex group allowed us to detect subgroup physical activity differences of 49 counts/min and aerobic fitness differences of 1.6 mL/kg/min ($1 - \beta = 0.80$; two-tailed $\alpha = 0.05$), using a two-tailed test. Because of cluster sampling, we incorporated a design effect of 1.1, yielding a final target sample size of 488 individuals per age and sex group.

Statistical analyses

We tested 8.6% of the 9-year-olds in Oslo compared with 1.5% of the 9-year-olds in the rest of the country. The results for weighted means were not notably different from the non-weighted means, and we therefore present only non-weighted means here. Even if the recruitment was carried out by school clusters, the results presented here are mainly descriptive and therefore we have not adjusted for the clustering by school design. To assess potential differences in activity levels between individuals with different numbers of assessment days, we calculated physical activity levels separately for individuals with 2, 3 and 4 days of valid activity recordings. Because no differences were found (data not shown), all children with at least 2 days of valid assessments are included in the analyses. We assessed differences between groups using one-way analysis of variance (ANOVA), and differences between proportions of individuals achieving activity guidelines using

chi-square analyses. When we examined the seasonal effects of physical activity, the first step was to test the three-way interaction between sex, age group and season. We then tested the three two-way interactions, and found an interaction between season and age group ($P = 0.01$); consequently, the regression analysis was run separately for the two age groups. We analyzed all data using the Statistical Package for the Social Sciences (SPSS) version 15.

Results

Group characteristics are presented in Table 1. The difference in the overall physical activity between 9-year-old girls and boys was 103 counts/min, which translates into a 14.9% [95% confidence interval (CI): 12.8, 16.9] difference. Fifteen-year-old boys were 11.3% (95% CI: 8.9, 13.6) more physically active than the 15-year-old girls; furthermore, 9-year-olds were 45.5% (95% CI: 43.2, 47.8) more physically active than 15-year-olds (Table 2).

In all age and sex groups, a higher physical activity level was seen during weekdays than during weekends. Nine-year-old boys were 14.9% (95% CI: 12.8, 17.0) and 11.9% (95% CI: 9.9, 13.8) more physically active than the girls during the weekdays and weekends, respectively. Fifteen-year-old boys were 16.0% (95% CI: 13.1, 18.9) more physically active than the

girls during weekdays; however, we found no sex difference in the activity level during weekends ($P = 0.86$). The hour-by-hour activity level during weekdays and weekends is presented in Fig. 1.

Overall, on a daily basis, 9-year-olds spent 86.5 min in MVPA and 50.5 min in VPA, while 15-year-olds spent 64.9 and 42.7 min in MVPA and VPA, respectively. Nine-year-old boys were involved in more time MVPA ($P < 0.001$) and VPA ($P < 0.001$) than girls. A similar pattern was also seen among the 15-year-olds, but the sex difference was smaller ($P = 0.007$ for MVPA and $P = 0.002$ for VPA) (Table 1).

Among 9-year-olds, 75.2% (95% CI: 71.5, 78.9) of the girls and 90.5% (95% CI: 88.2, 92.8) of the boys met the Norwegian physical activity guidelines of 60 min of moderate-intensity physical activity every day. The corresponding value among the 15-year-olds was 49.9% (95% CI: 44.7, 55.1) among the girls and 54.1% (95% CI: 48.8, 59.4) among the boys.

Figure 2 shows the influence of season on physical activity level. We observed a significant association between physical activity level and season among 9-year-olds but not among 15-year-olds. Nine-year-olds were most physically active during spring.

Overall, the median maximal HR during the peak VO_2 test was 199 beats/min (range 173–223).

Table 1. Anthropometric characteristics of the sample by sex and age group[†]

	9-year-olds		15-year-olds	
	Girls ($n = 598$)	Boys ($n = 693$)	Girls ($n = 469$)	Boys ($n = 506$)
Height (cm)	138.3 (6.8)	139.9 (6.3)*	165.9 (6.2)	175.8 (7.2)*
Weight (kg)	33.8 (7.1)	34.0 (6.5)	58.3 (8.9)	64.6 (12.1)*
BMI (kg/m^2)	17.5 (2.7)	17.3 (2.5)**	21.2 (2.9)	20.8 (3.4)**

[†]Values are mean (standard deviation).
*$P < 0.001$.
**$P < 0.05$ for sex within age group.
BMI, body mass index.

Table 2. Physical activity and aerobic fitness data by age group and sex*

	9-year-olds				15-year-olds			
	Girls	Boys	Mean difference	95% CI	Girls	Boys	Mean difference	95% CI
PA	$n = 525$	$n = 602$			$n = 359$	$n = 338$		
Overall PA (counts/min)	693 (251)	796 (281)	103	72–134	487 (167)	542 (199)	55	27–82
PA weekdays (counts/min)	715 (253)	821 (276)	106	74–137	500 (177)	580 (211)	80	49–111
PA weekend (counts/min)	665 (383)	744 (363)	79	34–124	455 (215)	472 (257)	17	− 20–55
MVPA (min/day)	76.4 (23.1)	95.4 (31.1)	19.0	15.8–22.2	62.2 (25.4)	67.7 (28.0)	5.5	1.5–9.5
VPA (min/day)	43.8 (17.0)	56.4 (23.0)	12.6	10.3–15.0	40.4 (19.3)	45.1 (22.1)	4.7	1.7–7.9
Aerobic fitness	$n = 538$	$n = 634$			$n = 391$	$n = 464$		
Peak VO_2 (L/min)	1.4 (0.2)	1.6 (0.2)	0.2	0.16–0.21	2.4 (0.4)	3.3 (0.5)	0.9	0.89–1.01
Peak VO_2 (mL/min/kg)	42.9 (6.7)	48.2 (7.1)	5.3	4.5–6.1	41.1 (6.0)	51.9 (8.0)	10.8	9.9–11.8

*Values are mean (standard deviation).
PA, physical activity; CI, confidence interval; MVPA, moderate-to-vigorous physical activity; VPA, vigorous physical activity; VO_2, oxygen uptake.
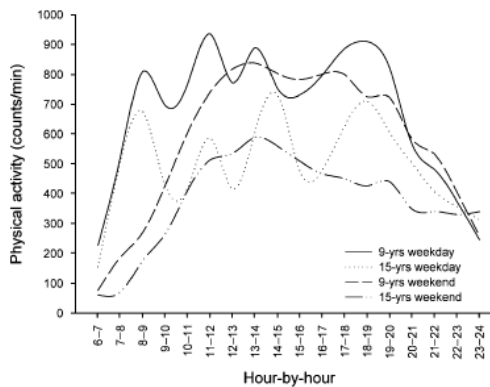
Fig. 1. Hour-by-hour physical activity levels for 9- and 15-year-old boys and girls during weekdays and weekends. The plotted values are the mean physical activity level (counts/min).
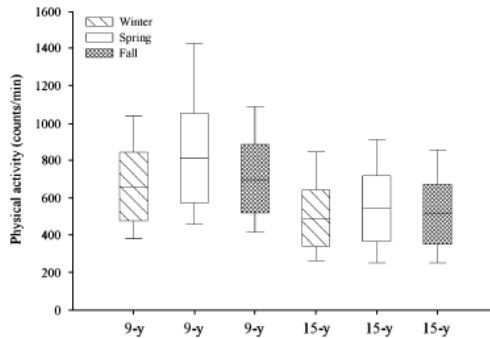

Fig. 2. Box plot of physical activity level (counts/min) during the different seasons. Seasons: winter, December–February; spring, March–June; and fall, September–November. The box covers the range between the lower and the upper quartiles; the whiskers cover the range between the 5th and the 95th percentiles, and the horizontal bar dividing the box indicates the mean.

Figure 3 shows the distribution of peak VO$_2$ data. Nine-year-old boys had 5.3 mL/min/kg higher peak VO$_2$ than girls, while the corresponding difference among the 15 year olds was 10.8 mL/min/kg (Table 2). Furthermore, 15-year-old boys had 3.7 mL/min/kg (95% CI: -4.6, -2.9) higher peak VO$_2$ than 9-year-old boys ($P < 0.001$), whereas 9-year-old girls had 1.8 mL/min/kg (95% CI: 1.0, 2.6) higher peak VO$_2$ than 15-year-old girls ($P < 0.001$).

Discussion

In this nationally representative cohort of children and adolescents, we have demonstrated that: boys are more physically active than girls, the sex differ-
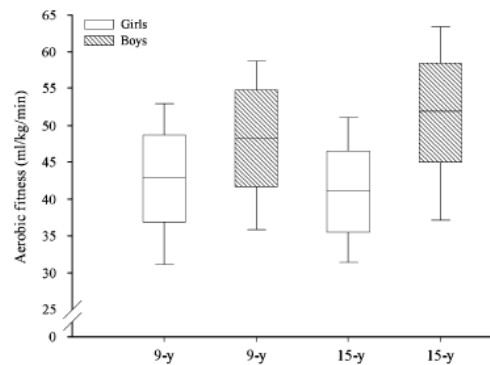

Fig. 3. Box plot of the aerobic fitness data (mL/min/kg) by sex and age group. The box covers the range between the lower and the upper quartiles; the whiskers cover the range between the 5th and the 95th percentiles, and the horizontal bar dividing the box indicates the mean.

ence in physical activity is particularly pronounced at activities of moderate and vigorous intensities, the physical activity level is higher during weekdays than during weekends and 9-year-old children are most active during spring. Four out of five children met current physical activity guidelines, but only half of the adolescents did. Furthermore, we have shown that boys had a significantly higher peak VO$_2$ than girls, already at the age of 9 years.

This study was unique because we determined physical activity and aerobic fitness objectively. The study had a number of strengths including the large study sample with direct measurements of the oxygen uptake, the high participation rate and the random inclusion of children and adolescents from the whole population.

The findings of the study should be interpreted in light of the following limitations. First, the accumulation of physical activity over 2–4 days may not represent the true physical activity level of the subject, but only a rough estimate of the subject's activity level. Second, we chose to include individuals who had minimum two valid days of physical activity recordings. Because no difference in the mean physical activity was found for the individuals with a different number of valid assessment days we do not think that any major errors are introduced by including these individuals. Third, despite our high participation rate, in the end only 79% of the participating boys and girls had valid physical activity data, while 88% had valid aerobic fitness data. However, approximately 40% of the children and adolescents not meeting the physical activity inclusion criteria can be explained by instrument breakage, which must be expected to be random across the range of physical activity levels.

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Every fifth year from 1920 to 1975, children living in Oslo have had their body weight and height measured (Brundtland et al., 1980). Nine-year-old girls in the present study were 4.6 kg heavier and 3.3 cm taller than girls in 1975 (age 8.5–9.5 years), resulting in 1.5 kg/m^2 higher BMI. Higher body weight (+4.5 kg), height (+4.4 cm) and BMI (+1.3 kg/m^2) were also observed among 9-year-old boys. Fifteen-year-old girls in the present study were 4.5 kg heavier and 0.6 cm taller than girls in 1975, resulting in 1.6 kg/m^2 higher BMI, whereas the corresponding increases among 15-year-old boys were 6.6 kg, 4.9 cm and 0.9 kg/m^2. More recent national data among fourth graders (mean age 8.9 years) (Andersen et al., 2005) show that 9-year-old girls in the present study were 1.3 cm taller and 1.8 kg heavier, and thus had a 0.4 higher BMI than 9-year-olds in 2000. Similar increases were also seen among boys. When interpreting these data, the individuals' age must be taken into consideration as 9-year-old children gain several kilos and grow numerous centimeters annually. Despite the age difference, there seems to have been a secular increase in body weight, height and BMI from 1975 to 2000; however, this increase seemed to have impeded from 2000 to 2006. With regard to body weight, height and BMI, our sample seems to be representative for 9- and 15-year-olds in Norway.

This study confirms previous research showing that boys are more active than girls (Klasson-Heggebo & Anderssen, 2003; Riddoch et al., 2004, 2007). The sex difference was higher among the 9-year-olds compared with the 15-year-olds, and most pronounced at activities of moderate and vigorous intensities. The consistent observation that boys participate in substantially more physical activity at all intensity levels underscores the need for intervention programs targeting girls of all ages. The decline in physical activity with age may be the most consistent finding in physical activity epidemiology (Caspersen et al., 1994). When using the two age cohorts to simulate a longitudinal change, the results indicate a decline in activity that was similar among girls and boys (29.7% and 31.9%, respectively). The decline equals a 4.5% annual reduction, which must be considered to be substantial. Furthermore, studies have shown that the period with the greatest physical activity decline is between 12 and 18 years of age (Caspersen et al., 2000; Telama & Yang, 2000; van Mechelen et al., 2000). This emphasizes the importance of measures aimed at increasing the physical activity among adolescents.

The higher physical activity level during weekdays may be linked to school activities and organized activities in the afternoon. The activity patterns throughout the days appear to confirm this interpretation. During weekdays the activity was characterized by several peaks during school hours and in the afternoon, while the activity during weekends was generally low throughout the day, thus, indicating that attempts should be made to increase the activity during weekends.

The Norwegian physical activity guidelines state that all children and adolescents need moderate-intensity physical activity for a minimum of 60 min every day. Despite the well-known benefits of physical activity, half of the nation's adolescents fall short of meeting the guidelines. The current physical activity recommendations are not built on a strong body of evidence; however, it is of concern that one out of two 15-year-olds in Norway is not sufficiently active. Regular physical activity has beneficial effects on musculo-skeletal health, adiposity in overweight youth and blood pressure in mildly hypertensive adolescents (Strong et al., 2005). Moreover, recent data suggest that physical activity is independently associated with metabolic health in children (Ekelund et al., 2007). Physical activity might be necessary to prevent insulin resistance, which seems to be the central feature for clustering of cardiovascular disease risk factors (Andersen et al., 2006).

Knowledge of seasonal participation in physical activity is important, as it will be useful to interventions and health promotion planning. Among the 9-year-olds in our study, we found a higher physical activity level during spring than during winter and fall, which is similar to what has been reported previously (Fisher et al., 2005; Riddoch et al., 2007; Kristensen et al., 2008). On the other hand, adolescents' participation in physical activity was not influenced by seasonality. Similar findings have also been reported in Denmark (Kristensen et al., 2008), but the finding is not consistent (Santos et al., 2005). The finding that adolescents' physical activity is not influenced by seasonality is plausible. While young children's physical activity often consists of active play and non-organized sports, adolescents' physical activity tend to be organized and to be of more regular nature. Hence, the 15-year-olds, who are physically active are active throughout the whole year independent of season.

Among children (8–12-year-olds), mean peak VO$_2$ values of 35.8–49.9 and 41.1–57.6 mL/min/kg have been reported for girls and boys, respectively (Andersen et al., 1980; Armstrong et al., 1995; Fredriksen et al., 1999; Rowland et al., 2000; Dencker et al., 2007). The corresponding peak VO$_2$ values among adolescents (14–19-year-olds) are 40.0–48.9 and 51.7–60.8 mL/min/kg for girls and boys, respectively (Andersen et al., 1987; Fredriksen et al., 1999). This indicates that the girls and boys in our sample did not differ markedly with respect to the peak VO$_2$ values that have been reported pre-

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viously. However, the studies reporting direct measured oxygen uptake in children and adolescents include a limited number of individuals and different test protocols and instruments, resulting in limitations to the comparisons. There have been few published studies that have addressed the issue of secular trends in directly measured peak VO_2. A review of peak VO_2 data from children and adolescents over the last 50 years does not indicate a secular trend in aerobic fitness (Armstrong & Welsman, 2007), whereas aerobic test performance in children and adolescence has shown a rapid secular decline over the past 20 years (Tomkinson et al., 2003). Data on secular trends in peak VO_2 expressed in ratio with body mass need to be interpreted with caution. However, peak VO_2 data from the present study are similar to those reported previously, and hence indicate a lack of secular decline in aerobic fitness.

A peak VO_2 of ≥ 35–38 mL/min/kg for girls and ≥ 40–42 mL/min/kg for boys have been suggested as a criterion standard for the "Healthy Fitness Zone" (Bell et al., 1986; Ruiz et al., 2007; Welk & Meredith, 2008). When applying these limits to our data, we found that approximately 11.7% and 11.8% of the girls and boys, respectively, were below the criterion standard and therefore have a hypothetical risk of having a clustering of metabolic risk factors. However, longitudinal studies are needed to investigate the impact of low aerobic fitness in childhood on the probability of having cardiovascular disease later in life.

Perspectives

This study has some public health implications. Firstly, we have demonstrated that the use of accelerometry and direct determination of peak oxygen uptake is feasible in a large field-based epidemiologic study to evaluate physical activity and aerobic fitness among children and adolescents. Secondly, this was intended as the initial survey in a regular national surveillance system to monitor secular trends in physical activity levels and aerobic fitness. This is important because few scientific data are available to assess purely time-dependent trends in physical activity and aerobic fitness. Thirdly, information on children and adolescents activity patterns, together with the factors that influence them, can inform the design and delivery of public health interventions to promote physical activity in children. Finally, girls and adolescents seem appropriate targets when promoting physical activity in order to increase the proportion meeting the recommendations.

Key words: adolescent, child, cross-sectional, Norway/epidemiology, motor activity.

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PAPER II

Research

Seasonal variation in objectively assessed physical activity among children and adolescents in Norway: a cross-sectional study

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Abstract

Background: The literature on seasonality in children and youth's physical activity participation is inconsistent. The aims of this study were to: 1) compare physical activity across seasons and describe activity patterns within seasons, and 2) to determine compliance with current physical activity recommendations across seasons among 9- and 15-year-olds living in a climatically diverse country.

Methods: Participants were 2,299 9- and 15-year-olds from all regions in Norway. Physical activity was assessed using the Actigraph accelerometer for 4 consecutive days. Physical activity data were collected during winter, spring and fall. General linear models were used to study the associations between physical activity and season.

Results: Nine-year-old children had significantly higher mean physical activity levels in spring than in winter and fall. In the two latter seasons, physical activity levels were especially low after school hours and on weekends. Logistic regression models demonstrated that 9-year-olds had 3.3 times (95% Confidence Interval (CI): 2.08, 5.18) higher odds of meeting recommended levels of physical activity in spring than in winter. No associations were found between mean physical activity level and season among the 15-year-olds. However, the adolescents also had higher odds (OR = 1.56; 95% CI: 1.05, 2.32) of meeting the physical activity recommendations in spring than in winter.

Conclusion: In a large population-based sample, we observed substantial seasonal differences in physical activity among 9-year-olds, and the activity pattern varied across the seasons. The results emphasize the need to take season into account when developing physical activity interventions for children. Season appears to have less influence on adolescent's physical activity; interventions for increasing physical activity in this group could therefore be implemented throughout the year.

Background

Despite the immediate and likely long-term benefits of physical activity in childhood [1,2], many children and particularly adolescents, fail to meet the recommended 60 minutes of moderate-to-vigorous physical activity (MVPA) daily [3-5]. Given this situation, several interven-

tions have been developed to promote physical activity participation in the young population. Successful and effective interventions depend on a thorough understanding of the determinants of physical activity [6]. Recently, studies have sought to understand the role of environmental variables [7] such as neighbourhood, school, and community characteristics, in physical activity participation. As physical activity is performed in specific physical settings, it is believed that environmental conditions exert either a facilitating or constraining influence on physical activity [8].

Seasonality has received little attention as a potential environmental determinant of physical activity. In temperate and polar regions four seasons are generally recognized (winter, spring, summer and fall). Temperatures, precipitation, and day length may vary substantially across seasons, and such attributes might affect physical activity participation. The literature on seasonality in children and youth's physical activity participation is inconsistent. While some studies have shown that season has an impact on physical activity [9-14], other studies fail to do so [14,15]. Furthermore, few studies have described physical activity patterns during different seasons. The use of accelerometers to assess physical activity provides an opportunity to improve the understanding about the duration, intensity, and frequency of activity. Such knowledge is useful for intervention and health promotion planning, as it might be able to identify seasons that can be targeted for promotion of physical activity.

Norway comprises the western part of Scandinavia and stretches over 2,500 km. The country is climatically diverse, and due to it's high latitude (latitude range: 57° N to 72° N, longitude: 10° E), there are large seasonal variations in daylight. It is possible that in countries where seasonal variations are large, daily physical activity may be more influenced by seasons than in countries where seasonal variations are smaller. Thus, the aims of this study were to: 1) compare physical activity across seasons and describe activity patterns within seasons, and 2) to determine compliance with current physical activity recommendations across seasons among 9- and 15-year-olds living in Norway.

Methods
This is a national, cross-sectional examination of randomly selected 9- and 15-year-old children and adolescents (fourth and tenth grade) in Norway. Statistics Norway selected the cohorts by cluster sampling, with schools as the primary unit. When a school consented to participate, all children in fourth or tenth grade were invited to participate in the study. We recruited subjects from 40 elementary schools and 23 high schools repre-

senting all regions in Norway. Of 2,818 invited participants, 2,299 agreed to participate, giving a participation rate of 89% among the 9-year-olds and 74% among the 15-year olds. The study was approved by the Regional Committee for Medical Research Ethics and Norwegian Social Science Data Services. Each participant's parent or guardian provided written consent before he or she was included in the study.

Measures
Height and weight were measured by standardized procedures and Body mass index (BMI) was calculated as weight (kg) divided by the height squared (m^2).

Physical activity
The uni-axial MTI Actigraph accelerometer (model 7164; Manufacturing Technology Inc., Fort Walton Beach, FL) was used to assess physical activity. This is an electronic motion sensor comprising a single plane (vertical) accelerometer. Movement in the vertical plane is detected as a combined function of the frequency and intensity of the movement. The Actigraph accelerometer has been validated in both children and adolescents against heart-rate telemetry [16], indirect calorimetry [17], observational techniques [18], and energy expenditure measured by doubly-labelled water [19].

The participants were visited at their school, and each child and adolescent was fitted with an accelerometer in an elastic belt around their waist, worn for 4 consecutive days (2 weekdays and 2 weekend days). Children and adolescents were asked to wear their accelerometers during waking hours and to take it off only for showering, bathing or water sports. The Actigraphs were initialized to start recording at 6 am on the day following distribution. An epoch time of 10 seconds was used. A SAS-based software program (SAS Institute Inc., Cary, North Carolina, USA) called CSA-analyzer (csa.svenssonsport.dk) was used to analyze accelerometer data. In the analysis, we excluded all night activity (between 12 am and 6 am), and ten or more minutes of consecutive zeros were regarded as periods in which the monitor was unworn, and these were deleted from each file. A newly published study (20) reported that the single-day intraclass correlation coefficient (ICC) for 600 minutes of assessment was 0.45, while the ICC for 480 minutes of assessment was 0.44. To avoid loosing statistical power, we chose to specify a valid day as 480 minutes. In the present study, data were considered valid if a child provided a minimum of 2 days of at least 480 minutes per day recorded. A total of 1,824 (79%) subjects provided valid physical activity recordings. Reasons for exclusion (N = 475) were failing to achieve at least two days of measurement (25%), not wearing the accelerometer (36%), and instrument malfunction (39%). Although

a weekend day was not specified in order to fulfil validity criteria, 93% of the participants had at least one weekend day of recording.

The total amount of physical activity from the activity monitor was expressed as the average of total counts per minute of registered time (counts/min). We defined MVPA as all activity above 2,000 counts/min. This threshold corresponds to a walking pace of about 4 km/h in children (3 metabolic equivalents) [20,21] and has been applied in previous studies [22-24]. The proportion of children and adolescents who achieved the recommended 60 minutes of daily MVPA was established by dividing total time in MVPA (min) by the number of valid days of recording, giving an average (min/day) across the assessment period.

Season
Data were collected from March 2005 through October 2006, with physical activity assessments throughout the year, except during summer vacation (July and August). Seasons were defined as periods which fluctuate by weather conditions, daylight hours and temperature, as: "Winter", 1 December – 28 February; "Spring", 1 March – 15 June; and "Fall", 1 September – 30 November. Note that assessments taken in June (summer) (N = 121) were categorized as "Spring".

Statistical analysis
Data are presented as mean (SD) unless otherwise stated. To assess potential differences in activity levels between subjects with different numbers of assessment days, we calculated physical activity levels separately for subjects

with 2, 3 and 4 days of valid activity recordings. No differences in mean physical activity were found between subjects with different number of assessment days (9-yrs: p = 0.085; 15-yrs: p = 0.201). Further, we did the seasonal analyses including only subjects with ≥3 days of valid physical activity assessment and the results did not alter our conclusions. To avoid the loss of statistical power we chose to include children with ≥2 days of valid physical activity recordings in the analyses. General linear models were used to study the associations between sex, age group, mean physical activity and season. We found no three-way interaction between sex, age group and season, however, the analyses revealed an interaction between season and age group (p = 0.001) and sex and age group (p = 0.03). Consequently the analyses were run separately for each sex and age group. Logistic regression analysis was applied to study the percentage meeting the physical activity recommendations in relation to sex, age group and season. As an interaction was found between sex and age group (p < 0.001) the analysis was run separately for each age group. The results are presented as adjusted odds ratios (ORs) with 95% CIs. All analyses were performed by using the Statistical Package for Social Sciences (SPSS, version 15.0).

Results
Valid physical activity assessments were obtained from 1,127 9-year-olds (525 girls and 602 boys) and 697 15-year-olds (359 girls and 338 boys). The mean anthropometric data and mean physical activity data by sex and age group are shown in Table 1, which also shows the numbers of participants studied in each of the three seasons. In each age and sex group, there was no significant difference

Table 1: Characteristics of the participants by sex and age group (*N* = 1824)

	9-yrs		15-yrs	
	Girls	**Boys**	**Girls**	**Boys**
N	525	602	359	338
Height (cm)	138.4 (7.0)	139.9 (6.2)	165.6 (6.5)	175.7 (7.1)
Weight (kg)	34.0 (7.1)	33.9 (6.3)	57.9 (8.7)	65.2 (12.8)
Body Mass Index (kg/m²)	17.6 (2.7)	17.2 (2.4)	21.1 (2.8)	21.1 (3.7)
Physical activity (PA)				
Days of PA assessment	3.6 (0.6)	3.7 (0.6)	3.4 (0.8)	3.3 (0.8)
Total PA[a] (min/day)	759 (59)	769 (61)	779 (77)	778 (80)
Mean PA (counts/min)	693 (251)	796 (281)	487 (167)	542 (199)
MVPA (min/day)	76 (23)	95 (31)	62 (25)	68 (28)
Season, N (%)[b]				
Winter	74 (14)	88 (15)	110 (31)	115 (34)
Spring	248 (47)	304 (50)	83 (23)	92 (27)
Fall	203 (39)	210 (35)	166 (46)	131 (39)

Values are mean (SD) unless otherwise mentioned
PA. physical activity; MVPA, moderate-to-vigorous physical activity
[a]Total minutes of recorded physical activity each day
[b]The number (%) of participants studied in each season
Winter, 1 December – 28 February; Spring, 1 March – 15 June; Fall, 1 September – 30 November

in height, mass or BMI (when adjusting for age) among the participants measured in the different seasons.

Mean physical activity levels by sex, age group and season are displayed in Table 2. No significant differences in mean number of valid assessment days or mean number of valid physical activity recordings per day were detected between children assessed in different seasons (p > 0.05). Among 9-year-olds, there were significant seasonal differences in mean physical activity level. Both 9-year-old girls and boys were significantly more active during spring than during winter (girls: mean difference: 188 counts/ min, 95% CI: 112, 265, p < 0.001; boys: mean difference 121 counts/min, 95% CI: 41, 201, p = 0.001) and fall (girls: mean difference: 112 counts/min, 95% CI: 57, 167, p < 0.001; boys: mean difference: 113 counts/min, 95% CI: 53, 172, p < 0.001). There were no seasonal differences in mean physical activity levels in the 15-year-old girls or boys.

Among 9-year-olds, the seasonal variation in mean physical activity level was particularly large during weekends (Figure 1). Among girls, the spring-winter difference in weekend physical activity was 240 counts/min (95% CI: 120, 361; p < 0.001) while the spring-fall difference was 174 counts/min (95% CI: 87, 260; p < 0.001). Among boys, the spring-winter difference in weekend physical activity was 204 counts/min (95% CI: 99, 309; p < 0.001) while the spring-fall difference was 159 counts/min (95% CI: 82, 237; p < 0.001). Smaller, but statistically significant differences were also found in 9-year-olds' weekday physical activity. Among girls, the spring-winter difference in weekday physical activity was 158 counts/min (95% CI: 80, 236; p < 0.001) while the spring-fall difference was 73 counts/min (95% CI: 17, 129; p = 0.005). Among boys, the only significant difference in weekday physical activity was found between spring and fall where the difference was 74 counts/min (95% CI: 12, 135; p = 0.01). The results revealed no significant association between season and mean physical activity level during weekdays or weekends among the 15-year-old girls and boys.

Figure 2 shows the daily activity patterns of 9- and 15-year-olds during the three seasons. For the 9-year-olds,

marked differences in activity patterns were observed between the three seasons, particularly in the period between end of school and bedtime. Activity levels were higher during spring and lower physical activity during winter. For the 15-year-olds, the daily activity patterns during the three seasons were remarkably similar. The activity pattern was characterised by several peaks throughout the day, but none of the seasons was characterised by especially low or especially high physical activity levels.

Among 9-year-olds, the odds of meeting recommended levels of physical activity were higher among boys than among girls (Table 3). No difference in odds was observed by sex among the 15-year-olds. Both 9- and 15-year-olds had higher odds of meeting physical activity recommendations during spring than during winter.

Discussion

Objective assessment of physical activity revealed seasonal differences in physical activity in 9-year-old children living in a climatically diverse country. Norwegian 9-year-olds had higher physical activity levels in spring than in fall and winter. In the two latter seasons, activity levels were particularly low after school hours and on weekends. No seasonal differences in mean physical activity were observed among the 15-year-olds. However, both 9- and 15-year-olds had higher odds of meeting recommended levels of physical activity during spring than during winter.

Associations between season and children's daily physical activity have been reported in several other countries. For example, in US pre-schoolers [10] an association has been reported between season and physical activity assessed by observation, activity was consistently higher outdoors than indoors, and outdoor activity was lower during the summer months. In contrast, a Scottish study [11] found that physical activity (assessed by accelerometers) was highest in summer and lowest in spring. As was the case in this study, several others have shown that younger children's physical activity levels are higher in spring than at other times of the year. For example, a study with 7-year-old children living in Vermont and Alabama, reported

Table 2: Mean (SD) physical activity level (counts/min) stratified by sex, age group and season

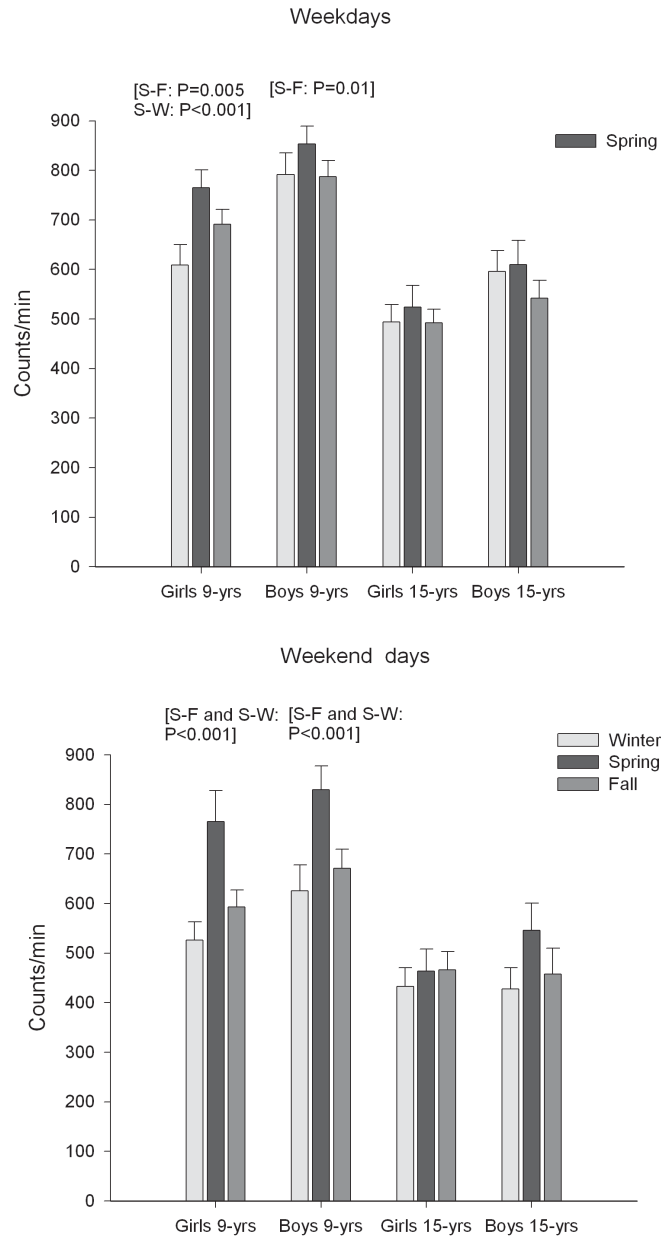| Seasons	9-yrs				15-yrs			
	Girls		Boys		Girls		Boys	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Winter	74	575 (141)	88	732 (213)	110	460 (157)	115	520 (180)
Spring	248	763 (294)	304	853 (322)	83	503 (185)	92	580 (204)
Fall	203	651 (195)	210	741 (219)	166	497 (164)	131	535 (207)

Figure 1
Weekday and weekend physical activity. Mean (95% CI) physical activity level (counts/min) during weekdays (top) and weekend days (bottom) stratified by sex, age group and season. W, Winter; S, Spring; F, Fall.
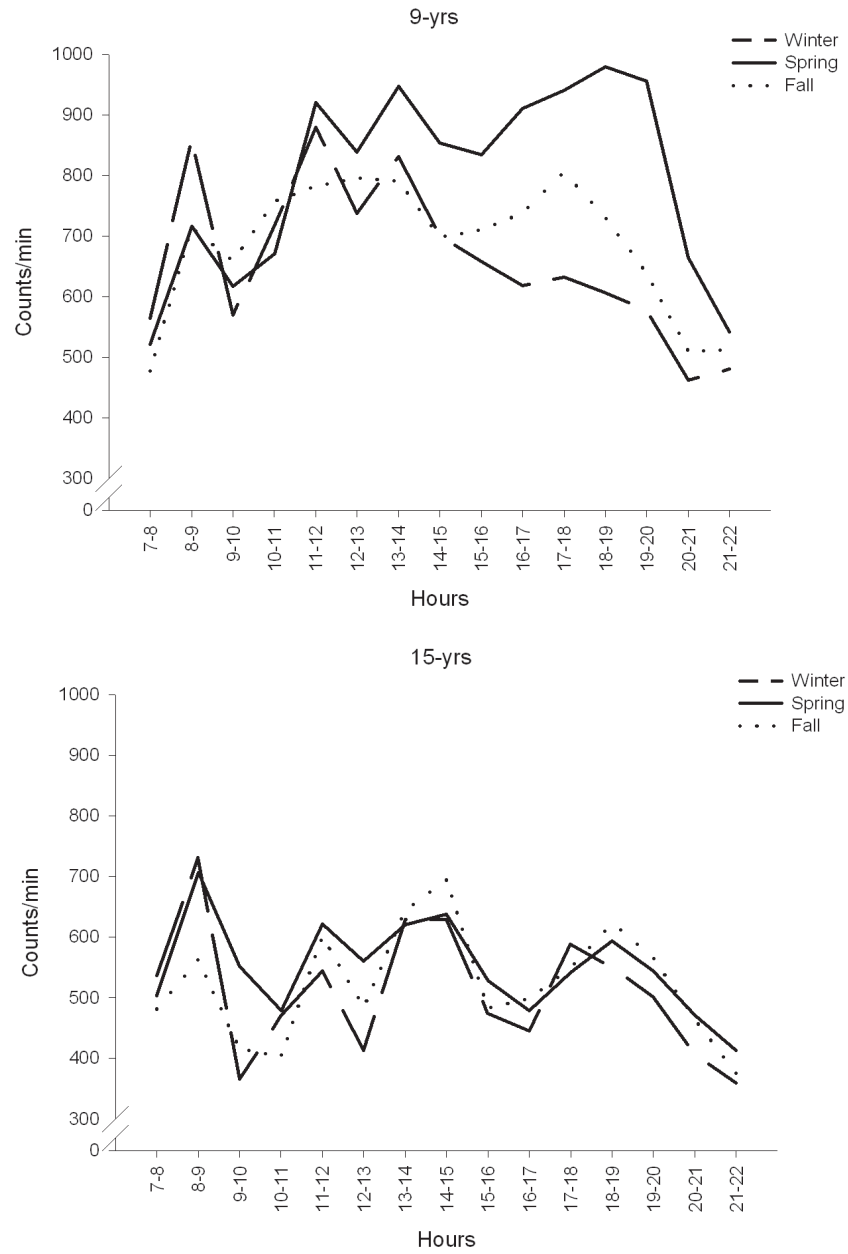
Figure 2
Daily physical activity patterns of 9- and 15-year-olds during the three seasons. Plotted values are mean physical activity level (counts/min).

Table 3: Odds ratios (and 95% CI) for meeting physical activity recommendations by sex and age goup

	Odds Ratio (95% Confidence Interval)	
	9-yrs	**15-yrs**
Sex		
Girls	1.00	1.00
Boys	3.19 (2.26, 4.49)*	1.19 (0.88, 1.61)
Season		
Winter	1.00	1.00
Spring	3.28 (2.08, 5.18)*	1.56 (1.05, 2.32)**
Fall	1.44 (0.93, 2.22)	1.28 (0.90, 1.81)

*P < 0.001, **P = 0.03

higher total energy expenditure measured by doubly-labelled water in spring than in fall [25], and a study in the southern US [26], which used pedometers to assess physical activity, also found that activity levels were higher in spring than in winter among first through fifth grade students. Similar results were reported in a pedometer study with 8–10-year-old boys in the UK [13]. Higher activity levels (assessed by accelerometers) were also reported during spring than during summer, fall and winter in Danish 8–10-year-old girls and boys [14]. In general, it seems clear that seasons have some effect on children's activity level; five out of six studies reported higher activity levels in spring [13,14,25,26] or summer [11], while the remaining study reported lowest activity level in summer [10]. The low summer activity level in the latter study is probably explained by the extreme heat experienced in Texas during summer.

Research studying the impact of season on adolescents' (individuals aged 11–17-years) physical activity level has shown conflicting results. Studies conducted among 15-year-olds in Denmark [14] and the United States [15] found no association between season and physical activity assessed by accelerometers and 7-day recall questionnaire, respectively. Conversely, a study including 10–17-year-old Portuguese adolescents indicated that physical activity level assessed by questionnaire was significantly higher in summer/spring than in fall/winter [27]. Moreover, a study including 11–12-year-olds in the UK reported that physical activity assessed by accelerometer was highest in summer and lowest in winter [12]. Measurement error, different sample characteristic, different geographic regions, and different analysis strategies all increase the likelihood of inconsistent findings across studies.

The reason for reduced physical activity level during fall and winter remains unclear, however, weather and daylight availability might be the key determinants for low physical activity levels during the cold seasons. In Oslo (the capital), the hours of daylight differ from approxi-

mately 6 hours in December to 19 hours in June, while the areas above the Arctic Circle experience both months with no daylight (winter) and months where the sun never sets (summer). In addition, the months of fall and winter are often characterized by periods of continuous poor and harsh weather (rain, snow and wind), which have shown to be strong deterrents to daily physical activity [28]. A combination of low daylight availability and continuous harsh weather might lead to children spending more time indoors. As time spent outdoors is a significant predictor of children's physical activity [6,10], the consequence might be reduced physical activity level during fall and winter, and lower odds of meeting recommended levels of physical activity.

Our results suggest the after-school time period as an opportunity to promote physical activity. After-school programs are optimal for enhancing physical activity because of the capacity and infrastructure to reach large numbers of children, and both organized and unorganized activities can be promoted. One study from the US [29] has shown that children in grade 3 through 6 accumulate significant amounts of MVPA while attending after-school programs. Physical activity levels were higher during free-play sessions than in organized or structured activity. In Norway, after-school programs could use indoor facilities, sport halls, and swimming pools to facilitate children's natural inclination to move and play during fall and winter when playing outdoors is impractical. However, this would require qualified teachers and leaders with skills in physical activity instruction and programming. After school activities should be enjoyable [30] and affordable so that children from all socioeconomic groups can participate. Parental support, which is known to be an important determinant of children's physical activity would also be crucial [31]. Through encouragement, provision of transport, participation with the child and observation of the child being active, parents can have a strong influence on children's physical activity [32,33]. It is therefore essential to increase parents' awareness of the importance of adequate physical activity, so they can provide opportunities for physical activity at times of the year when the levels are low.

It appears that seasonality has limited effect on physical activity behaviour during adolescence. This period is characterized by a decrease in physical activity [34], which is caused both by a decline in both organized and non-organized activities. As children go through adolescence there is less free play outdoors, and physical activity mainly consists of participation in organized leisure-time activities, for example in sport clubs. It is therefore plausible that 15-year-olds' physical activity is less influenced by fluctuation in daylight and weather, as most organized activities take place all year around. Since seasonal varia-

tions are less important for physical activity participation in adolescence, interventions to increase physical activity should be targeted all year round. A newly published Norwegian study [35] showed that 54% of 15-year-old girls and 62% of 15-year-old boys were members of a sports club. One solution to increase 15-year-olds' physical activity levels might be to provide more organized activities.

A major strength of this study was the use of objective monitoring to assess both the quantity and intensity of physical activity. This is important as children lack the cognitive ability to accurately recall details of their physical activity patterns [36]. Also, the use of accelerometers are known to compare favourably with other similar instruments such as pedometers [37]. Furthermore, our study included a large random selected study sample and the participation rate was high.

A limitation of the study was the use of a cross-sectional design and thus the lack of physical activity assessments at multiple time points. This was, however, not possible due to the time- and labour-consuming nature of conducting multiple physical activity assessments. Further, we did not collect data on temperature, precipitation, amount of daylight or time spent outdoors, which may be important because the weather and daylight hours can differ significantly across the seasons.

Conclusion
Norway is climatically diverse country with large seasonal variations in temperature, precipitation and hours of daylight. In a large population-based sample, we observed substantial differences in physical activity levels and patterns among 9-year-olds across the seasons. Our results emphasize the importance of taking season into account when promoting physical activity in children. When promoting physical activity among adolescents, season is of less importance and interventions aiming to increase physical activity should be implemented throughout the year. Finally, this study emphasizes the need to take season into consideration when conducting prevalence studies of physical activity in children.

List of abbreviations
BMI: Body Mass Index; CI: Confidence Interval; MVPA: Moderate-to-Vigorous Physical Activity.

Competing interests
The authors declare that they have none competing interests.

Authors' contributions
EK was active in the planning of the study and coordinated the data collection, did the conception and design, analysed and interpreted the data and drafted the manu-

script. JSJ was active in the planning of the study and coordinated the data collection, was involved in the conception and design, discussed the analysis and interpretation of the data and reviewed the manuscript critically. LBA was active in the planning of the study, was involved in the conception and design of the article, contributed particularly in the statistical analyses and interpretation of the data, and reviewed the article critically. SAA was project manager of the study, was active in planning of the study, was involved in the conception and design of the article, discussed the analysis and interpretation of the data, and reviewed the manuscript critically.

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PAPER III

Kolle E, Steene-Johannessen J, Klasson-Heggebø L, Andersen LB, Anderssen SA. A 5-year change in Norwegian 9-year-olds objectively assessed physical activity level. Med Sci Sports Exerc. 2009; 41:1368-1373.

A 5-yr Change in Norwegian 9-yr-Olds' Objectively Assessed Physical Activity Level

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ABSTRACT

KOLLE, E., J. STEENE-JOHANNESSEN, L. KLASSON-HEGGEBØ, L. B. ANDERSEN, and S. A. ANDERSSEN. A 5-yr Change in Norwegian 9-yr-Olds' Objectively Assessed Physical Activity Level. *Med. Sci. Sports Exerc.*, Vol. 41, No. 7, pp. 1368–1373, 2009. **Purpose**: To describe changes in objectively assessed physical activity by socioeconomic status (SES) between 1999–2000 and 2005 in 9-yr-old children living in Oslo, Norway. **Methods**: Two cross-sectional studies were conducted in 1999–2000 and 2005. The participation rate was 70.9% in 1999–2000 and 91.4% in 2005. Participants were identified by SES based on whether the school they attended was in an area designated as high, middle, or low mean income. Physical activity was assessed objectively by accelerometers. A total of 718 children (1999–2000, $n = 340$; 2005, $n = 378$) provided valid physical activity assessments that met all inclusion criteria. General linear models were used to assess the changes in physical activity between 1999–2000 and 2005. **Results**: A significant increase in mean physical activity level and physical activity during weekends was observed between the two study periods ($P = 0.02$ and <0.001, respectively), with the patterns being similar for girls and boys. Interactions were found between change in physical activity and SES. Although the mean physical activity level and moderate-to-vigorous physical activity (MVPA) among children from low-SES groups showed no change over time, an increase was seen among children from middle-SES groups. Moreover, in high-SES groups, an increase was observed for mean physical activity level (girls only) between study periods, whereas no change was seen for MVPA participation. **Conclusions**: Nine-year-old children living in Oslo, Norway, have increased both their mean and weekend physical activity level between 1999–2000 and 2005. However, because these opportunities are not equal across SES groups, interventions are required to focus on the needs of children from low-SES groups. **Key Words**: SOCIOECONOMIC STATUS, CROSS-SECTIONAL STUDIES, MODERATE-TO-VIGOROUS PHYSICAL ACTIVITY, CHILD

The focus on health-related physical activity is tremendous and has in recent years led to its intensive promotion in Norwegian society. Nevertheless, children today are thought to be less physically active than in previous generations. This perception is based on the increased prevalence of overweight and obesity seen from an early age (2,19) as well as the drastic increase in the time that children devote to sedentary activities in recent decades (29). Although several studies show longitudinal decline in physical activity from childhood through adolescence and into adulthood (3,25,35), there are few reliable data obtained from using objective methods assessing changes in physical activity level in children (11,23,27). Moreover, children's physical activity has provided serious measurement challenges for researchers, and there are limitations to existing data. Much of the data provide crude estimates of physical activity that are based on some form of children's self-report (11,25). This may be problematic because assessing physical activity participation in children is challenging because they rarely engage in lengthy sustained bouts of activity but have a physical activity pattern that is typically intermittent and spontaneous (4). Children tend to overestimate high-intensity physical activity behavior and to underestimate moderate physical activity when completing self-report instruments. Moreover, children lack the cognitive ability to accurately recall details of their physical activity patterns (16,33,38).

Some uncertainties surround the associations between socioeconomic status (SES) and physical activity participation in childhood. Although some studies reveal a positive association between SES and physical activity (12,18,21), others find no association (5,6,14,17,30) or an inverse association (22). Furthermore, few studies have examined the extent to which the changes in childhood physical activity vary by SES. A study from Australia (11) revealed that moderate-to-vigorous physical activity (MVPA) increased across all SES tertiles. However, the greatest increase was seen in adolescents from middle- and high-SES areas. The study, however, was based on self-report data and included adolescents only.

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BASIC SCIENCES

A study from Denmark using objective methods to assess changes in habitual physical activity among 8- to 10-yr-olds showed that changes in physical activity did not differ among SES groups (23). There is a need to gain a better understanding of how children in different SES groups change their physical activity level over time.

The aim of this study was to describe changes in objectively assessed physical activity over a 5-yr period using representative samples of 9-yr-olds living in Oslo, Norway. In addition, we tested whether there was an interaction between change in mean physical activity level and time spent at MVPA between study periods and SES.

METHODS

Design

Data were collected in two cross-sectional studies: the European Youth Heart Study carried out from 1999 to 2000 and the Physical Activity among Norwegian Children Study carried out in 2005. In 1999, all elementary schools in Oslo were stratified according to the socioeconomic character of their local area. From each of three socioeconomic strata (low, middle, and high) and at an individual level based on the number of students attending each school, a proportional sample of schools was randomly selected. In 1999–2000, children were recruited from nine elementary schools in Oslo, and the same schools were included in the 2005 study. In 1999–2000, 410 of 578 invited fourth graders participated in the study, giving a participation rate of 70.9%. In 2005, 449 of 491 invited children were included in the study, giving a participation rate of 91.4%. Before participation in the study, written informed consent was obtained from each subject and his or her primary guardian. The Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Services approved the study.

Measures

Anthropometry. Weight and height were measured while the children were in light clothing and without shoes. Weight was measured to the nearest 0.1 kg with a digital Seca 770 scale. Height was measured to the nearest 0.1 cm, using wall-mounted tapes, with the child standing upright against the wall. Body mass index (BMI) was calculated as weight (kg) divided by the squared height (m^2).

Socioeconomic status (SES). The classification of SES was based on the economic profile of the catchment area of the schools the children attended. On the basis of the average gross income per inhabitant aged between 30 and 66 yr liable to pay taxes within the different school catchment areas, the local authorities calculated the percentage inhabitants who had a gross income considered as high (in 1997 defined as >US $50,000). This calculation was used to divide the catchment areas into three gross income groups: low-, middle-, and high-SES areas. From these three subgroups, we included four schools from low-SES areas, two

schools from middle-SES areas, and three schools from high-SES areas. The clustered SES code was assigned to each child within the data set.

Assessment of physical activity. The uniaxial Actigraph accelerometer (MTI model 7164; Manufacturing Technology Inc, Fort Walton Beach, FL) was used to obtain objective assessment of physical activity. We visited the children at their schools, and each child was fitted with one accelerometer worn for four consecutive days (two weekdays and two weekend days). The children wore the monitor on the right hip, and we instructed them to wear the accelerometer during all waking hours, except during swimming and bathing. Accelerometers were initialized to start recording at 6 a.m. on the day after they were distributed to the children. In 1999–2000, we set the epoch to 60 s, and in 2005, we set the epoch to 10-s intervals, which subsequently were summed to 60-s intervals before further analyses. The physical activity measurements in both studies were undertaken during the same months of the year (February to June), with the exception of one school in 1999 where data were collected in October and November.

A SAS-based software program (SAS Institute Inc., Cary, NC) called CSA analyzer (http://csa.svenssonsport.dk) was used to analyze accelerometer data. In the analyses of accelerometer data, we excluded all night activity (12−6 a.m.) and all sequences of 10 min or more of consecutive zero counts from each subject's recording. The latter implies that the child has not been wearing the accelerometer. A newly published study (20) reported that the single-day intraclass correlation coefficient (ICC) for 600 min of assessment was 0.45, whereas the ICC for 480 min of assessment was 0.44. To avoid loosing statistical power, we chose to specify a valid day as 480 min. In the present study, data were considered valid if a child had at least 3 d of at least 480 min·d^{-1} recorded.

The primary physical activity variable was the mean number of counts per minute (counts·min^{-1}), and additional outcomes were time spent at different activity intensities. Published cutoffs for different intensity levels in children vary substantially between studies. We defined MVPA as >2000 counts·min^{-1}, whereas vigorous physical activity (VPA) was defined as >3000 counts·min^{-1}. The cutoff for moderate activity (i.e., 2000 counts·min^{-1}) is broadly equivalent to walking at 4 km·h^{-1} and has also been used elsewhere (1,8). The proportion of children who achieved the recommended levels of 60 min of MVPA each day (24) was established by dividing time spent on MVPA by the number of valid days of recording, giving an average number of minute per day across the assessment period.

Analysis. With physical activity (counts·min^{-1}) as the primary outcome variable, we used the variability known from the baseline population (SD = 286) to calculate the minimum size of differences we could distinguish between subgroups. With respect to this, 340 children in each group gave us the ability to detect subgroup physical activity differences of 30 counts·min^{-1} (4%) (α = 0.05) using a

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	1999–200		2005	
	Girls	Boys	Girls	Boys
n	167	173	169	209
Age (yr)	9.7 (0.3)	9.7 (0.3)	9.8 (0.3)	9.9 (0.3)
Height (cm)	138.6 (6.3)	139.8 (6.4)	139.6 (6.8)	141.4 (5.9)
Weight (kg)	33.1 (6.1)	33.3 (5.7)	34.9 (7.1)	34.6 (6.2)
BMI (kg·m^{-2})	17.2 (2.4)	17.0 (2.0)	17.8 (2.7)	17.2 (2.4)
SES, *n* (%)				
Low	65 (38.9)	61 (35.3)	71 (42.0)	93 (44.5)
Middle	38 (22.8)	40 (23.1)	42 (24.9)	36 (17.2)
High	64 (38.3)	72 (41.6)	56 (33.1)	80 (38.3)

Values presented are means (SD).

two-tailed test ($1 - \beta = 0.80$). General linear models were used to assess the changes in physical activity between 1999–2000 and 2005. We found no interaction between sex and study period for any of the physical activity variables; therefore, these analyses are presented by study period, adjusted for sex and school. We used chi-square analyses to study change in the proportions of children meeting the physical activity recommendations.

Two-way ANCOVA was used to study the associations between sex, SES, mean physical activity, and MVPA between the two time points. For mean physical activity, but not MVPA, a trend toward a three-way interaction was found between SES, study period, and sex ($P = 0.06$). Consequently, the results for the association between mean physical activity and SES are presented, stratified by sex. The patterns of associations were compared among different SES groups by testing interaction terms (study period × SES). Because SES can be confounded by BMI, all analyses are adjusted for BMI. One-way ANOVA with a Bonferroni correction for multiple comparisons was used to compare physical activity across SES groups for each time point. For the latter variables, a P value <0.02 (0.05/3) was required to declare significance. All analyses were conducted using the Statistical Package for the Social Sciences (version 15; SPSS Inc., Chicago, IL).

RESULTS

The 1999–2000 study comprised 340 children, and the 2005 study comprised 378 children with valid physical activity assessments. Descriptive characteristics of the study sample are presented in Table 1.

Mean physical activity level. In 1999–2000, the participants' mean (SD) physical activity was 779 (255)

counts·min^{-1}, whereas the corresponding value was 833 (322) counts·min^{-1} in 2005. Adjusted mean (SE) physical activity data are presented in Table 2. A significant increase in mean physical activity was observed between the two time points ($P = 0.02$). The difference in mean physical activity between the children in 1999–2000 and 2005 was 49 counts·min^{-1}, which translates into a 6.2% (95% CI = 4.5–8.0) difference. In 1999–2000, the participants' mean (SD) physical activity level was 815 (279) counts·min^{-1} during weekdays and 676 (345) counts·min^{-1} during weekends. The corresponding values were 839 (303) and 829 (480) counts·min^{-1} in 2005. As can be seen in Table 2, physical activity during weekdays showed no change over time ($P = 0.4$). However, an increase in physical activity during weekends was observed between the study periods ($P < 0.001$). Children in 2005 were 20.8% (95% CI = 17.8–23.8) more physically active during weekends than children in 1999–2000.

Time spent in MVPA and VPA (min·d^{-1}). Between study periods, no difference was seen for mean time spent in MVPA and VPA (Table 2). Changing the cutoff for VPA to >4000 or >4500 counts·min^{-1} did not alter the results (data not shown). In 1999–2000, 75.4% of girls and 86.7% of boys met the Norwegian physical activity recommendations of 60 min of daily MVPA. In 2005, 79.3% of the girls and 92.8% of the boys met the recommendations; the increase was significant among boys ($P = 0.05$).

Physical activity and SES. In 1999–2000, boys from middle-SES groups had significantly lower mean physical activity level than boys from the low- and the high-SES groups ($P = 0.001$ and <0.001, respectively). In 2005, girls from the high-SES groups were significantly more active than girls from the low-SES groups ($P = 0.003$). We found a significant interaction between study period and SES for mean physical activity for both girls ($P = 0.02$) and boys ($P = 0.05$). Between studies, the physical activity level among girls from low-SES groups remained relatively stable, whereas an increase in mean physical activity was seen among girls from middle- and high-SES groups. The mean physical activity level among boys from low- and high-SES areas remained fairly stable; however, an increase was seen among boys from middle-SES groups (Table 3).

In 1999–2000, children from low-SES groups participated in more MVPA than children from middle- and high-SES groups ($P < 0.001$ and $P = 0.007$, respectively). In 2005,

	1999–2000	2005	Mean Difference (95% CI)	P Value
Girls, *n* (%)	167 (49.1)	169 (44.7)		
Boys, *n* (%)	173 (50.9)	209 (55.3)		
Mean PA (counts·min^{-1})	782 (15.5)	831 (14.7)	49 (7.1, 90.9)	0.02
PA weekdays (counts·min^{-1})	819 (15.5)	836 (14.7)	17 (−24.9, 58.9)	0.4
PA weekend (counts·min^{-1})	678 (23.3)	828 (21.7)	150 (87.6, 212.4)	<0.001
MVPA (min·d^{-1})	90 (1.8)	92 (1.7)	2 (−2.9, 6.9)	0.5
VPA (min·d^{-1})	47 (1.3)	48 (1.2)	1 (−2.5, 4.5)	0.7

ANCOVA is used to calculate statistical significance.
[a] Data are adjusted for school and sex.
CI, confidence interval; PA, physical activity; MVPA, moderate-to-vigorous physical activity; VPA, vigorous physical activity.

TABLE 3. Adjusted[a] mean (SE) physical activity (counts·min^{-1}) stratified by socioeconomic status (SES) among girls and boys in 1999–2000 and 2005.

	Girls				Boys			
	1999–2000, Mean (SE)	2005, Mean (SE)	Mean Difference (95% CI)	P Value	1999–2000, Mean (SE)	2005, Mean (SE)	Mean Difference (95% CI)	P Value
Low SES	738 (31.9)	705 (34.9)	33 (−60, 126)	0.5	881 (38.6)	896 (31.3)	−15 (−116, 86)	0.7
Middle SES	650 (41.7)	751 (40.1)	−101 (−214, 12)	0.05	666 (48.4)	843 (51.0)	−177 (−315, −39)	0.001
High SES	717 (32.3)	871 (30.7)	−154 (−241, −67)	0.006	904 (35.5)	897 (31.2)	7 (−86, 100)	0.9

Interaction between SES and study period: $P = 0.02$ (girls), $P = 0.05$ (boys).
ANCOVA is used to calculate statistical significance.
[a] Data are adjusted for BMI.
CI, confidence interval; PA, physical activity.

there was no association between time spent in MVPA and SES. A significant interaction was found between study period and SES for time spent in MVPA ($P = 0.02$). Between studies, the MVPA participation among children from low- and high-SES groups remained fairly stable, whereas participation in MVPA increased in children from middle-SES groups (Fig. 1).

DISCUSSION

Our study has two main findings. First, 9-yr-old children living in Oslo, Norway, have increased both their mean physical activity level and their activity level during weekends between 1999–2000 and 2005, with the patterns being similar for girls and boys. Second, interactions were found between change in physical activity and SES. Although no change was seen in mean physical activity level and MVPA participation among children from low-SES groups, an increase was seen among children from middle-SES groups. Moreover, children from high-SES groups had an increase in mean physical activity level (girls only) between study periods, whereas their MVPA participation remained fairly stable.

Strengths and limitations. A major strength of this study was the use of an objective assessment of physical activity. Accelerometers are regarded as optimal for quantification of the amount and intensity of physical activity (28), and the use of the device has shown to be both valid and reliable (37). In both studies, we used identical data

FIGURE 1—Adjusted* daily min (95% CI) spent at moderate-to-vigorous physical activity (MVPA) by study period and socioeconomic status (SES). *Data are adjusted for sex.

reduction methods, which should exclude any systematic differences among studies. Furthermore, both studies included large population-based samples with high participation rates.

Some limitations in the study should be noted. First, in 1999–2000, approximately 30% of the invited children chose not to participate, and we cannot completely rule out the issue of selection bias. Because the aim of the study was, among others, to assess physical activity level, aerobic fitness, and body composition, it is likely that the leanest and most physically active children chose to participate. If this is true, there are reasons to believe that our results are underestimated rather than overestimated. Second, we chose to define SES on an area level, which may be biased on the individual level. However, it has been argued that household and neighborhood factors could be important modifiers of physical activity (32). In Oslo, there are strong regional links between socioeconomic background factors and disability and mortality (31). By defining SES on an area level, our study could add significantly to the knowledge of whether neighborhood context affect childhood behavior. Third, data were collected over several months, and it is a possibility that seasonal variation in daily physical activity might influence the results. However, as both studies were conducted during the same months of the year and the months when data were collected in the different SES areas were random in both studies, we do not think that changes in physical activity were caused by seasonal variation.

Changes in physical activity. Previous self-report data have suggested that US adolescents have had relatively stable MVPA participation during recent decades (25,26), whereas Australian adolescents increased their MVPA participation between 1997 and 2004 (11). At present, few studies have reported on changes in objectively assessed physical activity; however, the few that have been conducted show similar changes as those using self-report measures. A study from Denmark reported a stable physical activity level in 8- to 10-yr-old children between 1997–98 and 2003–04 (23), whereas Swedish 7- to 9-yr-olds increased their weekday physical activity (steps per day) between 2000 and 2006 (27).

One of the most notable findings of the present study was the large increase in physical activity during weekends. Because children in 1999–2000 were 17% less physically active during weekends than during weekdays, the weekend days had the greatest potential for increased physical activity. During weekdays, a lot of the physical activity is
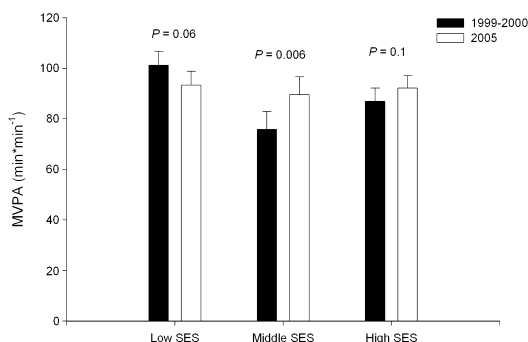
connected to school activities and organized activities in the afternoon. On the weekends, however, parents and significant others are primarily responsible for ensuring that children are sufficiently physically active. Our results therefore suggest that the intensive promotion of physical activity has contributed to significant parental investment in increasing physical activity during weekend days.

The recent increases in physical activity found in the present study are likely to have resulted from an interaction of different factors. First, the Norwegian government has developed a national physical activity action plan aimed at increasing and strengthening factors that promote physical activity in the population and reducing the factors that lead to physical inactivity (36). The vision of the action plan is a general improvement in public health through increased physical activity in the population. However, children and adolescents are identified as target group number one. Second, several school interventions have been initiated to increase children's physical activity participation. Third, the mass media have emphasized the positive health benefits associated with regular physical activity, and attention has been given to the prevention of obesity, which may stimulate further interest in physical activity.

Physical activity and SES. The association between childhood physical activity and SES is still unclear, and results remain inconclusive. Riddoch et al. (30) reported that the mother's and partner's education levels were inversely associated with 11-yr-olds' activity level. However, the association was lost for mother's education and attenuated for partner's education when adjusting for age, sex, season, maternal age, and social class. Hesketh et al. (12) reported that maternal employment was associated with objectively assessed MVPA in Australian 6-yr-olds, whereas no associations were found between Scottish preschoolers' objectively assessed physical activity levels and SES (14). Moreover, a study from the United States revealed that a lower level of parental education was associated with greater physical activity decline when going from childhood through adolescence (15). The reason for the inconsistencies among studies might be that behaviors may be differently related to SES in different cultures or the different classifications of SES used in each study. Whereas some studies use individual-level measures of SES (e.g., parent's education, occupation, and income), others use household-level measures (e.g., combined income earned by all members of the household, occupation of the "main income earner" in the household) or area-level measures (postcode of residence). Each method has its own strengths and weaknesses, making comparisons between studies and countries challenging.

Interactions were found between change in mean physical activity level, MVPA and SES. This indicates that some characteristics of the school environment influence children's opportunities for physical activity. It is possible that schools in high-SES areas have higher-quality and better-maintained physical activity facilities than do schools in less affluent areas. Previous studies have also shown that low-income neighborhoods have fewer facilities for recreational physical activity, and the presence of facilities in neighborhoods is directly correlated with individual physical activity (10). Moreover, studies have found that adults in high-SES groups are more physically active than adults from other SES groups (7,9,39). It might be that parents in high-SES areas are more aware of the health benefits of physical activity and therefore encourage their children to be physically active. Cultural factors may also influence the change in mean physical activity. In 1999–2000, 97% of the children in the high-SES group were of Western origin compared with 78% in the low-SES groups. In 2005, the corresponding numbers were 96% and 68%. It might be that ethnic minority girls experience less encouragement from parents and friends to be physically active and may also have fewer opportunities to be physically active than ethnic Norwegian girls, as the increase in mean physical activity was particularly large among high-SES girls.

Implications for public health. There is a need to gain a better understanding of how children's physical activity levels change during time. Our results suggest that there has been significant investment in providing children with greater physical activity opportunities. However, because these opportunities are not equal across SES groups, more emphasis should be put on increasing physical activity among children from low-SES groups, especially in girls. It is important that the activities that are offered are inexpensive and convenient to access (13). One solution could be making 60 min of daily physical activity mandatory in school curricula. This can be achieved in a cumulative manner during physical education, recess, and before and after school programs (34) and would give children from all SES groups the opportunity to be physically active. The activities should be of at least moderate intensity and require qualified teachers. Furthermore, policy makers should make an effort to improve accessibility of physical activity programs as well as the number and quality of recreational facilities in lower SES areas (13).

CONCLUSIONS

From 1999–2000 to 2005, 9-yr-old girls and boys living in Oslo increased their mean physical activity level as well as their activity level during weekends. The increase in physical activity was, however, not equal across SES groups. The results emphasize the need to increase physical activity level in children from low-SES areas.

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BASIC SCIENCES

PAPER IV

Five-year changes in body composition among 9-year-olds in Oslo, Norway

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Abstract

Background: The purpose of this study was to describe a five-year change in the prevalence of overweight and obesity among 9-year-old children, and to study changes in fatmass and fat distribution by investigating changes in waist circumference (WC) and skinfold thicknesses.

Methods: A total of 859 9-year-olds were included in two cross-sectional studies conducted in 1999−2000 and 2005. Measurements of body mass index (BMI; in kg/m^2), WC and skinfold thicknesses were taken by trained research assistants. The International Obesity Task Force cut-offs were used to define overweight and obese subjects, and logistic regression was applied to study changes in prevalence. Changes in anthropometric variables were assessed by using general linear models. Shifts in BMI, WC and skinfold thickness distribution were assessed by testing interaction terms between variable deciles and study periods.

Results: The overall prevalence of overweight (including obesity) did not change statistically from 1999−2000 and 2005. However, the prevalence was 5-7% higher in 2005 indicating that a shift has occurred. No change was reported for mean BMI, whereas a significant increase was observed in the children's WC and skinfold measurements (girls only). Shifts in percentile distribution were observed for BMI, WC and sum of 4 skinfold thickness, however, the shift appeared to be faster in the upper end of the population distribution.

Conclusions: Despite no changes in mean BMI among 9-year-olds, there have been increases in measures of fatness and WC over the last five years. Our results indicate that there is a need for large-scale monitoring of body composition in children.

Background

The prevalence of childhood overweight and obesity has increased over the past decades [1].
In the United States, 35% of school-aged children are currently classified as overweight or
obese [2], while the corresponding numbers are 23% in Australian 2-16-year-olds [3],
between 27 and 36% in 7-11-years-olds in Mediterranean countries [4], 20% in 4-18-year-
olds in the UK [5] and 15-20% in 8-14-year-olds in the Scandinavian countries [6,7]. These
findings are based on body mass index (BMI), and gender- and age-adjusted cut-offs
developed by the International Obesity Task Force (IOTF) [8].

Although BMI is widely used as a surrogate measure of adiposity, it is a measure of excess
weight relative to height, rather than excess body fat [9]. Furthermore, BMI fails to capture
how body fat is distributed. Obesity is not a homogeneous condition, and several studies in
adults have suggested that abdominal obesity is a better predictor of chronic diseases such as
type 2 diabetes, hypertension and dyslipidemias, than overall adiposity assessed using BMI
[10,11]. In children and adolescents, adverse concentrations of lipids and insulin have been
shown to correlate well with abdominal obesity [12].

Children can experience both physical and psychological adverse effect of overweight and
obesity. Furthermore, weight in childhood predicts weight in adulthood, and being overweight
as an adult comes with a whole set of consequences of its own. It is therefore essential to
monitor trends in the prevalence of overweight and obesity among children. However, fatness
can change without changes in BMI and it is possible that children may be getting fatter at the
expense of lean tissue, even if weight does not change [13]. Therefore, monitoring trends in
BMI alone may not identify changes in body composition. The aim of the current paper is to
describe a five-year change in prevalence of overweight and obesity using IOTF cut-off

values among 9-year-old children, and to study changes in fatmass and fat distribution by investigating changes in the children's waist circumference (WC) and skinfold thicknesses.

Methods

Participants

Participants were grade 4 girls and boys, living Oslo, Norway. Data were collected in two cross-sectional studies: the European Youth Heart Study, carried out in 1999−2000 and the Physical Activity among Norwegian Children Study, carried out in 2005. In 1999, all elementary schools in Oslo were stratified according to the socioeconomic character of their local area. A proportional sample of schools was randomly selected from each of three socioeconomic strata (low, middle and high) based on the number of students attending each school. In 1999−2000, children were recruited from nine elementary schools in Oslo, and the same schools were included in 2005. In 1999−2000, 410 of 578 invited children participated, giving a participation rate of 70.9%. In 2005, 449 of 491 invited children chose to participate, giving a participation rate of 91.4%. We obtained written, informed consent from the child's parent or legal guardian after they were given, in writing, a full explanation of the aims of the study and its possible hazards, discomfort, and inconvenience. The Regional Committee for Medical Research Ethics and Norwegian Social Science Data Services approved the study.

Anthropometric measures

Children had a physical examination at their school. Trained research assistants took all anthropometric measures, and an identical study protocol was used in both studies. Weight and height were measured in light clothing and without shoes. Weight was measured to the nearest 0.1 kg with a digital Seca 770 scale (SECA GmbH, Hamburg, Germany). Height was

measured to the nearest 0.1 cm, using wall mounted tapes, with the child standing upright against the wall. BMI was calculated as weight (kg) divided by the height squared (m^2). Waist circumference was measured with a metal anthropometric tape midway between the lower rib and the iliac crest at the end of a normal expiration.

Four skinfold thickness measurements (triceps, biceps, subscapular and suprailiac) were taken using a Harpenden skinfold caliper (John Bull; British Indicators Ltd., West Sussex, England) on the left side of the body according to the criteria described by Lohman et al [14]. Duplicate measurements were taken for each skinfold, with a third measure taken if the difference between the two measurements differed by ≥ 2 mm, and the two closest measurements were averaged. No data on reliability and accuracy of anthropometric measures were reported in 1999−2000. In 2005, the intra-class (within-observer) correlation coefficients were ≥ 0.95 for skinfold measurements and 0.93 for WC, while the inter-class (between observers) correlation coefficients were ≥ 0.84 for skinfold measurements and 0.94 for WC. We assessed the children's sexual maturity, using Tanner's 5-stage scale for breast development in girls and pubic hair in boys [15]. From the 859 subjects who participated, 788 subjects had complete anthropometric and sexual maturity data and were included in the analyses. There were no significant differences in BMI, WC, or skinfold thicknesses between the participants whose data were included or excluded (N=71) due to missing data.

In 1999−2000, 84% of the participants were of western origin (Caucasian), while the corresponding number was 77% in 2005. The non-Western origin sample included black-African, black-other, Pakistani, Vietnamese, Chinese, Indian, Arab and Other individuals.

Statistical analysis

All values are presented as mean (SD) unless otherwise stated. The IOTF recommended cut-offs based on the age and sex specific values of BMI extrapolated to the adult values of 25 kg/m^2 and 30 kg/m^2 have been used for the definition of overweight and obese children, respectively [8]. Four age intervals, 8.75–9.24, 9.25–9.74, 9.75–10.24 and 10.25–10.74 years were used to correspond to ages 9.0, 9.5, 10.0 and 10.5 years, respectively, by IOTF definition. As the prevalence of obesity was fairly low, the data from children classified as overweight or obese were merged for further analyses. The relative change (%) in overweight and obesity was calculated as ([prevalence at 2005 – prevalence at 1999−2000]*100/ prevalence at 1999−2000). The annualized change in the prevalence of overweight and obesity was calculated as ([prevalence at 2005 – prevalence at 1999−2000]/5).

Logistic regression was applied to study change in overweight (including obesity). The dependent variable in this model was the binary status of overweight (including obesity) and the study period was the main predictor, with the 1999–2000 study period as the reference category. The analyses were adjusted for school and sexual maturity, and the results are presented as adjusted odds ratios (ORs) with 95% confidence intervals (CIs). Changes in anthropometric variables between study periods were tested by using general linear models. The anthropometric variable was defined as the dependent variable, study period was the fixed factor, and the analysis was adjusted for age, sexual maturity and school. The study sample was split by sex due to interactions between sex and study period. Standardized change was assessed by investigating changes in Z-scores for BMI, WC and sum of 4 skinfold thicknesses ([mean 2005 – mean 1999–2000] / SD 1999–2000). Shift in BMI, distribution was assessed by using general linear model. BMI was defined as the dependent variable in the model, and study period and deciles of BMI were the main predictors. Shift in BMI

distribution was investigated by testing interaction terms (study period*deciles of BMI). The same procedure was performed to test for shift in WC and sum of 4 skinfold thicknesses. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, version 15.0).

Results

Table 1 displays the characteristics of the study participants. In both studies, 83% of the participants were prepubertal (Tanner stage I), and the rest were early pubertal (Tanner stage 2).

In 1999−2000, 12.6% of girls and 10.9% of boys were classified as overweight, while an additional 1.1% of girls and 0.6% of boys were obese. By 2005, 15.5% of girls and 15.4% of boys were classified as overweight, while an additional 4.7% of girls and 1.6% of boys were classified as obese. The changes in overweight (including obesity) are presented in Table 2. Over the five-year period, the prevalence of overweight (including obesity) in the total study sample increased by 1.16 percentage points annually, but the change was not statistically significant. In both study periods, logistic regression analyses revealed that children of non-Western origin had higher odds of being overweight than those of Western origin (1999−2000: OR = 2.3, 95% CI: 1.04, 5.00; 2005: OR = 2.0, 95% CI 1.1, 3.59). However, neither the children of Western origin nor the children of non-Western origin showed a significant increase in the prevalence of overweight over the five-year period.

Table 3 shows the mean values for BMI, WC and skinfold thicknesses. Between 1999−2000 and 2005, no change was seen for mean BMI, however, the age-adjusted mean WC increased from 60.1 cm to 65.8 cm among girls (p < 0.001), and from 61.5 cm to 63.4 cm among boys

(p < 0.001). In girls, significant increase was observed for all skinfold measurements. The differences ranged from 2.3 to 3.0 mm at the four sites, while the sum of 4 skinfold thicknesses increased by 10.5 mm which translates into a 25.7% difference (95% CI: 21.2, 30.2). In boys, increase in triceps and supra iliac skinfold thicknesses were borderline significant (p = 0.05), while no changes were observed for the other skinfold measurements. Figure 1 show the box plot of BMI, WC and sum of 4 skinfold thickness data. There appeared to be a shift to higher values at the upper end of the population distribution (p < 0.001 for interaction between study period and deciles of BMI, WC and sum of four skinfolds). Among girls, the standardized change (change in Z-score) was 0.21 for BMI, 1.0 for WC and 0.61 for sum of 4 skinfold thicknesses. The corresponding values for boys were 0.09, 0.47 and 0.27.

Discussion

In the current study, no statistically significant change in the prevalence of overweight (including obesity) was found between 1999−2000 and 2005. However, the prevalence of overweight (including obesity) was 5-7% higher in 2005 than in 1999−2000. Also, the proportion of obese girls increased fourfold in the present study, indicating that a shift has occurred. A recent study from the US [16] reported no increase in childhood obesity between 2003−04 and 2005−06. However, results are inconsistent. A Swedish study [7] reported a decrease in the prevalence of childhood overweight (including obesity) among girls from 2000−01 to 2004−05, while a study from Cyprus reported an increase in obesity among 11-year-olds from 1997−98 to 2002−03 [17]. The differences might be explained by different time periods and different age groups of the children included in the studies. Also, some studies included national representative samples, while others used small, non-representative samples. As these factors varied across studies comparability of findings is difficult.

In both study periods, race/ethnicity was associated with prevalence of overweight and obesity as has been reported in other countries. In the US, higher prevalence of overweight has been reported among children who are non-Hispanic black or Mexican American than among children who are non-Hispanic white [16]. In the UK, British Afro-Caribbean and Pakistani girls have increased risk of being obese, while Indian and Pakistani boys have an increased risk of being overweight than the general population [18]. Despite this, we did not observe an increase in the prevalence of overweight (including obesity) in either children of western or non-western origin over the five years period. This indicates that the prevalence of overweight is not rising faster among minority groups than in the general population. Similar trends have recently been reported in the US [16].

Our results revealed that where there was no change in mean BMI, there was a change in body shape and body composition. In particular, girls increased their WC by 5.7 cm in five years; an increase of 1.1 cm annually. In addition, the increased skinfold thicknesses observed in girls indicates increased fatmass, which are all factors associated with higher disease risk [19]. Our results are in accordance with several investigators showing increases in WC [20-22] and skinfold thickness [23,24] that are greater than increases in BMI. As was the case in our study, the increase was greater in girls than in boys in all previous studies. Different reasons for this sex difference have been suggested, such as sexually diverse changes in body composition that occur during puberty, or decreased habitual physical activity among girls. However, we found no evidence for an increase in the prevalence of early puberty, as an equal number of girls were categorized in Tanner stage 2 at both measurement points. Further, an increase in objectively assessed physical activity was seen in both girls and boys in our study population [25]. It is therefore unlikely that the sex difference reflects a rapid decrease in physical activity among girls.

Among boys, the patterns of shift (increase) of BMI, WC and sum of 4 skinfold thickness did not appear until approximately the 50th percentile. In contrast, shifts in the girls' values were observed in all percentiles, but BMI, WC, and sum of 4 skinfolds appeared to increase faster in the upper end of the population distribution. This means that the heavier children became heavier, and the fat children became fatter. The increase in the upper end of the population may partly be caused by the higher participation rate in 2005 (91.4%) than in 1999−2000 (70.9%). We have no data on the children who did not participate in the study, but as the aim was to measure body composition, it is possible that the heaviest children chose not to participate. If this is true, there are reasons to believe that the high acceleration of the anthropometric measures is somewhat overestimated.

Methodological differences may have accounted in part for the increase in WC and skinfold thicknesses. However, in both studies the sites of the measurements were defined identically. Further, the research assistants in 2005 were trained thoroughly by the project leader in 1999−2000 with the aim of collecting comparable anthropometric data at all examinations.

Our findings have some important public health implications. Over a few years, body composition of 9-year-olds has changed towards larger fat mass. As mean BMI did not change, this indicates a decrease in muscle mass which is of concern because resting metabolic rate is highly correlated with body weight in general and with muscle mass in particular. Hence, increased fat tissue and decreased muscle mass leads to decreased resting metabolic rate, decreased energy expenditure and the consequence is further increase in body weight. This highlights and emphasizes the important role of physical activity in both preventing and treating overweight and obesity in children. Furthermore, our results support

the suggestion from Dollman and Olds [20] that the reported increase in the prevalence of
obesity, based on BMI, may be an underestimate of the true extent of the problem. Data from
the Bogalusa Heart Study revealed that when WC was considered with BMI, children and
adolescents with large waist circumferences were more likely to have elevated cardiovascular
disease risk factors than were those with a smaller waist circumference, within a given BMI
category [26]. Even though this finding is not consistent, our results indicate that there is a
need for large-scale monitoring of fatness per se in children. Skinfold measurements have
been used widely to assess obesity and are considered good indicators since they directly
measure a layer of subcutaneous fat. The method is also simpler to use than laboratory
techniques and the costs are minimal, however, it is open to random and systematic errors
[13]. Waist circumference is relatively easy to measure, reliable and low cost. Measures of
waist circumference should, in addition to measures of height and weight, be standardized,
and routinely incorporated in clinical and epidemiological settings, as well as in school health
examinations.

A strength of this study is that several objective measures of body mass and body composition
were included. Further, the participation rates in both studies were high and the samples
described here are representative of the population of that age and time period in Oslo,
Norway. A limitation of the study is the inclusion of one single age-group. It would be useful
to know if the observations reported here are true for children of all age-groups.

Conclusions

In conclusion, we found that in Norwegian children aged 9-years-old there has been no
statistical change in the prevalence of overweight (including obesity) over a five year period.
However, the prevalence was 5-7% higher in 2005 indicating that a shift has occurred.

Whereas mean BMI did not change, rapid increases in WC and skinfold thickness were seen, indicating a change of body composition. Our results emphasize the need to monitor trends in waist circumference and skinfold thickness, in addition to BMI, to be able to identify changes in body composition in children.

List of abbreviations

BMI, body mass index; CI, confidence interval; IOTF, International Obesity Task Force, SF, skin fold; WC, waist circumference

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

EK and JSJ were responsible for conception of the study, study design and coordinated and participated in the data collection. IH, LBA and SAA were involved with conception of the study and study design. EK analyzed the data and drafted the manuscript. All authors were involved with data interpretation, critical revisions of the paper and provided approval for its publication.

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Table 1. Characteristics of the participants. Values are mean (SDs) unless otherwise stated.

Participant Characteristic	1999−2000 (n=348)	2005 (n=440)
Age (years)	9.7 (0.3)	9.9 (0.3)
No (%) girls	174 (50)	193 (44)
Height (cm)	139.1 (6.2)	140.7 (6.4)
Weight (kg)	33.3 (5.8)	34.7 (6.7)
BMI (kg/m^2)	17.1 (2.2)	17.4 (2.6)
Overweight (No, %)[1]	41 (11.8)	68 (15.5)
Obese (No, %)[1]	3 (0.9)	13 (3.0)
Waist circumference (cm)	60.5 (5.7)	64.7 (7.5)
Sum of 4 skinfolds (mm)	36.3 (17.1)	43.0 (24.6)
Ethnic background (No, %)[2]		
Western origin	280 (84)	304 (77)
Non-western origin	52 (16)	92 (23)

BMI, body mass index

[1]Defined on basis of BMI according to IOTF criteria

[2]Percentage is for number with complete data on this variable – 16 participants in 1999−2000 and 44 participants in 2005 had missing data on this variable

Table 2. Crude prevalence and odds ratios (ORs) for prevalence of overweight (including obese) children.

	Number (n) and prevalence (%) of overweight and obese children				Relative change (%)	Annualized change (%)	Adjusted OR (95% CI)
	1999-2000		2005				
	N	%	N	%			
Overall girls and boys	44	12.6	81	18.4	46.0	1.16	1.51 (0.99, 2.31)
Girls	24	13.8	39	20.2	46.4	1.28	1.58 (0.83, 2.98)
Boys	20	11.5	42	17.0	47.8	1.1	1.43 (0.80, 2.56)
Western origin	30	10.7	45	14.8	38.3	0.82	1.35 (0.81, 2.26)
Non-Western origin	13	25.0	28	30.4	21.6	1.08	1.45 (0.61, 3.46)

*The year 1999-2000 was used as the reference category. Analysis are adjusted for school and sexual maturity

Table 3. Mean* (SE) anthropometric data among the boys and girls in the two study samples, by sex.

	Girls				Boys			
	1999–2000	2005	Mean difference	P Value	1999–2000	2005	Mean difference	P Value
	(n=174)	(n=193)	(95% CI)		(n=174)	(n=247)	(95% CI)	
BMI (kg/m^2)	17.3 (0.2)	17.7 (0.2)	0.4 (-0.1, 0.9)	0.08	17.1 (0.2)	17.2 (0.1)	0.1 (-0.5, 0.5)	0.92
Waist circumference (cm)	60.1 (0.5)	65.8 (0.5)	5.7 (4.4, 7.0)	<0.001	61.5 (0.5)	63.4 (0.4)	1.9 (0.6, 3.2)	0.005
Triceps SF (mm)	13.1 (0.4)	15.4 (0.3)	2.3 (1.3, 3.3)	<0.001	10.8 (0.4)	11.7 (0.3)	1.1 (0.1, 2.1)	0.05
Biceps SF(mm)	8.9 (0.3)	11.2 (0.3)	2.3 (1.4, 3.2)	<0.001	7.3 (0.3)	7.9 (0.3)	0.6 (-0.3, 1.5)	0.19
Subscapula SF (mm)	9.5 (0.5)	12.5 (0.5)	3.0 (1.7, 4.3)	<0.001	7.8 (0.4)	8.1 (0.3)	0.3 (-0.8, 1.4)	0.58
Suprailiac SF (mm)	9.1 (0.5)	11.8 (0.4)	2.7 (1.4, 4.0)	<0.001	7.1 (0.5)	8.5 (0.4)	1.4 (0.1, 2.7)	0.05
Sum 4 SF (mm)	40.5 (1.5)	50.9 (1.4)	10.5 (6.4, 14.6)	<0.001	33.0 (1.5)	36.2 (1.3)	3.2 (-0.7, 7.1)	0.12

*Values are adjusted for age, sexual maturity and school. CI, Confidence Interval; BMI, Body Mass Index; SF, Skinfold.
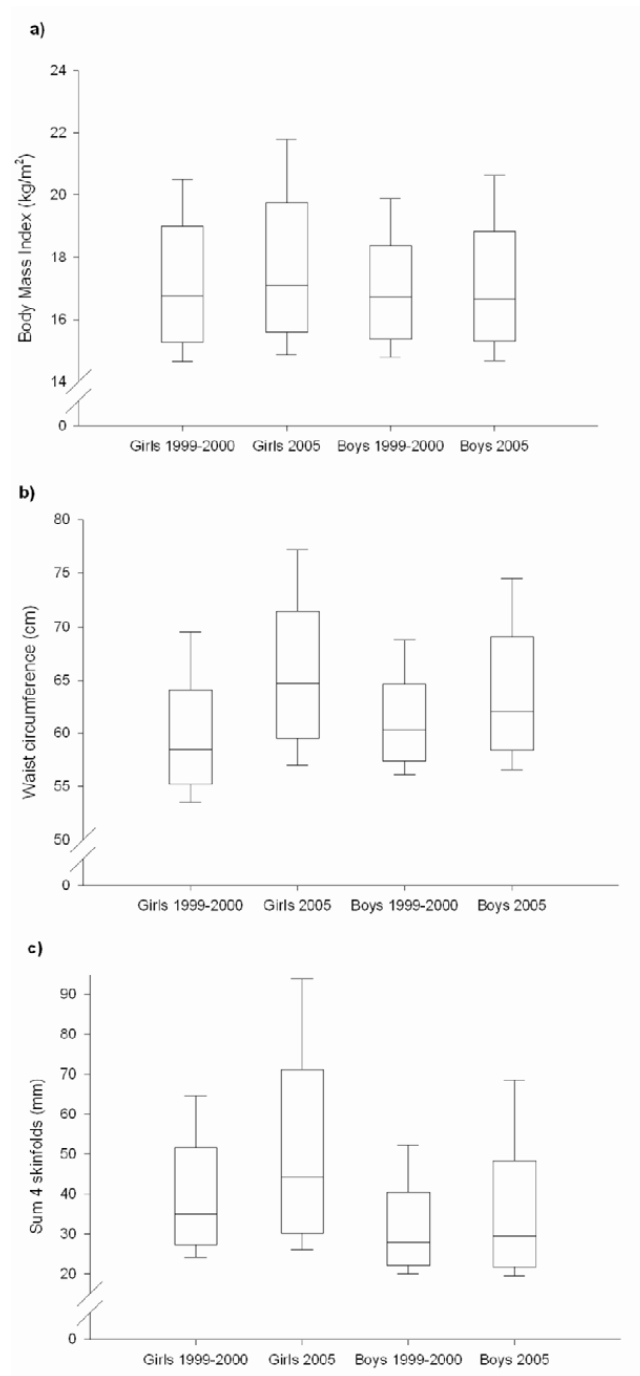
Figure 1. Box plot of the a) body mass index (kg/m^2), b) waist circumference data (cm), and c) sum 4 skinfolds (mm) by sex and study period. The box covers the range in between the lower and upper quartiles; the whiskers cover the range in between the 10th and 90th percentiles, and the horizontal bar dividing the box indicates the median.

APPENDIX 1:

Informed Consent

KJÆRE ELEV OG FORELDRE/FORESATTE

Fysisk aktivitet blant norske barn.
På oppdrag fra Sosial- og helsedirektoratet skal Norges idrettshøgskole i perioden 2005-2006 gjennomføre en kartlegging av kost og fysisk aktivitetsvaner, fysisk form og ulike helsevariabler på barn og unge. Lignende undersøkelser har blitt gjennomført i flere europeiske land. Et landsrepresentativt utvalg på 2000 barn og unge i aldersgruppen 9-10 år og 15-16 år skal delta i undersøkelsen. Vi har til nå testet 443 elever i Oslo området og ytterligere ca. 450 i de nordlige og vestlige deler av Norge. Testingen fortsetter inntil oktober 2006.

Det finnes i dag ikke nok informasjon om fysisk aktivitet og fysisk form i befolkningen for å kunne beskrive utviklingstrender og forskjeller mellom befolkningsgrupper. Slike data er sentrale for å kunne målrette og evaluere arbeidet med å øke graden av fysisk aktivitet i befolkningen. Barn og unge er en prioritert målgruppe i det helsefremmende arbeidet. Denne undersøkelsen vil gi oss verdifull informasjon og kunnskap om barn og unges aktivitetsvaner. *Deres barns skole har sagt ja til deltakelse i denne undersøkelsen, og alle tester skjer i full forståelse med skolens ledelse. Vi spør om dere vil delta i undersøkelsen.*

Registreringer i undersøkelsen
Alle testene vil skje i skolens lokaler i løpet av skoledagen. Det er planlagt at elevene skal gjennomføre flere tester, men de kan selvsagt velge om de vil avstå fra enkelte av disse.

Fysisk undersøkelse
Det vil være måling av høyde og vekt. Det vil gjøres hudfoldsmålinger på overarm, rygg, legg og hofte. Vi vil gjennomføre måling av hvileblodtrykk og analyse av fastende blodprøve for fett i blodet, samt insulin og blodsukker. Bedøvende krem vil bli benyttet i forbindelse med blodprøvetaking, og prøven tas av en erfaren bioingeniør. Blodprøven skal være fastende, og vi ber derfor om at barnet ikke spiser etter midnatt natten før testdagen. Barna vil få frokost umiddelbart etter at blodprøven er tatt.

Kondisjonstest og aktivitetsregistrering
Vi vil gjennomføre en arbeidstest på ergometersykkel. Testen blir utført med en gradvis økende belastning, og med en varighet på 6-10 minutter. Testen stoppes når barnet ikke ønsker å fortsette. Aktivitetsregistrering gjøres ved hjelp av en liten aktivitetsmåler som barnet skal bære på hoften i fire dager. Aktivitetsmåleren blir levert ut på skolen.

Muskelutholdenhet og motorisk kompetanse

Elevene gjennomfører enkle tester av styrke, bevegelighet og koordinasjon.

Spørreskjema

Elevene besvarer et spørreskjema vedrørende kost- og mosjonsvaner. Foresatte har rett til å se spørreskjemaet som skal besvares av elevene. Et kort spørreskjema vil også bli gitt foreldre/foresatte vedrørende deres fritids- og mosjonsvaner.

Generell informasjon

Deltagelsen i undersøkelsen er frivillig og deltagerne har rett til å trekke seg fra hele eller deler av forsøket uten å oppgi grunn, og uten at det får negative konsekvenser. Det er imidlertid vesentlig for utbyttet av undersøkelsen at så mange som mulig deltar. Dersom foreldre/foresatte ønsker å trekke biologiske prøver eller andre opplysninger fra studien kan dette gjøres ved å kontakte biobankansvarlig professor Lars Bo Andersen, på telefon 23 26 20 00. Foreldre/foresatte er velkomne til å være tilstede i løpet av testdagen dersom dere ønsker det. Testene vil bli utført av personer med relevant utdannelse og erfaring. Deltagerne er forsikret gjennom Gjensidige NOR; forsikringsnr 0398160

Hvis testresultatet eller blodprøvene til noen av elevene viser avvikende medisinske verdier vil skolehelsetjenesten informeres. Informasjonen til barn/foreldre vil ved disse tilfellene komme fra skolehelsetjenesten. Testresultatene registreres i et dataregister men personopplysningene blir avidentifisert. Etter prosjektslutt, forventet omkring utgangen av år 2006, blir datamaterialet anonymisert. Prosjektet er tilrådd av Regional komité for medisinsk forskningsetikk og er meldt til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste AS.

Ansvarlig for gjennomføringen av studien er Seksjon for Idrettsmedisin ved Norges idrettshøgskole, Oslo. Prosjektleder er professor Lars Bo Andersen. Dersom dere ønsker ytterligere informasjon er dere velkomne til å kontakte forsker Jostein Steene-Johannessen eller forsker Elin Kolle på telefon 41 08 28 98.

Vennligst returner samtykkeformularet (side 3) i svarkonvolutten til klasseforstander.
Med vennlig hilsen

Lars Bo Andersen
prosjektleder / professor

SAMTYKKESKJEMA

På deres skole vil testene foregå i midten av januar
Nærmere informasjon om dag for testene vil leveres senere.

☐ **Ja**, jeg bekrefter herved å ha mottatt informasjon om testene. Jeg/vi ønsker å delta og lar min/vår datter/sønn delta i studien.

Vennligst utfyll opplysningene nedenfor:
(Skriv tydelig helst med blokkbokstaver)

Fornavn: ....

Etternavn: ....

Personnummer (11 siffer): ....

Jeg er informert om at deltagelsen er frivillig og at mitt barn kan avstå fra enkelte deler av testene, eller trekke seg fra videre deltagelse uten å oppgi grunn. Jeg er også bekjent med at foresatte har rett til å trekke seg/trekke opplysninger om seg selv fra prosjektet.

_____
Foreldre/verges underskrift

_____
Elevens underskrift

Leveres klasseforstander i vedlagte konvolutt så snart som mulig.

APPENDIX 2:

Approval letters from the Regional Committees for Medical Research Ethics

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

Professor Dr.med Lars Bo Andersen
Norges idrettshøgskole

Regional komité for medisinsk forskningsetikk
Sør- Norge (REK Sør)
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 228 44 666
Telefaks: 228 44 661
E-post: rek-2@medisin.uio.no
Nettadresse: www.etikkom.no

Dato: 30.11.04
Deres ref.:
Vår ref.: S-04305

Kost, aktivitetsvaner og helse blant barn og unge i Norge

Komiteen behandlet prosjektet i sitt møte torsdag 18. november 2004.

Komiteen har følgende merknader til prosjektet:

1.   Hvordan følges eventuelle patologiske verdier på blodprøvene opp.

2.   Komiteen forutsetter at undersøkelsen gjennomføres slik at den enkeltes integritet og privatliv ivaretas.

Komiteen har følgende merknader til søknad om opprettelse av forskningsbiobank:

1.   Pkt 2: Stemmer det at prosjektleder er databehandlingsansvarlig, dette er vanligvis institusjonens øverste leder.

2.   Data i studien er avidentifisert, ikke anonymisert, da det eksisterer en nøkkel som prosjektleder har tilgang til.

Komiteen har følgende merknader til informasjonsskriv og samtykkeerklæring:

1.   Det må utarbeides egen informasjon til barna, evt. må overskriften på informasjonsskrivet endres dersom det er ment å være til både barn og foresatte (barna blir bedt om å signere samtykkeerklæringen).

2.   Informasjonsskrivet bør starte med forespørsel om å delta, ikke "Kan dere hjelpe oss til økt kunnskap...

3.   "Formuleringer som "vi håper dere returnerer...så snart som mulig" og "på forhånd takk for hjelpen" bes strøket da de er ledende.

4.   Det må stå eksplisitt at forsøkspersonene kan trekke seg uten å oppgi grunn.

5.   Personer som ikke ønsker å delta i studien skal ikke aktivt måtte takke nei (da samtykke skal innhentes i en klasseromssituasjon vil dette likevel bli kjent).

6.   Data i studien er avidentifiserte, ikke anonyme, da prosjektleder har tilgang til nøkkelen.

7.   Setningen: Vi spør om dere og deres barn vil hjelpe oss gjennom å delta bør endres til vi spør om dere vil delta i undersøkelsen...

8.   Det mangler informasjon om at cytokiner skal måles.

9.   Det mangler informasjon om at biologiske prøver kan trekkes fra studien dersom man ønsker dette.

10.   Navn på biobankansvarlig bør oppgis slik at man vet hvem som skal kontaktes for å trekke prøver.

11.   Det mangler informasjon om hvor lenge barna må faste (6 timer?).

12.   Gi informasjon til foreldrene om hvordan eventuelle patologiske blodprøveverdier vil bli fulgt opp.

Vedtak:

"Under forutsetning av tilfredsstillende tilbakemelding og revidert pasientinformasjon og søknad om forskningsbiobank, tilrås prosjektet gjennomført og forskningsbiobank opprettet. Komiteens leder og sekretær tar stilling til dette."

Med vennlig hilsen

Sigurd Nitter-Hauge (sign)
Professor dr.med.
Leder

Tone Haug
Rådgiver
Sekretær

UNIVERSITETET I OSLO

DET MEDISINSKE FAKULTET

Professor Dr.med Lars Bo Andersen
Norges idrettshøgskole

Regional komité for medisinsk forskningsetikk
Sør- Norge (REK Sør)
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 228 44 666
Telefaks: 228 44 661
E-post: rek-2@medisin.uio.no
Nettadresse: www.etikkom.no

Dato: 11.01.05
Deres ref.:
Vår ref.: S-04305

Kost, aktivitetsvaner og helse blant barn og unge i Norge

Vi viser til brev datert 20.12.04 med vedlegg: revidert informasjonsskriv og samtykkeerklæring.

Komiteen takker for grundig og oversiktlig svar på merknader, og tar disse til etterretning.
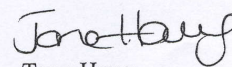
Komiteen har ingen merknader til revidert informasjonsskriv og samtykkeerklæring.

Komiteen tilrår at prosjektet gjennomføres og forskningsbiobank opprettes.

Vi ønsker lykke til med prosjektet!

Med vennlig hilsen

Sigurd Nitter-Hauge (sign)
Professor dr.med.
Leder

Tone Haug
Rådgiver
Sekretær

APPENDIX 3:

Approval letter from the Norwegian Social Science Data Services

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

Lars Bo Andersen
Seksjon for fysisk aktivitet og helse
Norges idrettshøgskole
Postboks 4014 Ullevål Stadion
0806 OSLO

Vår dato: 04.02.2005   Vår ref: 200500162 PB /RH   Deres dato: Deres ref:

KVITTERING FRA PERSONVERNOMBUDET

Vi viser til melding om behandling av personopplysninger, mottatt 24.01.2005. All nødvendig informasjon om prosjektet forelå i sin helhet 03.02.2005. Meldingen gjelder prosjektet:

12166	*Aktivitetsvaner og fysisk form blant barn og unge i Norge*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Lars Bo Andersen*

Norsk samfunnsvitenskapelig datatjeneste AS er utpekt som personvernombud av Norges idrettshøgskole, jf. personopplysningsforskriften § 7-12. Ordningen innebærer at meldeplikten til Datatilsynet er erstattet av meldeplikt til personvernombudet.

Personvernombudets vurdering

Etter gjennomgang av meldeskjema og dokumentasjon finner personvernombudet at behandlingen av personopplysningene vil være regulert av § 7-27 i personopplysningsforskriften. Dette betyr at behandlingen av personopplysningene vil være unntatt fra konsesjonsplikt etter personopplysningsloven § 33 første ledd, men underlagt meldeplikt etter personopplysningsloven § 31 første ledd, jf. personopplysningsforskriften § 7-20.

Unntak fra konsesjonsplikten etter § 7-27 gjelder bare dersom vilkårene i punktene a) – e) alle er oppfylt:

a) førstegangskontakt opprettes på grunnlag av offentlig tilgjengelige registre eller gjennom en faglig ansvarlig person ved virksomheten der respondenten er registrert,

b) respondenten, eller dennes verge dersom vedkommende er umyndig, har samtykket i alle deler av undersøkelsen,

c) prosjektet skal avsluttes på et tidspunkt som er fastsatt før prosjektet settes i gang,

d) det innsamlede materialet anonymiseres eller slettes ved prosjektavslutning,

e) prosjektet ikke gjør bruk av elektronisk sammenstilling av personregistre.

Personvernombudets vurdering forutsetter at prosjektet gjennomføres slik det er beskrevet i vedlegget.

Avdelingskontorer / *District Offices:*
OSLO: NSD. Universitetet i Oslo, Postboks 1055 Blindern, 0316 Oslo. Tel: +47/ 22 85 52 11. nsd@uio.no
TRONDHEIM: NSD. Norges teknisk-naturvitenskapelige universitet, 7491 Trondheim. Tel: +47/ 73 59 19 07. kyrre.svarva@svt.ntnu.no
TROMSØ: NSD. SVF, Universitetet i Tromsø, 9037 Tromsø. Tel: +47/ 77 64 43 36. nsdmaa@sv.uit.no

Behandlingen av personopplysninger kan settes i gang.

Ny melding

Det skal gis ny melding dersom behandlingen endres i forhold til de punktene som ligger til grunn for personvernombudets vurdering.

Selv om det ikke skjer endringer i behandlingsopplegget, skal det gis ny melding tre år etter at forrige melding ble gitt dersom prosjektet fortsatt pågår.

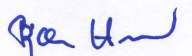Ny melding skal skje skriftlig til personvernombudet.

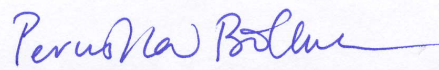**Offentlig register**

Personvernombudet har lagt ut meldingen i et offentlig register, www.nsd.uib.no/personvern/register/

Ny kontakt

Personvernombudet vil ved prosjektets avslutning, 31.12.2006, rette en henvendelse angående arkivering av data benyttet i prosjektet.

Vennlig hilsen

Bjørn Henrichsen

Pernilla Bollman

Kontaktperson: Pernilla Bollman tlf: 55583348
Vedlegg: Prosjektbeskrivelse

APPENDIX 4:

Parental Questionnaire

SPØRRESKJEMA TIL FORELDRE/FORESATTE

Fysisk aktivitet blant norske barn.
Denne undersøkelsen gjennomføres av Norges idrettshøgskole på oppdrag fra Sosial- og helsedirektoratet. Målet med undersøkelsen er å kartlegge fysisk aktivitets nivå, fysisk form og ulike helsevariabler blant barn og unge.

Informasjonen i dette spørreskjema behandles konfidensielt og er tilgjengelig kun for de som gjennomfører denne undersøkelsen. Ditt navn vil verken forekomme i datafiler eller skriftlig materiale.

Vennligst svar på spørsmålene så nøyaktig som mulig. Hvis det er spørsmål dere ikke ønsker å svare på kan de hoppes over. Sett bare et kryss for hvert spørsmål.
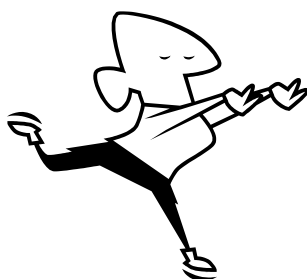
Del A kan fylles ut av en av foreldrene/foresatte.

Del B er rettet mot barnets mor/kvinnelige foresatte og **Del C** til barnets far/mannlige foresatte.

Vær oppmerksom på at spørreskjemaet har spørsmål på begge sider av papiret

Hvis kun en av foreldrene/foresatte har mulighet for å svare på spørsmålene så ber vi at det gjøres så utførlig som mulig for begge parter.

Ved eventuelle spørsmål kan dere ringe forsker Jostein Steene-Johannessen tlf 23 26 24 57 eller forsker Elin Kolle tlf 23 26 22 28.

PÅ FORHÅND TAKK FOR HJELPEN!

Vennligst lever spørreskjemaene i den vedlagte konvolutten til klassestyrer hurtigst mulig.

DEL A

Denne del kan fylles ut av hvilken som helst av foreldrene/foresatte. Skriv svaret på den stiplede linjen eller sett et kryss i den ruten dere synes passer best.

1. **Hva var fødselsvekten til deres barn?**..................... gram.

2. **Har deres barn en lang sykdomsperiode, kronisk sykdom eller annet medisinsk problem?**

   ☐ Ja
   ☐ Nei

   Hvis svaret er JA på spørsmål 2, vennligst gi en kortfattet beskrivelse under:

   ....

   ....

3. **Vennligst angi hvilken av gruppene under dere mener deres barn tilhører:**

   ☐ Hvit (kaukasisk)
   ☐ Svart – afrikansk
   ☐ Svart – vestindisk
   ☐ Pakistansk
   ☐ Vietnamesisk
   ☐ Kinesisk
   ☐ Indisk
   ☐ Arabisk
   ☐ Annet

DEL B

Denne del inneholder spørsmål til <u>**barnets mor**</u> **(eller kvinnelige foresatte).**
Skriv svaret på den stiplede linjen eller sett et kryss i den ruten du mener passer best.

1.   **Er du alene forelder i husstanden med barnet?**
☐ Ja
☐ Nei

2.   **Hva er ditt fødselsår?** 19☐☐

3.   **Hvor høy er du?** .... (cm)

4.   **Hvor mye veier du?** .... (kg)

5.   **Hvilken sivilstatus har du?**
☐ Gift/samboer
☐ Ugift/alene
☐ Enke
☐ Fraskilt
☐ Separert
☐ Skilt fra barnets far og omgift

6.   **Driver du regelmessig med mosjon eller sport?** (2 eller flere ganger per uke)
☐ Ja
☐ Nei

7.   **Hvor ofte er du fysisk aktiv med sykling, rask gange eller annen aktivitet cirka ½ -time per gang i løpet av en normal uke?**
☐ Hver dag
☐ 5-6 dager per uke
☐ 3-4 dager per uke
☐ 1-2 dager per uke
☐ Veldig sjelden

8.   **Hva er ditt høyeste utdannelsesnivå?**
☐ Grunnskole
☐ Videregående skole (yrkesskole inkl)
☐ Høyskole/universitet

TAKK FOR AT DU HAR BESVART SPØRRESKJEMAET!

VEND....

DEL C

Denne del inneholder spørsmål til <u>barnets far</u> (eller mannlige foresatte). Skriv svaret på den stiplede linjen eller sett et kryss i den ruten du mener passer best.

1. **Er du alene forelder i husstanden med barnet?**
   ☐ Ja
   ☐ Nei

2. **Hva er ditt fødselsår?** 19☐☐

3. **Hvor høy er du?** .... (cm)

4. **Hvor mye veier du?** ....(kg)

5. **Hvilken sivilstatus har du?**
   ☐ Gift/samboer
   ☐ Ugift/alene
   ☐ Enkemann
   ☐ Skilt
   ☐ Separert
   ☐ Skilt fra barnets mor og omgift

6. **Driver du regelmessig med mosjon eller sport?** (2 eller flere ganger per uke)
   ☐ Ja
   ☐ Nei

7. **Hvor ofte er du fysisk aktiv med sykling, rask gange eller annen aktivitet cirka ½ -time per gang i løpet av en normal uke?**
   ☐ Hver dag
   ☐ 5-6 dager per uke
   ☐ 3-4 dager per uke
   ☐ 1-2 dager per uke
   ☐ Veldig sjelden

8. **Hva er ditt høyeste utdannelsesnivå?**
   ☐ Grunnskole
   ☐ Videregående skole (yrkesskole inkl)
   ☐ Høyskole/universitet

TAKK FOR AT DU HAR BESVART SPØRRESKJEMAET!

Vennligst lever spørreskjemaene i den vedlagte konvolutten til klassestyrer hurtigst mulig.