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Cardiorespiratory fitness and cardiovascular disease risk factors in children - Effects of a two-year school-based daily physical activity intervention

The Sogndal school-intervention study

DISSERTATION FROM THE NORWEGIAN SCHOOL OF SPORT SCIENCES · 2010

SUMMARY

Background

Cardiovascular disease (CVD) is the leading cause of death in the Western world. Several studies have shown that the pathological processes of atherosclerosis begin in childhood and progress throughout life. Consequently, there is a need for preventive strategies early in life, and physical activity is an important tool for primary prevention of CVD. It was recently shown that low cardiorespiratory fitness (CRF) is a strong predictor for clustering of CVD risk factors, and that high CRF is associated with a healthier cardiovascular profile. The school setting is an ideal environment for population-based physical activity interventions. In Norway, schools exist in all municipalities, and most children and adolescents, from the age of six to 16, spend most of their day in school. Hence, the school setting may be the only means in society to reach a large number of children from all socio-economic backgrounds.

Aim

To investigate the effects of a school-based intervention, involving 60 minutes of daily physical activity over two school years, on CRF and CVD risk factors in nine-year-old children. Furthermore, to describe CRF levels and CVD risk factor levels in rural nine-year-old children and to examine the association between CRF and clustering of CVD risk factors in these children.

Methods

A total of 256 rural Norwegian children participated in this controlled intervention study. Intervention-school children carried out 60-minute physical activity over two school years. Control-school children had the regular curriculum-defined amount of physical activity in school, i.e. 45 minutes twice weekly. Peak oxygen uptake was directly measured during a continuous progressive treadmill protocol where the children ran until exhaustion. A blood sample was taken from each child for analyses of glucose, insulin, total cholesterol, high-density lipoprotein cholesterol and triglyceride. Also body mass, height, systolic and diastolic blood pressure and waist and hip circumference were measured.

Main results

The intervention resulted in a significant greater beneficial development in peak oxygen uptake, systolic and diastolic blood pressure, total cholesterol to high-density lipoprotein cholesterol ratio and triglyceride in intervention-school children than in control-school children. No significant differences in changes were observed in waist circumference, body mass index and the homeostasis model assessment for insulin resistance between the two groups. Furthermore, the intervention, primarily carried out at moderate intensity, showed that those children in the I-school with the least favorable starting point experienced the most beneficial effect of the intervention. The cross-sectional data suggested that low CRF, *and* low CRF and high fatness combined were highly associated with clustered CVD risk.

Conclusions

A daily school-based physical activity intervention can significantly increase children's CRF levels and beneficially modify their CVD risk profile if the intervention is sufficiently long and includes substantial daily physical activity, and if the physical activity is planned and organized by expert physical education teachers. Therefore, daily physical activity should be given due consideration in the design of school policies.

Keywords

Children, physical activity, cardiorespiratory fitness, cardiovascular disease risk factors, intervention, school.

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Geir Kåre Resaland

Abbreviations

BMI	Body mass index
BP	Blood pressure
CI	Confidence interval
CRF	Cardiorespiratory fitness
C-school	The control school
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
EYHS	European Youth Heart Study
HC	Hip circumference
HDL-C	High density lipoprotein cholesterol
HOMA-IR	Homeostasis model assessment for insulin resistance
HR _{peak}	Peak heart rate
I-school	The intervention school
LDL-C	Low density lipoprotein cholesterol
MSSRT	The multi-stage 20 m shuttle run test
MVPA	Moderate-to-vigorous physical activity
PANCS	Physical activity among Norwegian children study
PE	Physical education in school
PI	Ponderal Index
<i>P.I.</i>	Primary Investigator
RCT	Randomized control trial
RER	Respiratory exchange ratio
SD	Standard deviation
SBP	Systolic blood pressure
TC	Total cholesterol
TC:HDL ratio	Total cholesterol/high density lipoprotein cholesterol ratio
TG	Triglyceride
VO _{2peak}	Peak oxygen uptake
VPA	Vigorous physical activity
WC	Waist circumference

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. GK Resaland, A Mamen, SA Anderssen, LB Andersen. Cardiorespiratory fitness and body mass index values in nine-year-old rural Norwegian children. *Acta Paediatr.* 2009, 98(4):687-92.
- II. GK Resaland, SA Anderssen, IM Holme, A. Mamen, LB Andersen. Effects of a two-year school-based 60-minutes daily physical activity intervention on CVD risk factors. The Sogndal school-intervention study. *Submitted to Scand J Med Sci Sports.*
- III. GK Resaland, LB Andersen, A Mamen, SA Anderssen. Effects of a two-year school-based daily physical activity intervention on cardiorespiratory fitness. The Sogndal school-intervention study. *Scand J Med Sci Sports.* 2009, DOI: 10.1111/j.1600-0838.2009.01028.x
- IV. GK Resaland, A Mamen, C Boreham, SA Anderssen, LB Andersen. Cardiovascular risk factor clustering and its association with fitness in nine-year-old rural Norwegian children. *Scand J Med Sci Sports.* 2009, DOI: 10.1111/j.1600-0838.2009.00921.x

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1. INTRODUCTION

1.1 Physical activity and cardiorespiratory fitness in children - definitions and basic principles

Although physical activity and cardiorespiratory fitness (CRF) are related, the two terms differ in characteristics. On the one hand, physical activity is a complex behavior that occurs in a variety of forms and contexts including free play, exercise, organized sports and physical education (PE) in school, and is defined as any bodily movement produced by skeletal muscles that result in energy expenditure (Caspersen et al., 1985). On the other hand, CRF is a set of attributes rather than a behavior and it is a result of genetics (Bouchard and Rankinen, 2001) and stage in the lifespan, as well as physical activity levels (Caspersen et al., 1985). Two other factors which differentiate the two terms are: 1) CRF can be more accurately measured and 2) CRF varies less over time than physical activity. Therefore, CRF has a lower intra-individual day-to-day variability, leading to less misclassification of individuals and observed relationships may therefore be closer to reality than for physical activity (Boreham and Riddoch, 2001).

In adults, it has been shown that levels of physical activity are related to CRF, i.e. those who are habitually physically active are fitter than those who are inactive (Blair et al., 1989). However, this is not necessarily true in children (Malina et al., 2004; Rowland, 2005), and it has been suggested that an increase in daily physical activity cannot be expected to substantially alter children's peak oxygen uptake (VO_{2peak}) (Rowland, 2005). This view is mainly explained by the fact that children generally have a relatively high initial level of both physical activity and CRF, and that children's physical activity pattern is typically sporadic and non-continuous, both of which may make it difficult to alter their CRF levels. However, earlier studies have limitations, both pertaining to the measurement of physical activity (often cross-sectional studies using subjective methods) and CRF (often indirect testing of few and selected subjects). These limitations suggest that the relationship between physical activity and CRF in children needs to be further investigated.

1.2 Physical activity

Physical activity consists of and varies according to several dimensions including: duration (units of time), frequency (number of sessions per time unit, bouts or days), intensity (relative

to maximal capacity), mode (the type of physical activity behavior , e.g., walking or running), the activity domain (the context or reason for the physical activity, e.g., playground, transport, leisure, PE in school) and the pattern of the activity (e.g., whether the activity is performed at certain times or there are certain geographical characteristics) (Welk, 2002; Dollman et al., 2008). The duration, frequency and intensity of the activity make up the total volume of the activity, and yield the energy expenditure associated with total physical activity.

Having valid and reliable measures of physical activity in children is important for identifying dose-response associations with a variety of health, developmental, and cognitive outcomes. Moreover, valid and reliable measures are necessary for estimating physical activity participation and monitoring compliance with recommendations, for quantifying the biological and environmental correlates of physical activity, and for assessing the efficacy and effectiveness of interventions to promote physical activity behavior (Welk, 2002). Several methods exist for assessing physical activity, and the most frequently mentioned in the literature are indirect calorimetry, doubly labeled water, direct observation, heart rate monitoring, pedometers, accelerometers (*objective methods*), self-administrated recalls, interview-administrated recalls, diaries and proxy reports from parents (*subjective methods*) (Sirard and Pate, 2001). The most common methods used with children today are self-report and accelerometers and both these methods have strengths and weaknesses. Self-reported questionnaires are easy to use and inexpensive, but this is also a method with numerous limitations, mainly pertaining to children's limited ability to recall the physical activity's duration, level and intensity (Sallis and Saelens, 2000). Accelerometers provide objective and detailed measurements of frequency, duration and intensity of physical activity. However, accelerometers do not capture swimming and underestimate cycling. Furthermore, accelerometers are insensitive to whether a person moves uphill or downhill *or* if a person carries a heavy load on his back or not. Also, since physical activity is a spontaneous behavior, it is a great concern that the very act of measuring may induce changes in physical activity levels (Malina et al., 2004). This phenomenon is called reactivity, and is of concern since the accelerometers only assess a snapshot of a person's activity behavior, normally four to seven consecutive days. Therefore, assessing physical activity in children is a complex task and no single method can fully reflect a person's activity behavior and the energy cost of activity. Hence, to obtain a comprehensive picture of an individual's physical activity levels over time, a combination of methods may be needed (Malina et al., 2004).

The most striking conclusion in the existing physical activity literature in children is that boys are significantly more physically active than girls. Kolle et al. (2009) assessed physical activity objectively using accelerometers in a nationally representative sample of Norwegian nine-year-olds (Physical activity among Norwegian children study: PANCS). The results revealed that 9-year-old boys were 15% more physically active than 9-year-old girls. Riddoch et al. (2004), in the European youth heart study (EYHS), applied accelerometers to assess activity levels in a group of more than 2000 children from four European countries, and the results showed that 9-year-old boys were 21% more active than girls of the same age.

1.3 Guidelines and recommendations for physical activity in children

The first physical activity recommendations for children and adolescents were introduced in 1988 by the American College of Sports Medicine (ACSM, 1988). This proposal, that all children and adolescents should achieve 20 to 30 minutes of vigorous exercise each day, was solely based on guidelines for adults. In the 1990s, several studies focused on children's physical activity patterns, and as the result of two international consensus conferences, guidelines for health-related activity in children were formulated (Sallis and Patrick, 1994; Biddle et al., 1999). The guidelines developed in the 1990s were based on expert opinion and the then current scientific evidence. Unfortunately, the empirical studies that formed the basis for the guidelines were mainly cross-sectional observational studies using subjective methods to assess physical activity. Furthermore, the total physical activity level was rarely known. Nevertheless, the main conclusion from these studies was that children should achieve a total of at least 60 minutes of moderate intensity physical activity each day. At least twice a week this should include activities intended to improve bone health, muscle strength and flexibility (Biddle et al., 1999). This is similar to the current recommendations in Norway, first published in the year 2000, stating that all children and youth should participate in sport, physical activity or informal play for 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 (Sosial- og helsedirektoratet, 2000).

The recommendation of the “magical” 60 minutes of physical activity has been consistent in most guidelines since 1998, including a comprehensive systematic review of the evidence base for health and physical activity in school-age children by Strong et al. (2005). Their main conclusion was that children should participate every day in 60 minutes or more of moderate

to vigorous physical activity (MVPA) which is developmentally appropriate, enjoyable, and involves a variety of activities. Some children, such as those at risk for overweight or diabetes type II, may need more than 60 minutes per day in order to maintain adequate health status (Strong et al., 2005). However, due to the scant scientific foundation, several papers have questioned the current recommendations, and pointed to the fact that most published guidelines on physical activity are not evidence-based (Twisk, 2001). In fact, many reviewed studies did not show an association between physical activity and the health outcomes of interest. Boreham and Riddoch (2001) pointed to the fact that there is little evidence for a particular dose-response relation from which physical activity recommendation for children and adolescents can be obtained. Moreover, recommendations need to be tailored to different groups based on sex, age, weight status, health status and so on. Recommendations also tend to reinforce the concept of a health-related threshold, but it seems clear that neither the minimal nor the optimal dose of physical activity can be defined. In fact, on the one hand, recent cross-sectional data indicate that the current recommendation of at least 60 minutes per day of physical activity of at least moderate intensity may be an underestimation of the activity necessary to prevent clustering of cardiovascular disease (CVD) risk factors in children (Andersen et al., 2006). On the other hand, Strong et al (2005) suggested in their review that, for some health variables, fewer than 60 minutes is required. An example of this is lipid and lipoprotein levels, where a minimum of 40 minutes of activity per day, five days per week for four months is required to achieve significant improvement (Strong et al., 2005). This suggests that the recommendations are likely to differ depending on the outcome of interest.

1.4 Cardiorespiratory fitness

CRF refers to the ability of the circulatory and respiratory systems to deliver oxygen to the muscle and to utilize it to generate energy during physical activity. Different terms are applied to describe CRF, and these terms are used interchangeably (i.e. CRF, aerobic fitness, cardiorespiratory endurance and aerobic capacity). In this thesis, the term CRF will be used. CRF is one of three basic components included in the concept of physical fitness. The two other components are muscular strength and motor ability (Malina et al., 2004). The concept of physical fitness has evolved over the last thirty years from a primary focus on its motor and strength components (performance-related fitness) to more emphasis on health (health-related fitness) (Malina et al., 2004). The performance-related components of fitness, such as balance,

coordination, speed and reaction time, are closely related to athletic performance. In contrast, the health-related fitness components are primarily connected to biological outcomes, and high levels of health-related fitness are associated with lower risk for cardiovascular and metabolic disease (McKenzie and Kahan, 2008). Regarding CRF, the focus in this thesis is health-related fitness, meaning that the main topic undertaken is the association between CRF and CVD risk factors.

VO_{2peak} and maximal oxygen uptake (VO_{2max}) are two terms used interchangeably to define the highest rate at which an individual can consume O_2 during exercise (Armstrong and Welsman, 2006). VO_{2peak} and VO_{2max} have the same physiological meaning (Rowland 2005), and are widely recognized as the best single measure of the cardiorespiratory system's functional capacity. However, since the term VO_{2max} conventionally implies the existence of a VO_2 plateau, and such a plateau is not always observed in children, it has gradually become more common in paediatric exercise science to define the highest VO_2 observed as VO_{2peak} . In this thesis, the term VO_{2peak} will be used. Armstrong and colleagues have demonstrated in large samples of children who performed an acceptable VO_{2peak} -test that those children who plateau do not have higher VO_2 , heart rate (HR) or blood accumulation than those not exhibiting a VO_2 plateau (Armstrong et al., 1991; Armstrong et al., 1995). Moreover, Armstrong et al. (1996) and Rowland (1993) both showed that VO_{2peak} does not increase further in response to exercise intensities above the VO_{2peak} observed in rigorously performed progressive exercise test to voluntary exhaustion in children. Therefore, VO_{2peak} reflects the limits of CRF in children, and is a maximal index of children's CRF. VO_{2peak} is usually expressed either as an absolute rate (i.e. $l \cdot \text{min}^{-1}$) or relative to body weight (i.e. $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$).

VO_{2peak} can be estimated using maximal or sub-maximal tests, by direct or indirect methods. VO_{2peak} measured directly is normally assessed on a bicycle ergometer or running on a treadmill to exhaustion. Since a larger muscle mass is utilized in the latter, five to ten percent higher VO_{2peak} values are observed when children are running on a treadmill compared to using a cycle ergometer (Armstrong et al., 1991; Turley et al., 1997; LeMura et al., 2001, Mamen et al., 2008). This difference in VO_{2peak} must be taken into account when comparing different studies of children who have used running or cycling as work form. Most school-based interventions have measured VO_{2peak} indirectly (Shaya et al., 2008; Katz et al., 2008,

Brown and Summerbell, 2009). Examples of indirect tests are the multi-stage 20m shuttle run test (MSSRT) (Léger et al., 1988) and the Andersen test (Andersen et al., 2008). Only a few school-based interventions, such as the Prospective Copenhagen School Child Interventions Study (CoSCIS) (Andersen and Froberg, 2006), have tested VO_{2peak} directly. There are other studies reporting direct VO_{2peak} measurements in children, but these are not school-based interventions (e.g. Armstrong et al., 1995; Fredriksen et al., 1998; Dencker et al., 2007; Kolle et al., 2009). A possible explanation for why there are so few interventions testing VO_{2max} directly could be that sophisticated, technical and expensive equipment and trained test leaders are required. Furthermore, since each test is carried out individually, the testing is time-consuming. Indirect tests therefore have great practical advantages compared to direct tests, but have a wider margin of error and are less accurate in predicting CRF.

Since a VO_{2peak} test requires an “all-out” effort from the subject, it is essential to determine whether the child truly performs an exhaustive effort. Therefore, several criteria have been suggested. These include objective criteria such as the respiratory exchange ratio (RER: VCO_2/VO_2) (i.e. ≥ 1.0) and peak heart rate (HR_{peak}) (i.e. ≥ 200 beats·min⁻¹), and subjective criteria such as an unsteady running pattern, and verbal and body language clearly indicating that the child wants to stop the test despite repeated strong verbal encouragement.

The literature shows that boys have a significantly higher CRF than girls. Kolle et al. (2009) assessed CRF directly using a cycle ergometer in PANCS. The results revealed that 9-year-old boys had 12% higher VO_{2peak} (expressed as ml·kg⁻¹·min⁻¹) than girls. Eiberg et al. (2005) tested 592 6-7-year-olds and found that boys had an 8% higher VO_{2peak} than girls.

1.5 Physical activity, CRF and CVD risk factors in children

Physical activity, CRF and the health of children are interrelated, and all three factors are influenced by other factors, including heredity, environment and lifestyle behaviors, but the precise connection between these three factors is unclear (Strong et al., 2005; McKenzie and Kahan, 2008). Still, the literature suggests that regular physical activity is important for children’s healthy growth and development (Malina et al., 2001). Also, cross-sectional data suggest a strong association between CRF and clustered metabolic risk score in children (Anderssen et al., 2007; Eisenmann et al., 2007 (1); Ruiz et al., 2007; Kriemler et al., 2008; Steene-Johannessen et al., 2009).

Two important points need to be considered when discussing the association between physical activity, CRF and children's status in CVD risk factors. Firstly, there is a lack of hard health end-points, such as hypertension and diabetes type II, in children. Therefore, an unfavorable level of CVD risk factors, such as high blood pressure (BP) and high levels of blood lipids, poses little immediate risk to most children. Secondly, there have been two major obstacles regarding analyses of the association between physical activity and CVD risk factors in children (Andersen et al., 2006). A) Since obtaining accurate measures of habitual physical activity is difficult in children, previous studies have relied on subjective measures of physical activity. Because of the potential misclassification in physical activity, the observed relationships may have been weakened. B) Studies have analyzed the associations between physical activity and single CVD risk factors, and these associations are often weak. However, the challenges demonstrated in A) and B) have recently been partly solved with the introduction of accelerometers (problem A) and the introduction of analyses of physical activity and the clustered risk of CVD risk factors in children (problem B) (Andersen et al., 2006).

1.6 Physical activity and physical education in school

There are a number of strong arguments in favor of schools playing a key role in promoting physical activity for children and the school setting is defined as is an ideal environment for population-based physical activity interventions (Pate et al., 2005; Naylor and McKay, 2009; Dobbins et al., 2009). In Norway, schools exist in all municipalities, and most children and adolescents, from the age of six to 16, spend most of their day in school. Hence, the school setting may be the only means in society to reach a large number of children from all socio-economic backgrounds and irrespective of their parents' behavior and attitude towards physical activity. Because PE is mandatory in schools, all children will be involved in a physical activity/PE intervention, not only the motivated children. Additionally, the school offers a safe environment and facilities in an arena designed for learning, creating optimal surroundings for increasing the children's physical activity levels and thereby providing children with some of their recommended physical activity, and also teaching the children generalizable movement skills (McKenzie and Lounsberry, 2009). Finally, a major strength in the school setting is the regular dialogue with the parents. For information regarding physical activity and PE in the Norwegian school system, see appendix no 1.

1.7 School-based physical activity interventions

This brief summary includes controlled school-based physical activity interventions in 6-12-year-old children with a duration of at least one school-year published in peer-review journals since 2005. The summary does not include studies with small sample sizes or studies involving special populations.

Andersen and Froberg, 2006. Denmark. The Prospective Copenhagen School Child Interventions Study (CoSCIS). Three-year intervention.

The CoSCIS recruited 6-7-year-old children (n=342) from 18 schools in two suburbs of Copenhagen (Ballerup and Taarnby). The twice-weekly physical activity classes for the children from the intervention schools (I-schools) were doubled from 45 to 90 minutes in the course of three years. VO_{2peak} was measured directly during a continuous treadmill protocol, and physical activity was measured objectively with accelerometers. A blood sample was taken from each child to assess traditional CVD risk factors. BP, skin folds, bone health, and anthropometrics were also measured. Post-intervention results showed that there was no significant difference between the I-schools and control schools (C-schools) in VO_{2peak} when expressed as $ml \cdot kg^{-1} \cdot min^{-1}$. Also, the children from the I-schools benefited significantly more in Δ glucose and Δ waist circumference (WC)-to-hip circumference (HC)-ratio than the C-school children.

Sollerhed and Ejlertsson, 2007. Sweden. The Sollerhed and Ejlertsson study. Three-year intervention.

In Sweden, 132 children participated in a three-year physical activity intervention, where the time spent on physical activity was expanded from one or two lessons to four lessons weekly, each lesson lasting for at least 40 minutes. In addition to these four weekly sessions of physical activity, the children were engaged in one hour of outdoor activities on the fifth school day of the week. Eleven physical tests, including the MSSRT, were used to assess physical performance by a physical index. Furthermore, CRF was also assessed by a six-minute running test. Post-intervention results showed that the children in the I-school had a significantly more favorable change in the physical index and the six-minute running test than the C-school children. Furthermore, changes in body mass index (BMI) were significantly more favorable in the I-school than in the C-school.

Graf et al., 2008. Germany. The school-based Children's Health Interventional Trial (CHILT). Four-year intervention.

In Germany, 12 primary schools were selected in the Cologne area to serve as I-schools. Five C-schools were randomly selected from the same region. A total of 615 children took part in both the baseline and the post-intervention tests. The teachers were asked to give one extra health education lesson per week (20–30 min). During the first school year, a trained nutritionist together with the classroom teacher gave a six-hour course which communicated a behavior message to children, parents and teachers. This course was followed by 20 minutes of so-called “active breaks”. Additionally, physical activity breaks (5 min each) were to be permitted during lessons once every morning. Pupils were also given physical activity opportunities during breaks. CRF was assessed by a six-minute running test. Motor skills were measured and anthropometric data were collected. Post-intervention results showed that there was no significant difference between the I-schools and the C-schools in the CRF test or the motor skill tests. Surprisingly, the increase in BMI was significantly higher in the I-school children compared to the controls. There was no difference between the I-school and the C-school children in any of the other anthropometric variables. Graf et al. (2008) hypothesized that a more intensive implementation of the program, together with parental integration, could have a more beneficial influence on the BMI.

Reed et al., 2008. Canada. Action Schools! BC (AC! BC) 16-months intervention.

AC! BC was a cluster-randomized controlled school-based trial involving 237 nine-to-eleven-year-old Canadian children. The 16-month intervention had a multi-component whole-school approach including 75 minutes of extra physical activity per week in addition to the ordinary 2·40-minute PE classes. Changes in CRF between I-schools and C-schools were assessed with MSSRT. Additionally, BP, body mass and height were measured. Traditional and novel CVD risk factors were assessed by taking a blood sample from a subset of volunteers. The I-school children had a 20% greater increase in CRF and a 6% more beneficial change in BP compared with children attending C-schools. There was no significant difference between groups with regard to change in BMI or in any of the blood variables.

Marcus et al., 2009. Sweden. Stockholm Obesity Prevention Project (STOPP) 1 to 4 year intervention.

STOPP, a four-year, cluster-randomized controlled obesity prevention study involved ten primary schools from Stockholm County, Sweden. In total, 3135 children aged 6–10 years participated in this intervention, which also included an after-school program. Some children participated in the study for one school year, others for two, three or four school years. The intervention included 30 minutes' increased physical activity daily. Furthermore, to reduce sedentary behavior, children were not allowed to bring toys that might increase this behavior, such as hand-held computer games, to schools and after-school care centers. The maximum time allowed for playing computer games at the after-school care centers was restricted to 30 min per child per day. Finally, low-fat dairy products and whole-grain bread were promoted and all sweets and sweetened drinks were eliminated in the I-schools. The primary outcome was BMI, but physical activity was also measured objectively by accelerometry. Post-intervention results showed that the prevalence of overweight and obesity in children in grades 2, 3 and 4 in the I-schools was significantly reduced, while there was an increase in the C-school children. The effect of intervention was more pronounced in boys than in girls. Furthermore, there was no significant difference in overall physical activity levels between the I-schools and the C-schools, suggesting that physical activity carried out during school time probably only contributed to a minor extent to the observed change in overweight prevalence between the I-schools and the C-schools.

Donnelly et al., 2009. USA. Physical Activity Across the Curriculum (PAAC). Four-year intervention.

PAAC was a three-year, cluster RCT involving 24 elementary schools in Kansas, USA where 1490 children in grades two and three were followed through grades four and five. The I-school children received a total of 150 minutes of physical activity/PE each school week. BMI was the primary outcome. Physical activity, measured with accelerometers, and academic achievement were secondary outcomes measured in a sub-sample. Post-intervention results showed that there was no significant difference in BMI between the I-schools and the C-schools. Results indicated that on average over the three-year intervention, children in the I-schools had 13% more physical activity compared to children in the C-schools. Children in I-schools had significantly greater levels of PA during the school day and on weekends, and also exhibited greater levels of PA on weekdays compared to children in control schools.

Children from the I-schools also exhibited 27% greater levels of MVPA compared to children in C-schools. Finally, significant improvements in academic achievement from baseline to 3 years were observed in the I-school compared to the C-school.

1.8 Need for new information

CVD is the leading cause of death in the Western world (Bonow et al., 2002). Hence, there is a need for preventive strategies, and physical activity is an important tool for primary prevention of CVD. Although a strong association between physical activity and cardiovascular and metabolic health has been well established in adults (Laaksonen et al., 2002; Haskell et al., 2007), the same strong association has not been found in children (Strong et al., 2005). This gap is mainly due to the fact that CVD is usually manifested after the fourth decade of life. However, several studies using post-mortem autopsy; as the Bogalusa Heart Study (Berenson et al., 1992, 1998), the Pathological Determinants of Atherosclerosis in Youth study (Strong et al., 1999, McGill et al., 2000), and studies of 20-22-year-old soldiers who were killed in the Korean and Vietnam wars (Enos et al., 1955, McNamara et al., 1971) have shown that the pathological processes of atherosclerosis begin in childhood and progress throughout life. Consequently, there is a need to initiate preventive strategies of physical activity targeting CVD risk factors early in life. Furthermore, a major reason for examining whether physical activity ameliorates CVD risk factors in children is that several cross-sectional studies have demonstrated an inverse association between physical activity and CVD risk factors in children (Ribeiro et al., 2004; Andersen et al., 2006; Kriemler et al., 2008). Moreover, individual CVD risk factors, such as BP (Chen and Wang, 2008), obesity (Singh et al., 2008) and lipids/lipoproteins (Nicklas et al., 2002) have been shown to persist from childhood to adulthood. Furthermore, CVD risk factors have been shown to cluster in children as young as nine years old (Raitakari et al., 1994; Andersen et al., 2003; Steene-Johannessen et al., 2009), and evidence exists that this clustered risk also tracks from childhood to adulthood (Twisk et al., 1997; Raitakari et al., 2003; Eisenmann et al., 2004) possibly creating a lifetime of exposure to and elevated risk of CVD. Therefore, there is a rationale to investigate the effect of physical activity on CVD risk factors and also to monitor these CVD risk factors in children over time.

It was recently shown that low CRF is a strong predictor for clustering of CVD risk factors, and that high CRF is associated with a healthier cardiovascular profile (Anderssen et al.,

2007). However, limited research exists on nine-year-old children regarding this topic. Hence, there is a need to further examine the association between CRF and clustering of CVD risk factors.

Physical activity interventions in schools have shown conflicting results regarding the effect of physical activity on CVD risk factors in children (van Sluijs et al., 2008). Notably, many intervention studies are hampered by several methodological weaknesses including low sample size, and inadequate duration and volume of MVPA (Brown and Summerbell, 2009). There is therefore a need for physical activity interventions in school which have a substantial amount of MVPA, preferably every school day over a long intervention period.

Taken together, there is a strong rationale to investigate the effect of physical activity on CVD risk factors *and* the association between CRF and CVD risk factors in children. This thesis strives to accomplish both these goals.

1.9 Aim of the thesis

This thesis has a primary and a secondary aim.

Primary aim

To investigate the effects of a school-based intervention, involving 60 minutes of daily physical activity over two school years, on CRF and CVD risk factors in nine-year-old children (paper II and III).

Secondary aim

To describe CRF levels and CVD risk factor levels in rural nine-year-old children and to examine the association between CRF and clustering of CVD risk factors in these children (paper I and IV).

2. MATERIALS AND METHODS

2.1 Population

A total of 259 children, corresponding to all fourth-graders enrolled in 2004 (born 1995) and 2005 (born 1996) in two elementary schools in two rural municipalities in Western Norway, were invited to participate. The two municipalities, Sogndal (population 6,836) (intervention site) and Førde (11,327) (control site) (Statistics Norway, 2006), are located 105 kilometres apart and are similar with regard to the size of both the number of inhabitants and the number of children in the intervention and control schools. Also, the teacher-to-student ratio is approximately the same in the schools. Furthermore, the majority of the children in both municipalities are Caucasian (>95%) and the number of people with a University/University College education is similar (23.5% in Sogndal and 24.5% in Førde) (Statistics Norway, 2006). Both schools agreed to be project participants before any testing was conducted.

The study had a controlled non-randomized design. Figure 1 gives an overview of the study design and the participants. All children (boys n=63 and girls n=62) in the I-school agreed to participate. However, nine children either experienced injuries that occurred outside of school time during the intervention period (n=4), or family relocation during the intervention period (n=5) and were thus excluded. Regarding the C-school (boys n=63 and girls n=71), 16 children were unable or unwilling to travel to the test venue, and were thus excluded. Furthermore, six children were excluded because of chronic diseases (n=3), injuries that occurred outside of school time during the intervention period (n=2), or family relocation during the intervention (n=1). Therefore, a total of 228 (88%) children had a valid measurement in at least one variable at both baseline and post-intervention.

At baseline, body mass and height were collected from 256 of the 259, and there were no significant differences between the 228 included and the 28 excluded children in body mass, height or BMI at baseline. Of the 228 included children, 174 (76.3%) (I-school, n=92, C-school, n=82) successfully completed both the baseline and post-intervention measurements for all CVD risk factors. There were no significant differences in body mass, height or BMI between those 174 children with complete measurements and those 82 children with incomplete measurements.

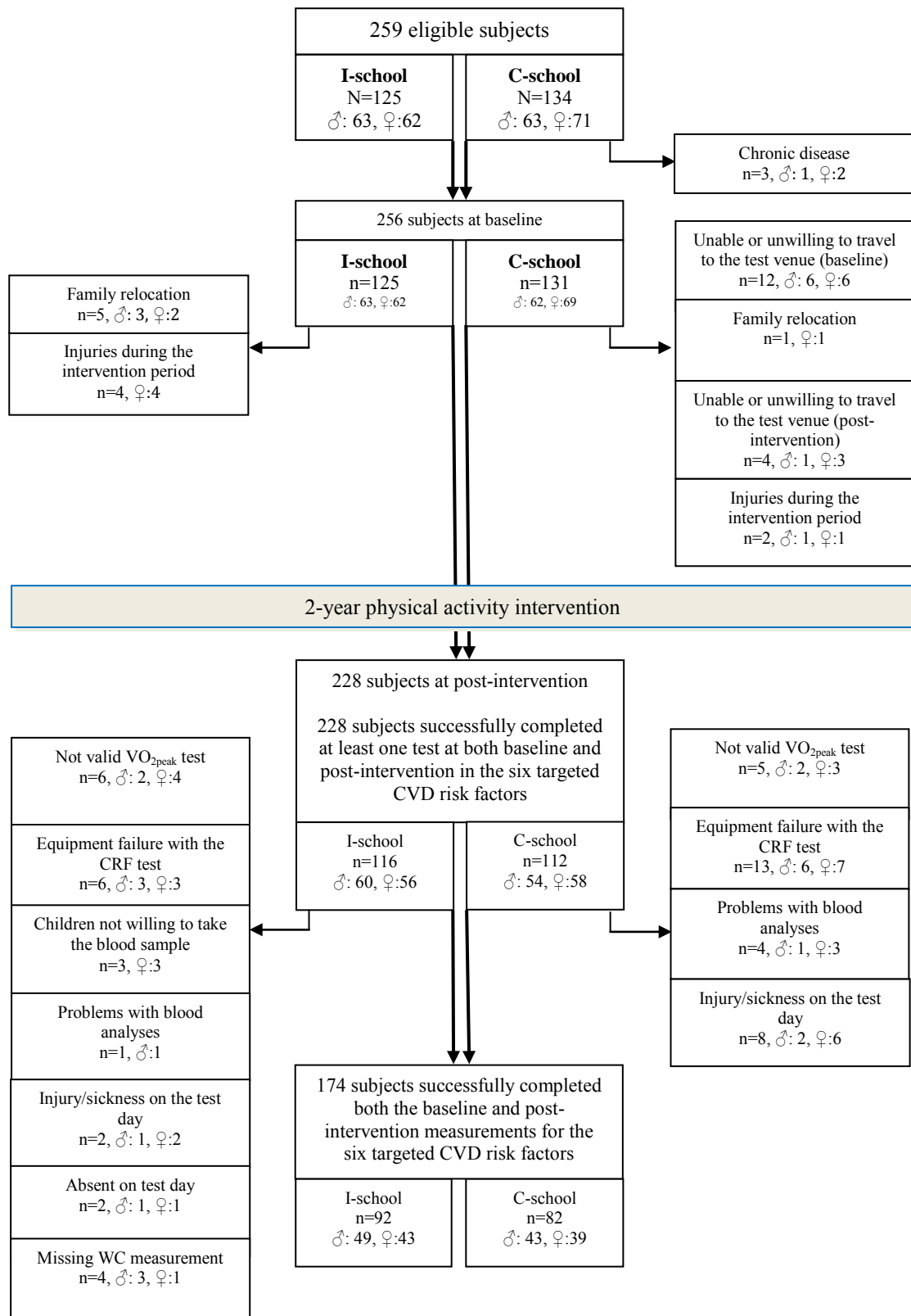


Figure 1. Flow chart. Overview over the study design and the participants.

2.2 Ethics

Procedures and methods used in the present study conform to the ethical guidelines defined by the World Medical Association's Declaration of Helsinki and its subsequent revisions. The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Services. The Norwegian Directorate of Health also approved the study in accordance with the Biobank Act. After information meetings and a written explanation of the study, written consent was obtained from the children's parents/guardians prior to all testing. Participants were free to withdraw from all measurements at any time, without explanation.

2.3 Intervention

The intervention consisted of a 60-minute daily mandatory physical activity lesson during the school week and was implemented over two school years (from the start of the 4th grade to the end of the 5th grade) for each of the two different age groups in the I-school. The 60-minute daily physical activity did not include time for changing clothes before or after the physical activity, shower after the physical activity or active play in recess or before or after school.

Sixty minutes' daily physical activity was chosen as the intervention dose because guidelines from the Norwegian Directory of Health (2000) and international recommendations (Strong et al., 2005) call for children to accumulate at least 60 minutes' of MVPA on most days, and preferably every day of the week.

The teachers were always present during the physical activity lesson and were instructed to be as efficient as possible in using time allotted for physical activity, e.g. to limit the time that children were standing in line. However, teachers found it necessary to spend about five of the 60 minutes on teachers' explanations, organising the children, and various other low-intensity activities. The teachers were instructed to carry out MVPA for the remaining 55 minutes, of which 15 minutes were planned to be at vigorous intensity, meaning that the children should be sweating and out of breath. The vigorous physical activity component was achieved by selecting a variety of activities such as running, relay racing, obstacle courses and various forms of active play of a high intensity nature. Most of these activities were non-competitive. *Ballgames* (accounting for 19.4% of the physical activity time over the two intervention years) were the most frequent activity, with football (soccer) and basketball as

the two most dominant (see Figure 2). *Brisk walking* (13.1%) was usually done every school day, and often at a relatively fast pace. *Active play* (12.1%) included a variety of fun activities and games, such as tag and hide-and-seek. *Skiing* (10.7%) was mainly cross-country, and the children spent 11 full school days skiing. *Gymnastics* (9.6%) included a variety of gymnastics exercises. *Relay race* (8.5%) also included completing obstacle courses. The term *Others* (10.7%) includes miscellaneous activities, such as orienteering, cycling, jumping rope and ice skating.

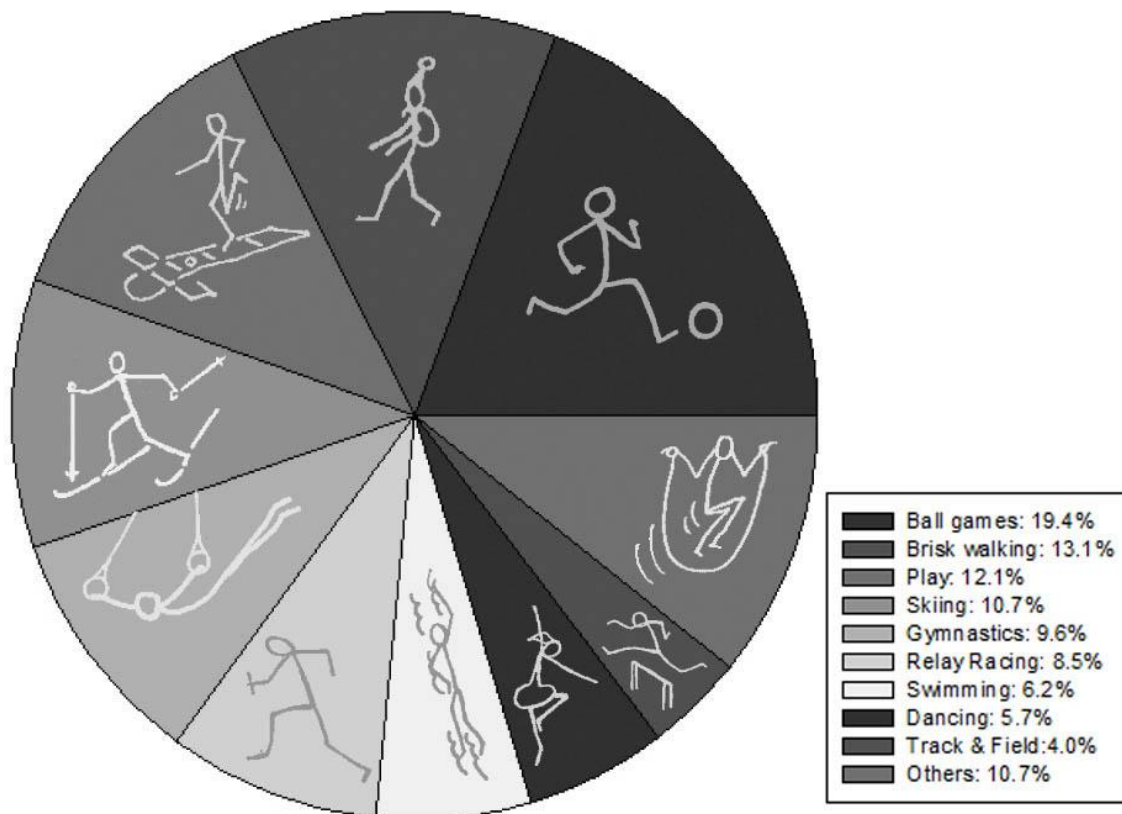


Figure 2. Overview over the different activities carried out by the children in the I-school.

At the I-school, the physical activity school week included the two already-existing weekly PE lessons (each lasting 40 minutes) which were supplemented with 20 minutes of physical activity to ensure that the required daily 60 minutes were obtained. On the remaining of the school days, a 60-minute physical activity program was carried out. Since the I-school had a system of four-day school weeks for 4th graders and five-day school weeks for 5th graders, the amount of teacher-organized physical activity performed each week was 240 minutes during the first intervention year and 300 minutes during the second intervention year. At the I-school there was no conflict between PE, which is a normal school subject with a

standardized curriculum, and the “new” concept of physical activity. Henceforth, in this thesis these two will both be termed physical activity.

Physical activity lessons were planned by two expert PE teachers at the I-school in collaboration with Geir K. Resaland, the primary investigator (*P.I.*), and carried out mostly by expert teachers at the I-school. Each lesson was planned to include a variety of activities that were enjoyable and exciting for the children. Importantly, it was emphasized to the teachers that the extra physical activity should not be used as a means of improving the skills of the fit and talented children, but be inclusive for all children, and especially for those who were not particularly fit and interested. One goal was to provide as many children as possible with a positive experience of physical activity.

Physical activity lessons were organized in a variety of ways. Most often, all children in one grade (approximately 60 children) had physical activity together, where they were divided into four groups of 15 children that rotated between four activity stations every 15 minutes. One teacher was responsible for a station the entire physical activity lesson, thereby providing continuity and expertise for that activity. Another way of organising the physical activity was to allow the children to decide which activity they would participate in for a period of time, e.g. every Thursday for six consecutive weeks. Regular visits from the *P.I.* ensured that the intentions of the intervention were fulfilled. Furthermore, a project coordinator from the I-school systematically reported all activities both in written form (into a physical activity database) via email and in regular face-to-face meetings with the *P.I.* where the latter provided mentorship and functioned as a consultant and a discussion partner for problems that arose.

Regarding adherence to the intervention program, the administration at the I-school systematically recorded the children’s absence from school, and any child who had an absence of more than 15% was excluded. Only one child was excluded for this reason. On average, the mean (SD) absence from school was 12 (9) days over the two years, corresponding to 4% mean absence annually. In the C-school, the average absence was 13 (12) days over the two years, and only two children were excluded because of an absence of more than 15%.

The C-school was asked to participate because of similarity in size, structure and location. Children from the C-school were exposed to the curriculum-prescribed amount of PE in school, i.e. 45 minutes twice weekly including time for teachers to organize activities, and for the children to change clothes and shower.

2.4 Measurements

2.4.1 Anthropometry

Body mass was measured to the nearest 0.1 kg using an electronic scale (Seca 770, SECA GmbH, Hamburg, Germany) with children wearing light clothing and being shoeless, for which an allowance of 0.2 kg was subtracted from results. The electronic scale was calibrated regularly throughout the data collection. Height, without stretch, was measured to the nearest 0.1 cm, with children standing shoeless facing forward using wall mounted tapes. BMI ($\text{kg}\cdot\text{m}^{-2}$) was calculated as weight (kg) divided by the height squared (m^2). Overweight and obese children were defined according to Cole et al's cut-off points (2000), and the Ponderal Index (PI, $\text{kg}\cdot\text{m}^{-3}$) was also analyzed. WC was measured underneath the subjects' clothing at the level of the umbilicus to the nearest 0.5 cm with the child's abdomen relaxed at the end of a gentle expiration. The child was standing with arms hanging slightly away from the body. Hip circumference (HC) was measured at the point of maximum protrusion of the buttocks.

2.4.2 Cardiorespiratory fitness

$\text{VO}_{2\text{peak}}$ was measured directly with a MetaMax I analyzer (Cortex Biophysik GmbH, Leipzig, Germany) using their MetaSoft 1.11.05 software without curve smoothing during a continuous progressive treadmill protocol. MetaMax I uses a mixing chamber, and ventilation is measured with a triple-V sensor on the expired air. The analyzer was calibrated each test day. Additionally, the barometric pressure in the analyzer was calibrated against values from the local weather station. Between each test, calibration of volume and a two-point gas calibration were performed, as well as a measurement of ambient air.

The parents/guardians were asked if their child had any disease or condition that could be an obstacle to the CRF testing. In case of doubt a physician was consulted. The child and parents/guardians were also informed of test procedures before testing, and the child's parents/guardians were allowed and encouraged to observe testing. All children were instructed not to eat for two hours prior to testing, and to engage in normal activity the day

before the test and on the test day. Before testing, a Polar HR monitor (Polar OY, Kempele, Finland) was fitted to the chest by an elastic strap. The monitor registered HR throughout testing. Also, a safety rope connected to a chest belt system from Cosmos (h/p/cosmos sports & medical GmbH, Nussdorf-Traunstein, Germany) was put on the children. Throughout the test, one test leader (*P.I.*) was in charge of the safety of the subject by tightly holding the safety rope. If the subject stumbled, the test leader could pull the rope, thereby raising the subject, and prevent a fall. To apply such a safety measure is vital because it excludes the subject's fear of tripping or falling. Such a fear could cause some children to terminate the test prematurely (Malina et al., 2004). When ready for testing, subjects mounted the treadmill (PPS 55, Woodway GmbH, Germany), and began walking slowly ($1-2 \text{ km}\cdot\text{h}^{-1}$). As the subject's technique improved, speed was increased and safety procedures on how to stop the test by jumping off the treadmill or pushing the stop button were rehearsed. A face mask (Hans Rudolph Inc, Shawanee, USA) was put on, controlled for air tightness and connected to the oxygen analyzer.

The methodology differed slightly for the baseline and post-intervention $\text{VO}_{2\text{peak}}$ tests. In the baseline test, testing started with five minutes' walking at $5 \text{ km}\cdot\text{h}^{-1}$ at an inclination of 5.3%, followed by two minutes' jogging at $7 \text{ km}\cdot\text{h}^{-1}$. Depending on how the subject was performing, speed was either maintained or increased by $1 \text{ km}\cdot\text{h}^{-1}$ every minute, until a maximum speed of $10 \text{ km}\cdot\text{h}^{-1}$ was reached. Thereafter, the workload was increased through inclination, which was raised by 1.5% each minute until exhaustion. At the post-intervention test, there was a fixed protocol where the children started with five minutes' walking at $5 \text{ km}\cdot\text{h}^{-1}$ at an inclination of 5.3%, and after this, speed was increased every minute until a maximum speed of $11 \text{ km}\cdot\text{h}^{-1}$ was reached. After this point, the load was increased by elevating the treadmill's gradient by 1.0 % every minute until exhaustion.

Test leaders discussed several subjective criteria after each test; hyperpnoea, unsteady running pattern, and verbal and body language clearly indicating that the child wanted to stop testing despite repeated strong verbal encouragement. Additionally, the objective criteria of RER (≥ 1.0) and HR_{peak} ($\geq 200 \text{ beats}\cdot\text{min}^{-1}$) were taken into consideration. VO_2 was measured at 10-second intervals, and $\text{VO}_{2\text{peak}}$ was defined as the mean of the six highest successive measurements.

The reliability of VO_{2peak} tested directly in children is shown to be approximately 4%, which compares favorably with the reliability of adults' VO_{2max} (Welsman et al., 2005). The MetaMax I system used in the present study was validated against the Douglas Bag technique, regarded as the gold standard (Medbø et al., 2002). The validation showed a systematic overestimation by the MetaMax I at all work rates by 5%. Consequently, all VO_{2peak} measurements were corrected downwards by a factor of 1.05, and the data presented have been adjusted accordingly. This trend was confirmed in later internal validation tests (data not shown). Furthermore, this pattern of overestimation in the VO_2 measurements for the MetaMax-system was confirmed in PANCS (Kolle et al., 2009).

The VO_{2peak} is presented in absolute values ($l \cdot min^{-1}$), relative values ($ml \cdot kg^{-1} \cdot min^{-1}$) and scaled as a function of body mass^{0.67} ($ml \cdot kg^{-0.67} \cdot min^{-1}$) as suggested by Åstrand et al. (2003).

2.4.3 Blood sampling, treatment and analysis

After an overnight fast, intravenous blood samples were taken from each child's antecubital vein in the morning between 0900 and 1030 one hour after the application of an anaesthetic band-aid (lidocaine/prilocaine Emla cream, Astra, Albertslund, Denmark). Those children that had eaten or drunk on the morning of the test, were rescheduled to take the blood sample another day. If a vein could not be found or was missed, the phlebotomist was instructed not to puncture the vein more than once. Blood samples were mechanically agitated for 30 minutes to prevent clotting, and were then aliquoted and separated. The samples were spun for 10 minutes at 2500G. Two samples were obtained from each child. One sample per subject was analysed at the FÜRST Medical Laboratory (Oslo, Norway) for glucose, TC, high-density lipoprotein cholesterol (HDL) and Triglyceride (TG). Low-density lipoprotein cholesterol (LDL) was estimated from total cholesterol, HDL and TG by the Friedewald formula (Friedewald et al., 1972). The ratio of TC to HDL (TC:HDL ratio) was calculated. The other sample was frozen immediately after sampling and stored at $-80^{\circ}C$. These samples were later analyzed for insulin using a radioimmunoassay kit (Linco Research, Inc., St. Charles, MO, USA) at the Hormone Laboratory, Aker University Hospital (Oslo, Norway). Insulin resistance was estimated according to the homeostasis model assessment for insulin resistance (HOMA-IR) using the formula $[(\text{glucose (mmol/l)} \cdot \text{insulin (pmol/l)})/135]$ (Matthews et al., 1985). Both laboratories are subject to external quality assessment and are internationally accredited.

2.4.4 Resting blood pressure

Systolic (SBP) and diastolic (DBP) blood pressure were measured using the Omron HEM-907 automated BP monitor (Omron Healthcare, Inc, Vernon Hills, IL, US). The device was validated according to the AAMI validation protocol (White and Anwar, 2001) and the validation criteria of the published proposal of the international protocol for the validation of blood pressure measuring devices (El Assaad et al., 2002). Our own reliability study revealed that there was no significant difference between using the Omron HEM-907 and manual measurement. Children rested quietly for 10 minutes in a sitting position with no distractions before BP was measured. During the measurement, each child sat motionless in a quiet room, and BP was measured on the upper right arm, using the appropriate sized cuff. The BP monitor was programmed to take four measurements with a two-minute break between each measurement. For all tables and analyses, the mean value of the last two measurements was used.

2.4.5 Data collection

Baseline data were collected in the September–October period in both 2004 and 2005. Post-intervention data were collected in the May–June period in both 2006 and 2007. The children from the C-school travelled to *Sogn og Fjordane University College* in Sogndal where their body mass and height, WC and HC, BP and VO_{2peak} were measured at the Human Physiology Laboratory during weekends. Therefore, these measurements were performed between 0900 and 2000. The I-school children's VO_{2peak} was measured at the same laboratory on weekdays between 1200 and 1900 while their body mass and height, WC and HC and BP were measured at their school (between 0900 and 1500). All blood sampling was carried out in the morning at the schools on a different day than all other testing. The same experienced nurse carried out all the anthropometric measurements. The same experienced phlebotomist carried out all the blood sampling tests. The same two experienced test leaders carried out all VO_{2peak} tests. One test leader (the *P.I.*) urged subjects on, trying to ensure they gave maximum effort. The other test leader controlled measurements and treadmill speed.

2.4.6 Statistics

Data were analyzed using SPSS versions 15.0 to 17.0 (SPSS Inc, Chicago, IL, USA). Results are presented as mean \pm SD, mean \pm SEM or mean (95% CI). Significance level was set at $p<0.05$. Variables were tested for normality of distribution before analyses, and skewed

variables were logarithmically transformed (natural log) for all statistical analyses. Firstly, the statistical approach and analyses used for the pre-post data will be presented. Secondly, the statistical approach and analyses used for the baseline data will be presented.

Post-intervention vs. baseline data: Differences-in- Δ between the I-school and the C-school, the net effect of the intervention, were analyzed with a linear multiple regression adjusted for sex (paper II and III) (**Table 3 and 5**). For secondary analyses in paper II, a clustered metabolic risk score at baseline using the Z-score technique $z = (\text{value} - \text{mean}) / \text{SD}$ stratified by sex and location was constructed (**Table 6a-b**). CVD risk factors included were SBP, $\text{VO}_{2\text{peak}}$, TG, TC:HDL ratio, WC and HOMA-IR. A median-split procedure was used to divide both the I-school and the C-school children into two groups: a) *under median (UM)* and b) *over median (OM)*. The children who constitute the UM group had the least favorable clustered metabolic risk profile at baseline, while the children in the OM group had the most favorable clustered metabolic risk profile at baseline. A one-way ANOVA with a Sidak post hoc comparison was used to compare the Δ clustered metabolic risk score for the four different sub-groups. Approximately the same number of boys and girls were located in each subgroup. For secondary analyses in paper III, ANCOVA with Tukey's post hoc test was used to compare $\Delta \text{VO}_{2\text{peak}}$ between quartiles in the I-school and in the C-school (**Table 4**). To test for a potential regression towards the mean (RTM) effect, a formula suggested by Beach and Baron (1998) was used.

Baseline data: Differences in baseline means between the I-school and the C-school children (paper II and III) (**Table 2a-c**) and baseline means between the sexes (paper I and IV) (**Table 7a-c**) were determined by an independent-sample *t*-test. To analyze the association between CRF and clustering of CVD risk factors (paper IV) (**Figure 3**), a clustered risk score Z-score including five biological CVD risk factors (HOMA-IR, WC, TG, SBP, TC:HDL ratio) was constructed by sex and analysed in a one-way-ANOVA including Tukey's Post hoc comparison. Furthermore, four fitness/BMI groups (fit/normal BMI; unfit/normal BMI; unfit/overweight or obese; fit/overweight or obese) were compared in relation to CVD risk factors by sex (Paper IV). Weight status was defined by the BMI classification from Cole et al. (2000). High fitness was defined as being in the highest (best) quartile of fitness and unfit in the lowest (worst) quartile. Differences across CRF/BMI groups and these groups'

clustered risk (Z-score) were assessed by one-way ANOVA and Tukey's or Sidak Post-hoc comparison (Table 8 and Figure 4).

Sample size and power calculations

Sample size calculations were performed a priori, and power calculation was performed after testing to test power (SigmaStat 3.1 Systat Software GmbH, Erkrath, Germany). In the sample size and power calculations, VO_{2peak} was the primary outcome variable. The sample size calculation were based on the numbers required per cell to detect a difference between the I-school and the C-school of $3.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ with a standard deviation (SD) of $7.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Calculations were made using a two-tailed test assuming Type 1 error rate = 0.05; and statistical power = 0.8. Calculations indicated that the study would require 75 subjects in each of the groups. Because this was an intervention study, and a substantial number of drop outs could be expected, a design effect of 1.2 was incorporated, given a final target sample size of 180 subjects in total. Power calculations were performed after testing to ensure that power was still sufficient. For VO_{2peak} , the least detectable difference at the 5% significance level between the I-school (n=102) and the C-school (n=86) with a power of 0.80 and a SD of 3.7 was $1.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. The choice of VO_{2peak} as the variable to assess sample size and power prompts questions regarding other CVD risk factor variables investigated, as i.e. TG has been shown to be more sensitive than VO_{2peak} . Therefore, in Table 1, we present the least detectable difference at the 5% with a power of 0.80 for the included CVD risk factors.

Table 1. The least detectable difference at the 5% with a power of 0.80 for the included CVD risk factors

CVD risk factor	n	SD*	The least detectable difference
Systolic BP (mm Hg)	224	6.5	2.5 mm Hg
Diastolic BP (mm Hg)	224	5.4	2.1 mm Hg
Triglyceride ($\text{mmol}\cdot\text{l}^{-1}$)	225	0.33	$0.13 \text{ mmol}\cdot\text{l}^{-1}$
TC:HDL ratio	225	0.39	0.15
Waist circumference (cm)	220	2.8	1.1 cm
BMI ($\text{kg}\cdot\text{m}^{-2}$)	226	0.9	$0.9 \text{ kg}\cdot\text{m}^{-2}$
HOMA-IR	220	1.12	0.43

*SD for the pooled Δ value for each CVD risk factor

3. RESULTS

This section consists of three parts. Firstly, the baseline values for the children at the I-school and the C-school will be described. Secondly, results from the intervention will be presented (primary aim). Thirdly, the baseline data from both the I-school and the C-school children are merged and presented by sex (secondary aim). These data describe CVD risk factor levels and the association between CRF and clustering of CVD risk factors. For details, the reader is referred to the original articles included at the end of the thesis.

3.1 Baseline characteristics of subjects

Tables 2a-c shows the descriptive characteristics at baseline for the I-school and the C-school children. There were no significant differences between the I-school and the C-school children in the 23 variables presented except for LDL and glucose; hence the two groups can be considered similar at baseline. Regarding the VO_{2peak} test, it is noteworthy that the two groups had the same HR_{peak} (204 ± 7 and 204 ± 8 $\text{beat} \cdot \text{min}^{-1}$) and that there was no significant difference in running time_{peak} between the I-school and C-school children.

Table 2a. Participants' characteristics in anthropometric variables and blood pressure at baseline by I-school and C-school

	I-school		C-school		<i>p</i> for location
	n	mean±SD	n	mean±SD	
Age (years)	125	9.2±0.3	131	9.3±0.3	0.785
Body mass (kg)	125	32.6±6.5	131	32.6±6.7	0.987
Height (cm)	125	137.2±6.0	131	137.0±5.7	0.772
BMI ($\text{kg} \cdot \text{m}^{-2}$)	125	17.2±2.6	131	17.3±2.9	0.825
PI ($\text{kg} \cdot \text{m}^{-3}$)	125	12.5±1.8	131	12.6 ±2.1	0.744
Waist circumference (cm)	125	61.2±6.3	119	61.6±7.0	0.586
Hip circumference (cm)	125	64.9±7.7	119	65.4±8.2	0.659
Waist-to-hip ratio	125	0.94±0.03	119	0.94±0.03	0.943
Systolic BP (mm Hg)	125	108.6±7.9	119	109.3±7.9	0.464
Diastolic BP (mm Hg)	125	62.4±6.5	119	62.1±6.3	0.714

Table 2b. Participants' characteristics in peak oxygen uptake, peak running time and peak heart rate at baseline by I-school and C-school

	I-school		C-school		<i>p</i> for location
	n	mean±SD	n	mean±SD	
VO _{2peak} (ml·kg ⁻¹ ·min ⁻¹)	117	49.0±7.5	110	50.6±7.4	0.097
VO _{2peak} (ml·kg ^{-0.67} ·min ⁻¹)	117	153.4±19.0	110	158.1±19.2	0.065
VO _{2peak} (l·min ⁻¹)	117	1.57±0.22	110	1.61±0.22	0.217
Running time _{peak} (min)	116	10.8±1.5	109	11.1±1.4	0.153
HR _{peak} (beat·min ⁻¹)	113	204.2±6.8	110	204.4±7.7	0.870

Table 2c. Participants' characteristics in blood variables at baseline by I-school and C-school

	I-school		C-school		<i>p</i> for location
	n	mean±SD	n	mean±SD	
Total cholesterol (mmol·l ⁻¹)	125	4.8±0.8	122	4.6±0.6	0.090
HDL cholesterol (mmol·l ⁻¹)	125	1.7±0.4	122	1.7±0.4	0.563
LDL cholesterol (mmol·l ⁻¹)	125	2.8±0.7	122	2.6±0.6	0.015
TC:HDL ratio	125	3.0±0.7	122	2.8±0.6	0.086
Triglyceride (mmol·l ⁻¹)	125	0.7±0.3	122	0.8±0.5	0.320
Insulin (pmol·l ⁻¹)	125	57.7±17.3	122	61.8±31.4	0.206
Glucose (mmol·l ⁻¹)	125	4.6±0.4	122	4.8±0.3	<i>p</i><0.001
HOMA-IR	125	2.0±0.6	122	2.2±1.1	0.064

All variables are presented as mean±SD. Significant values are given in *italics*.

3.2 Effects of the intervention

The main finding is that the I-school children significantly improved CRF and several CVD risk factors to a greater extent than the children from the C-school.

3.2.1 CRF

The I-school children improved their mean (95% CI) VO_{2peak} by 3.6 (2.5–4.6) ml·kg⁻¹·min⁻¹ more than the children from the C-school. Expressed as a percentage, the difference-in-ΔVO_{2peak} was 8% higher in the I-school children than in the C-school children (8.8% vs. 0.8%). These results are adjusted for sex and VO_{2peak} at baseline. The unadjusted difference-in-ΔVO_{2peak} (ml·kg⁻¹·min⁻¹) was 3.9 (2.8–5.0) ml·kg⁻¹·min⁻¹ (**Table 3**). In crude values, the I-school children increased their mean (SD) VO_{2peak} from 49.1 (7.3) ml·kg⁻¹·min⁻¹ to 53.4 (6.8) ml·kg⁻¹·min⁻¹. The C-school children increased their VO_{2peak} (mean, SD) from 50.7 (6.9) ml·kg⁻¹·min⁻¹ to 51.1 (7.5) ml·kg⁻¹·min⁻¹. Furthermore, the significant increase in VO_{2peak} for the I-school children was accompanied by a significant increase in running time_{peak} but not in HR_{peak} compared to the C-school children.

Table 3. Post-Intervention and delta values for VO_{2peak} , running time_{peak} and HR_{peak} by I-school and C-school

	I-school (n=102)			C-school (n=86)			Difference-in- Δ^* (mean, 95% CI).	p ^{**}
	Post-interv. (mean \pm SD)	Δ (mean, SEM)	$\Delta\%$	Post-interv. (mean \pm SD)	Δ (mean, SEM)	$\Delta\%$		
VO_{2peak} (ml·kg ⁻¹ ·min ⁻¹)	53.4 \pm 6.8	4.3 (0.4)	8.8	51.1 \pm 7.5	0.4 (0.4)	0.8	3.9 (2.8 to 5.0)	<0.001
VO_{2peak} (l·min ⁻¹)	2.06 \pm 0.28	0.48 (0.02)	30.4	1.90 \pm 0.28	0.31 (0.02)	19.4	0.17 (0.12–0.22)	<0.001
VO_{2peak} (ml·kg ^{0.67} ·min ⁻¹)	177.4 \pm 17.1	23.6 (1.3)	15.3	168.0 \pm 20.3	10.1 (1.2)	6.4	12.3 (9.1–15.5)	<0.001
Run. time _{peak} (min)	11.32 \pm 1.69	0.38 (0.1)	3.5	10.69 \pm 1.61	-0.50 (0.1)	-4.5	0.82 (0.49–1.15)	<0.001
HR _{peak} (beats·min ⁻¹)	202.5 \pm 6.7	-1.2 (0.3)	-0.6	203.1 \pm 7.6	-0.5 (0.5)	-0.2	-0.6 (-1.6–0.4)	0.230

Post-intervention, Δ (both mean and %) for the intervention school and control school are crude values (not adjusted). Δ is the post-intervention value minus the baseline value. * *Difference-in- Δ* between I-school and C-school is the net effect of the intervention. This is a crude value adjusted for sex. ** *p*-values adjusted for sex. VO_{2peak} : peak oxygen uptake, a proxy measure for CRF. Run. time_{peak}: peak running time on the treadmill in the VO_{2peak} test. HR_{peak}: peak heart rate at the VO_{2peak} test. Significant values are given in *italics*.

When analysing ΔVO_{2peak} by quartiles of VO_{2peak} baseline, ΔVO_{2peak} in both quartiles 1 (Q1) and 2 (Q2) in the I-school was found to be significantly higher than in all quartiles in the C-school (**Table 4**). Furthermore, ΔVO_{2peak} for Q3 in the I-school was significantly higher than ΔVO_{2peak} in all quartiles in the C-school except Q1. ΔVO_{2peak} for Q4 in the I-school was not significantly different from ΔVO_{2peak} in any of the quartiles in the C-school. The difference-in- Δ in VO_{2peak} between Q1 in the I-school and Q1 in the C-school was 5.2 (3.3–7.1) ml·kg⁻¹·min⁻¹. For the three other quartiles the differences were 5.4 (3.7–7.2), 3.4 (1.3–5.5) and 1.7 (-0.8–4.3) ml·kg⁻¹·min⁻¹, for Q2 vs. Q2, Q3 vs. Q3 and Q4 vs. Q4, respectively.

Table 4. VO_{2peak} at post-intervention and delta by quartiles of VO_{2peak} baseline for children by I-school and C-school

	I-school \neq			C-school \neq		
	Post-inter. (mean \pm SD)	Δ (mean, SEM)	$\Delta\%$	Post-inter. (mean \pm SD)	Δ (mean, SEM)	$\Delta\%$
Quartile 1	46.4 \pm 5.1	6.1 (0.7)*	15.1	44.1 \pm 5.7	0.9 (0.6)	2.0
Quartile 2	52.2 \pm 4.3	5.2 (0.6)**	11.1	48.9 \pm 5.2	-0.1 (0.6)	-0.2
Quartile 3	55.7 \pm 4.2	3.8 (0.8)***	7.3	53.6 \pm 5.5	0.4 (0.8)	0.7
Quartile 4	59.5 \pm 5.6	2.1 (0.8)	3.7	58.1 \pm 5.5	0.3 (1.0)	0.5

Δ represents difference between baseline and post-intervention values. $\Delta\%$ is the difference between the baseline and the post-intervention test in percent. Children in the fourth quartile (Q4) are the fittest. The 25 % least fit boys in the I-school (n=14) and the 25 % least fit girls in the I-school (n=12) constitute Q1 for the I-school. There are approximately the same number of boys and girls in each group. \neq : *n* between 21 and 26 in each quartile. * Significantly higher than in all quartiles in the C-school (p<0.001). ** Significantly higher than in all quartiles in the C-school (p<0.003). *** Significantly higher than Q2, Q3 and Q4 in the C-school p<0.05).

3.2.2 CVD risk factors

The I-school children had a more favorable development in SBP, DBP, TG and TC:HDL ratio than did the C-school children. There were no significant differences between children from the I-school and C-school in $\Delta W C$, $\Delta B M I$ or $\Delta H O M A - I R$ (**Table 5**). Since there is a strong

correlation between BP and body mass in children (Thompson et al., 2007) we performed additional regression analyses for Δ BP where we adjusted for a: *body mass at baseline* and b: Δ *body mass*. However, the same intervention effect emerged (Δ SBP a: $p=0.005$ and b: $p=0.004$, Δ DBP a: $p=0.002$ and b: $p=0.002$).

Table 5. Post-intervention and delta values for children by I-school and C-school

	I-school \neq			C-school \neq			Difference-in- Δ^* (mean, 95% CI).	<i>p</i> **
	Post-inter. (mean \pm SD)	Δ (mean, SEM)	$\Delta\%$	Post-inter. (mean \pm SD)	Δ (mean, SEM)	$\Delta\%$		
SBP (mm Hg)	107.3 \pm 6.4	-1.72 (0.57)	-1.6	109.7 \pm 7.7	0.85 (0.66)	0.8	- 2.6 (-4.3 to -0.9)	0.003
DBP (mm Hg)	59.5 \pm 5.8	-3.0 (0.5)	-4.8	61.1 \pm 6.1	-0.8 (0.5)	-1.3	- 2.3 (-3.7 to -0.8)	0.002
TG (mmol·l ⁻¹)	0.73 \pm 0.28	0.00 (0.03)	0	0.80 \pm 0.34	0.08 (0.03)	11.1	-0.09 (-0.17 to 0.00)	0.030
TC:HDL ratio	2.81 \pm 0.59	-0.12 (0.04)	-4.1	2.82 \pm 0.61	0.05 (0.04)	1.8	-0.17 (-0.27 to 0.07)	0.011
WC (cm)	65.2 \pm 7.6	3.6 (0.27)	5.8	64.9 \pm 7.9	3.7 (0.27)	6.0	-0.1 (-0.7 to 0.8)	0.943
BMI (kg·m ⁻²)	18.1 \pm 3.0	0.8 (0.1)	4.6	18.0 \pm 3.0	0.9 (0.1)	5.2	-0.1 (-0.3 to 0.2)	0.530
HOMA-IR	2.78 \pm 1.01	0.80 (0.09)	40.4	2.68 \pm 1.27	0.53 (0.12)	24.7	0.28 (-0.02 to 0.57)	0.058

Δ is the post-intervention value minus the baseline value. * *Difference-in- Δ* between I-school and C-school is the net effect of the intervention and is a crude value adjusted for sex. ** *P-values* adjusted for sex. For those variables with more than 5% difference between I-school and C-school at baseline (TC:HDL ratio: 5.5% HOMA-IR: 7.9%) we also adjusted for their respective baseline value. \neq : *n* between 109 and 116. Only children with a valid test both at baseline and post-intervention were included for each variable. SBP: Systolic blood pressure. DBP: Diastolic blood pressure. TG: Triglyceride. TC:HDL ratio: Total cholesterol/high density lipoprotein ratio. WC: Waist circumference. BMI: Body mass index. HOMA-IR: Homeostasis model assessment for insulin resistance. Significant values are given in *italics*.

3.2.3 Effects of the intervention – secondary analyses

To investigate subgroup changes, we divided both the I-school and C-school children into two groups, using a median split based on a clustered risk score at baseline (**Tables 6a and 6b**). Significant differences in Δ -values were found in four CVD risk factors. For Δ SBP, the UM group (least favorable clustered metabolic risk profile at baseline) in the I-school had a significantly greater reduction than the UM group in the C-school. For Δ DBP, the OM group (most favorable clustered metabolic risk profile at baseline) in the I-school had a significantly greater reduction than did the UM group in the C-school. For Δ TC:HDL ratio, the UM in the I-school had a significantly more favorable development than UM in the C-school. For Δ VO_{2peak}, both UM and OM groups in the I-school had a significantly greater Δ VO_{2peak} than both UM and OM groups in the C-school. Regarding Δ HOMA-IR, there was a significant difference in HOMA-IR between UM in the I-school and OM in the C-school.

Table 6a. Baseline and Δ -values for CVD risk factors split at the median of the clustered risk score for the I-school

I-school	Under median (n=46)		Over median (n=46)	
	Baseline (mean \pm SD)	Δ (mean, SEM)	Baseline (mean \pm SD)	Δ (mean, SEM)
SBP (mm Hg)	113.1 \pm 6.3 [#]	-4.8 (1.0) [*]	105.3 \pm 7.6	0.3 (0.8)
DBP (mm Hg)	65.3 \pm 5.8 [#]	-4.1 (0.8)	59.4 \pm 5.7	-1.8 (0.7) ^{**}
VO _{2peak} (ml \cdot kg ⁻¹ \cdot min ⁻¹)	45.7 \pm 6.8 ^{###}	4.6 (0.6) ^{***}	51.9 \pm 5.7	4.0 (0.6) ^{***}
TG (mmol \cdot l ⁻¹)	0.86 \pm 0.30 [#]	-0.08 (0.05)	0.58 \pm 0.15	0.09 (0.04)
TC:HDL ratio	3.25 \pm 0.70 [#]	-0.25 (0.07) [*]	2.67 \pm 0.53	-0.01 (0.04)
WC (cm)	64.4 \pm 6.7 [#]	4.2 (0.5)	58.4 \pm 4.5	3.3 (0.4)
BMI (kg \cdot m ⁻²)	18.6 \pm 2.8 [#]	1.0 (0.2)	16.0 \pm 1.6	0.8 (0.1)
HOMA-IR	2.29 \pm 0.57 [#]	0.83 (0.17)	1.71 \pm 0.52	0.76 (0.13)

Table 6b. Baseline and Δ -values for CVD risk factors split at the median of the clustered risk score for the C-school

C-school	Under median (n=42)		Over median (n=40)	
	Baseline (mean \pm SD)	Δ (mean, SEM)	Baseline (mean \pm SD)	Δ (mean, SEM)
SBP (mm Hg)	111.8 \pm 8.6 [#]	0.5 (1.2)	105.2 \pm 6.5	1.9 (0.9)
DBP (mm Hg)	63.2 \pm 6.0 ^{##}	-0.8 (0.7)	59.8 \pm 6.5	-0.6 (1.0)
VO _{2peak} (ml \cdot kg ⁻¹ \cdot min ⁻¹)	47.7 \pm 7.3 ^{####}	0.3 (0.5)	53.9 \pm 5.1	0.3 (0.6)
TG (mmol \cdot l ⁻¹)	0.83 \pm 0.31 [#]	0.09 (0.07)	0.58 \pm 0.14	0.15 (0.03)
TC:HDL ratio	2.92 \pm 0.44 ^{#####}	0.12 (0.07)	2.53 \pm 0.42	0.02 (0.03)
WC (cm)	64.0 \pm 7.7 [#]	3.6 (0.5)	58.4 \pm 3.5	3.1 (0.4)
BMI (kg \cdot m ⁻²)	18.1 \pm 3.3 ^{#####}	0.9 (0.2)	16.2 \pm 1.5	0.7 (0.1)
HOMA-IR	2.42 \pm 1.18 [#]	0.49 (0.21)	1.64 \pm 0.60	0.54 (0.16) ^{****}

The children in the UM group have the least favorable clustered health profile at baseline while the children in the OM group have the most favorable clustered health profile at baseline. Due to baseline differences between the groups, all analyses are adjusted for each CVD risk factor baseline value. [#] Sig. higher than both the OM group in the I-school and the OM group in the C-school ($p < 0.001$). ^{##} Sig. higher than the OM group in the I-school ($p = 0.021$). ^{###} Sig. lower than both the OM group in the I-school and the OM group in the C-school ($p < 0.001$). ^{####} Sig. lower than both the OM group in the I-school ($p = 0.011$) and the OM group in the C-school ($p < 0.001$). ^{#####} Sig. higher than both the OM group in the I-school ($p < 0.001$) and the OM group in the C-school ($p = 0.004$). ^{*****} Sig. higher than both the OM group in the I-school ($p < 0.001$) and the OM group in the C-school ($p = 0.002$). ^{*} Sig. higher than the UM group in the C-school ($p = 0.001$). ^{**} Sig. higher than the UM group in the C-school ($p = 0.022$). ^{***} Sig. higher than both the UM group and the OM group in the C-school ($p < 0.001$). ^{****} Sig. higher than the UM group in the I-school ($p = 0.017$).

3.3 CVD risk factor levels and the association between CRF and clustering of CVD risk factors

This section presents cross-sectional data based on the baseline data. All variables are pooled between the I-school and the C-school and presented by sex.

3.3.1 Descriptive characteristics

Age, body mass, height, BMI, WC, SBP, HR_{peak} and TC were not significantly different between the sexes (Tables 7a-c). However, a significant difference was observed in PI, HC, waist-to-hip ratio, DBP, all variants of VO_{2peak} and all blood variables measured except total cholesterol.

Table 7a. Participants' characteristics in anthropometric variables and blood pressure at baseline by sex

	Boys		Girls		<i>p</i>
	n	mean±SD	n	mean±SD	
Age (years)	125	9.2±0.3	131	9.3±0.3	0.085
Body mass (kg)	125	32.1±5.2	131	33.0±7.7	0.271
Height (cm)	125	137.7±5.4	131	136.6±6.2	0.172
BMI (kg·m ⁻²)	125	16.9±2.2	131	17.6±3.1	0.054
PI (kg·m ⁻³)	125	12.3±1.6	131	12.9±2.2	0.016
Waist circumference (cm)	119	60.9±5.3	125	61.9±7.7	0.276
Hip circumference (cm)	119	63.4±6.4	125	66.8±8.8	0.001
Waist-to-hip ratio	119	0.96±0.02	125	0.93±0.03	<i>p</i><0.001
Systolic BP (mm Hg)	119	108.9±8.4	125	109.0±7.5	0.921
Diastolic BP (mm Hg)	119	61.3±6.7	125	63.0±6.0	0.040

Table 7b. Participants' characteristics in peak oxygen uptake, peak running time and peak heart rate at baseline by sex

	Boys		Girls		<i>p</i>
	n	mean±SD	n	mean±SD	
VO _{2peak} (ml·kg ⁻¹ ·min ⁻¹)	111	52.8±6.5	116	46.9±7.2	<i>p</i><0.001
VO _{2peak} (ml·kg ^{-0.67} ·min ⁻¹)	111	165.0±15.9	116	146.7±17.2	<i>p</i><0.001
VO _{2peak} (l·min ⁻¹)	111	1.68±0.20	116	1.51±0.21	<i>p</i><0.001
Running time _{peak} (min)	111	11.5±1.4	114	10.4±1.3	<i>p</i><0.001
HR _{peak} (beat·min ⁻¹)	111	203.1±6.8	112	205.5±7.5	0.013

Table 7c. Participants' characteristics in blood variables at baseline by sex

	Boys		Girls		<i>p</i>
	n	mean±SD	n	mean±SD	
Total cholesterol (mmol·l ⁻¹)	121	4.63±0.70	126	4.76±0.74	0.152
HDL cholesterol (mmol·l ⁻¹)	121	1.75±0.38	126	1.62±0.32	0.004
LDL cholesterol (mmol·l ⁻¹)	121	2.57±0.63	126	2.78±0.69	0.010
TC:HDL ratio	121	2.73±0.57	126	3.02±0.71	<i>p</i><0.001
Triglyceride (mmol·l ⁻¹)	121	0.69±0.27	126	0.80±0.44	0.023
Insulin (pmol·l ⁻¹)	121	52.8±15.9	126	66.4±30.6	<i>p</i><0.001
Glucose (mmol·l ⁻¹)	121	4.74±0.34	126	4.62±0.36	0.004
HOMA-IR	121	1.87±0.60	126	2.29±1.1	0.003

All variables are presented as mean±SD. P-value for sex is presented after adjustment for location. Significant values are given in *italics*.

3.3.2 Clustering of CVD risk factors by quartiles of VO_{2peak}

The differences in Z-score between the upper and lower quartiles of CRF were 3.43 for boys and 5.14 for girls (**Figure 3**). A one-way ANOVA analysis including a Tukey post hoc test showed significant differences for both boys and girls. For both sexes, the children in quartile 1 (the least fit children) had significantly poorer values than the children in all other quartiles. Additionally, for girls, the second quartile had significantly poorer values than the fittest quartile. If WC was excluded from the clustered risk score, the association attenuated for boys and remained strong for girls for quartiles 2, 3 and 4, respectively. For boys the difference between the least fit boys (Q1) and Q3 was no longer significant. For girls, the difference between Q2 and Q4 was no longer significant.

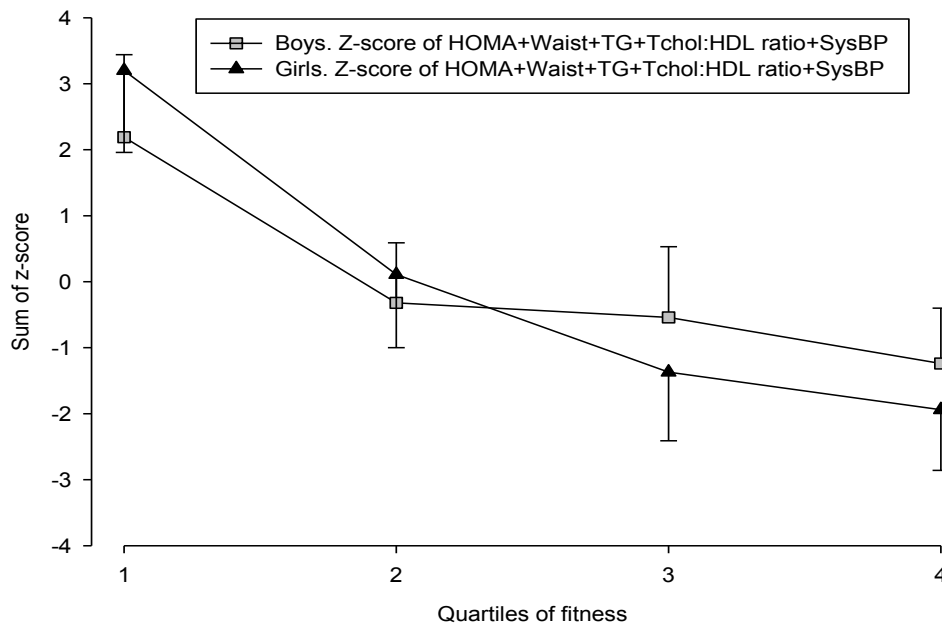


Figure 3. Z-score and 95%CI for the composite risk score for quartiles of CRF for boys and girls. A higher sum of Z-score indicates a less favourable metabolic profile. Children in the fourth quartile of CRF are the fittest.

3.3.3 CRF, BMI and CVD risk factors

Children were divided into groups by sex according to their combined CRF and BMI status. With regard to CRF and weight status *and* single CVD risk factors, there were significant differences between groups in HOMA-IR, WC, SBP, TG and TC:HDL ratio (**Table 8**). For girls, *the unfit & overweight/obese group* had significantly poorer values than *the fit & normal body mass group* in all five CVD risk factors (HOMA-IR, WC, SBP, TG, TC:HDL ratio). *The unfit & overweight/obese girl group* also had significantly poorer values than *the unfit & normal body mass group* in WC. Concerning boys, *the unfit & overweight/obese group* had significantly poorer values than *the fit & normal body mass group* in WC and SBP. Also, in WC and SBP, *the unfit & overweight/obese group* had significantly poorer values than *the unfit & normal body mass group*. Finally, in waist, *the unfit & normal body mass group* had significantly poorer values than *the fit & normal body mass group*.

Table 8 CRF and weight status *and* single CVD risk factors

Boys	n	HOMA-IR	Waist	SBP	TG	Tchol:HDL ratio
Fit and normal weight	28	1.79±0.63	57.5±3.0	106±7	0.67±0.23	2.76±0.54
Unfit and normal weight	18	2.11±0.67	63.3±4.7 ^c	109±9	0.81±0.43	3.02±0.77
Unfit and overweight/obese	9	2.17±0.54	71.7±5.2 ^{ab}	119±7 ^{ab}	0.65±0.21	2.62±0.39
Girls						
Fit and normal weight	28	1.93±0.58	56.6±3.3	105±6	0.71±0.27	2.81±0.40
Unfit and normal weight	9	2.26±0.72	59.8±3.3	109±6	0.76±0.06	3.14±0.57
Unfit and overweight/obese	21	3.00±1.56 ^a	74.2±6.9 ^{ab}	115±7 ^a	0.94±0.26 ^a	3.47±0.83 ^a

Mean±SD values for three CRF-BMI groups: *fit and normal weight*; *unfit and normal weight*; *unfit and overweight/obese* and CVD risk factors. Because of uneven group sizes, harmonic mean was used instead of arithmetic mean. **a** unfit and overweight/obese is significantly different than fit and normal weight ($p<0.05$). **b** unfit and overweight/obese is significantly different than unfit and normal weight ($p<0.05$). **c** unfit and normal weight is significantly different than fit and normal weight ($p<0.05$).

Regarding CRF and weight status *and* clustered CVD risk factors, for boys, *the fit and normal weight group* had a significantly lower Z-score than did both *the unfit and normal weight* and *the unfit and overweight/obese* (**Figure 4**). For girls *the unfit and overweight/obese group* was significantly different from both *the fit and normal weight* and *the unfit and normal weight*. If WC was excluded from the clustered risk score in boys, the significant association between *the fit and normal weight group* and *the unfit and normal weight* was weakened, while the difference between *the fit and normal weight group* and *the unfit and overweight/obese* was no longer significant. For girls, the association between *the unfit and overweight/obese group* and *the fit and normal weight* was unchanged. However, there was no longer a significant difference between *the unfit and overweight/obese group* and *the unfit and normal weight*.

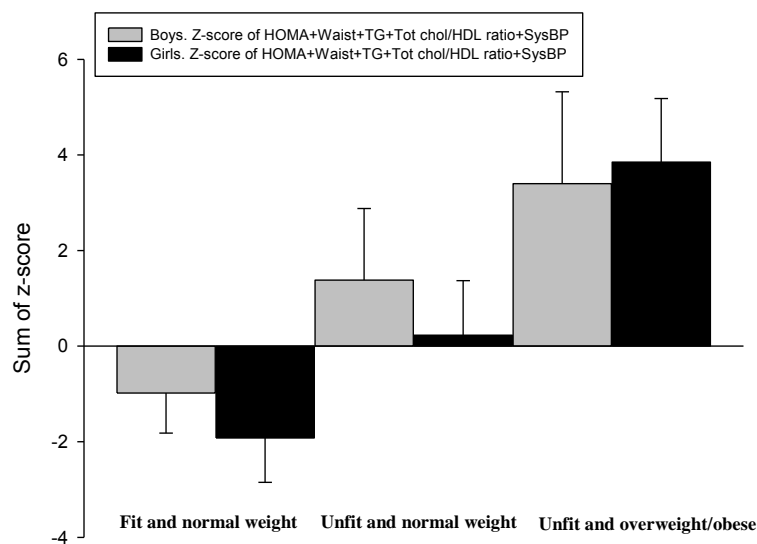


Figure 4. Z-score and 95%CI for the composite risk score for three CRF-BMI groups: *fit and normal weight*; *unfit and normal weight*; *unfit and overweight/obese*. A higher sum of Z-score indicates a less favourable metabolic profile.

4. GENERAL DISCUSSION

This thesis presents results from a two-year school-based daily physical activity intervention involving 256 nine-year-old rural Norwegian children. In addition, cross-sectional data from the same group of children pertaining to the association between CRF and CVD risk factors is presented. The main finding was that a 60-minute daily physical activity intervention can significantly improve children's CRF and beneficially modify children's CVD risk profile. Furthermore, cross-sectional suggest that low CRF is associated with an increased clustered metabolic risk.

4.1 Intervention effect on cardiorespiratory fitness

The present physical activity intervention significantly improved VO_{2peak} in children. The key reason for the positive changes in VO_{2peak} observed is most likely the substantial daily intervention dose of physical activity. This notion is supported by a recent multi-year large-scale school-based physical activity intervention (Sollerhed and Ejlertsson, 2007). The I-school children in the Sollerhed and Ejlertsson study (2007) also carried out daily physical activity, revealing a significant effect on both the six-minute running test and the MSSRT for the children from the I-school compared to the children from the C-school. In contrast, two other multi-year school-based interventions, where the children carried out less extra weekly physical activity than the children in the Sogndal school-intervention study *and* the Sollerhed and Ejlertsson (2007) study, demonstrated that the increased physical activity in their interventions was not sufficient to affect VO_{2peak} (Andersen and Froberg, 2006; Graf et al., 2008).

A potential explanation for the significantly higher ΔVO_{2peak} in the I-school children could be a lower Δ body mass compared with the C-school children. This was not the case, as there were no differences in Δ body mass between the I-school children and the C-school children. The C-school children showed a significant decrease in running performance on the treadmill. At the same time, they did not improve their VO_{2peak} . On the other hand, the I-school children's increase in VO_{2peak} was accompanied by a significant improvement in running performance on the treadmill. Most of this improvement is therefore most likely a function of cardiovascular adaptation.

When analysing the effect of physical activity on CRF, one should consider that the distribution might be uneven. Therefore, examining changes in subgroups is necessary, and subjects were divided into quartiles based on their baseline VO_{2peak} values. The least fit children from the I-school increased their ΔVO_{2peak} significantly more than the children in the upper quartile of VO_{2peak} , whereas there was no such finding in the C-school children. Furthermore, the least fit children in the I-school increased their ΔVO_{2peak} significantly more than all quartiles of the C-school children, while there was no difference in ΔVO_{2peak} between the fittest children from the I-school and all quartiles of the C-school children. These results suggest that those with low initial VO_{2peak} had the best effect from the intervention. To further investigate subgroup differences in ΔVO_{2peak} -values, both the I-school and C-school children were divided into two groups, using a median split based on a clustered metabolic risk score at baseline (Tables 6a and 6b). These results also suggested that those with the least favorable starting point experienced the most beneficial effect of the intervention.

4.2 Intervention effect on CVD risk factors

4.2.1 Blood pressure

The I-school children had a significantly greater beneficial development in both SBP and DBP than did the C-school children. A major reason for our positive findings could be that the intervention was carried out on a daily basis over two whole school years, accumulating into a relatively sizeable volume of MVPA. In both hypertensive and normotensive adults, studies have shown that aerobic exercise reduces BP (Whelton et al., 2002; Fagard, 2005). The same strong relationship is not usually shown in children. In a meta-analysis of RCTs in children, Kelley et al. (2003) concluded that short-term exercise does not appear to reduce SBP or DBP. However, the authors emphasized the plausibility of the contention that exercise over a longer time period would yield benefits to resting BP to both hypertensive and normotensive children not observed in shorter-term studies. Of the 12 studies included in the meta-analysis, Hansen et al.'s (1991) school-based intervention had the longest intervention period (32 weeks). Hansen et al. (1991) found no significant differences after three months between the PA group and the control group. However, the PA group showed a significantly greater reduction in SBP and DBP than the control group after eight months. According to Hansen et al. (1991), their findings indicate that the effect of PA occurs rather slowly over a

prolonged period. The present study has also clearly demonstrated that it is possible to significantly lower BP in children in a school-based physical activity intervention. Cross-sectional data from the Avon Longitudinal Study of Parents and Children study by Leary et al. (2008), showed an association between higher levels of physical activity and lower levels of BP after adjustment for a number of potentially confounding factors in a large, contemporary population of 11- to 12-year-olds. Leary et al. (2008) measured physical activity objectively using accelerometers and compared the effect of the volume of physical activity versus the intensity of physical activity on BP. They concluded that it may be the volume rather than the intensity of the activity that is more important when it comes to lowering the BP in children.

The reduction of BP after exercise/physical activity is most likely due to multiple factors, including neurohumoral, vascular and structural adaptations. McMurray et al. (2002) highlighted four plausible physiological mechanisms for the beneficial BP development in children caused by increased exercise/physical activity. Firstly, increased exercise/physical activity could lower body fat, which in turn can result in a lower BP (Epstein et al., 1985). In fact, the main cause for the increased number of children observed with a high value of BP seems to be the epidemic of overweight and obesity in children (Din-Dzietham et al., 2007; Thompson et al., 2007). Therefore, a highly plausible explanation for the significantly reduced SBP in the I-school children in the present study could be a lower Δ body mass compared with the C-school children. However, this was not the case. Also, height could be a factor in changed BP, but again, there were no differences in Δ height between the I-school children and the C-school children. Secondly, increased exercise/physical activity could affect insulin sensitivity in a favorable way, which could subsequently reduce skeletal muscle vascular resistance (Lind et al., 1993). As no significant difference between the Δ HOMA score of the I-school children's and C-school children's was observed, this is not a probable explanatory variable in the present group of children. Thirdly, a lower activity in the sympathetic nervous system might reduce total peripheral resistance, which could, in turn, lower BP (Winder et al., 1979). Fourthly, it has been shown that exercise/physical activity possibly lowers plasma rennin and aldosterone, which would influence BP (Greenleaf et al., 1981).

As for VO_{2peak} , sub-group analyses were performed using a median split of a clustered metabolic risk at baseline (Table 6a and 6b). Those I-school children in the least beneficial

half of the clustered metabolic risk at baseline, who initially had a relatively high SBP (113.1 (6.3) mm Hg), showed a significant reduction in Δ SBP. This was not observed in either the I-school children in the most beneficial half of the clustered metabolic risk at baseline, or either of the two groups in the C-school. The results suggested that those children in the I-school with the highest initial BP experienced the most positive effect of the physical activity intervention.

4.2.2. Blood lipids and lipoproteins

The present study showed a beneficial effect on lipid and lipoprotein concentrations in children. There are few available studies of physical activity interventions on changes in children's lipid and lipoprotein concentration (Dobbins et al., 2009). In fact, Dobbing et al., (2009) in their recent Cochrane Review, considering only RCT and controlled clinical trials in children, included only seven studies (Alexandrov et al., 1988; Walter et al., 1988; Bush et al., 1989; Lionis et al., 1991; Luepker et al., 1996; Manios et al., 1999; Bayne-Smith et al., 2004). Dobbins et al.'s (2009) overall conclusion was that some evidence supports the hypothesis that school-based interventions are effective in reducing lipids and lipoprotein levels in children and adolescents. However, since all seven studies also included a dietary component to the interventions; it is unclear whether their findings resulted from increased physical activity, a change in diet, or both.

Furthermore, well-controlled studies investigating the effect of exercise on lipid and lipoprotein concentrations in children are scarce (Tolfrey et al., 2000; Stoedefalke, 2007). Both these review papers concluded that methodological problems present in the majority of exercise training studies limit the ability to make a conclusive, evidence-based statement on the effect of exercise training on blood lipid levels in normolipidemic children. The several serious methodological design weaknesses include low sample size, inadequate exercise training volume and a lack of control individuals. Still, some exercise studies support the present study's conclusion that a physical activity intervention can positively affect lipid and lipoprotein concentrations in children. Tolfrey et al. (1998) carried out a well-controlled and structured 12-weeks intervention study. The exercise group significantly increased their HDL-C and decreased both their LDL-C levels and TC:HDL ratio compared to the control group. The authors underlined that alterations in overall exercise volume are paramount to the probable success in altering the lipoprotein profile.

Subgroups analyses in the present study showed that the I-school children with the least beneficial clustered risk score at baseline showed the greatest beneficial change in lipid and lipoprotein concentrations. Again, the results strongly suggest that the intervention succeeded in reaching those children with the greatest intervention potential.

4.2.3 WC and BMI

There was no difference between the I-school children and the C-school children in either ΔWC or ΔBMI . This finding is in agreement with the findings of most other studies (Wareham et al., 2005; Doak et al., 2006; Kamath et al., 2008; Brown and Summerbell, 2009; Harris et al., 2009). Changes in WC are seldom reported in large scale physical activity interventions. One exception is a six-month school-based intervention study from Chile where the 3rd to 8th grades (n=4086) performed 90 minutes of extra physical activity per week. This intervention also included a nutrition element (Kain et al., 2004). The authors reported significant improvement in both BMI and WC for boys, but not for girls.

The great majority of obesity treatment studies in children show a lack of longstanding effectiveness, primary prevention is therefore absolutely essential (Summerbell et al., 2003). Hence, it is unfortunate that school-based physical activity interventions show only small or no beneficial effects in BMI in children. However, most physical activity interventions included in the above-mentioned reviews are limited with regard to one or more of the following factors: length and intensity of the intervention and evaluation of the quality of the intervention. A recent systematic review and meta-analysis that included RCT and controlled clinical trials determined the effect of school-based physical activity interventions on children's BMI (Harris et al 2009). The review, which included 18 studies with an intervention duration range from six months to three years and comprised 18,141 children, reported that school-based physical activity interventions did not change children's BMI. This conclusion was also sustained also when only the RCTs were included. The authors, however, underlined that school-based physical activity interventions had other beneficial health effects, such as improved BP and CRF. Harris et al (2009) suggest three possible explanations for the lack of association between BMI and PA in school-based interventions. In the following these three points made by Harris et al (2009) will be discussed.

Firstly, Harris suggests that the physical activity “dose” achieved in these studies was insufficient to alter BMI. This is not unreasonable considering that none of the 18 studies included in Harris et al (2009) accumulated more than 200 minutes of physical activity in school per intervention week. Furthermore, only four studies had more than 150 minutes of physical activity in school per week, and two of these studies had intervention durations of fewer than 10 months. Therefore, none of the studies included in Harris et al.’s (2009) meta-analysis was as extensive as the present study concerning *both* the duration of the intervention *and* the weekly amount of physical activity. However, the present study was equally unable to observe a difference in either ΔWC or ΔBMI between the I-school children and the C-school children. Possible explanations for this could be that the amount of the accumulative time spent on physical activity during school hours was not sufficient to alter BMI, or that the I-school children compensated by increasing sedentary activity during out-of-school time. Another reason for the lack of association between physical activity and BMI observed in the studies included in Harris et al (2009) could be uncertainty due to the fact that only five of the 18 studies measured physical activity objectively, and those which did only applied these objective measures (accelerometers) for a short segment of the study protocol. The lack of objective physical activity registration combined with the inadequate assessment of the adherence of the intervention to both the individual and the school level is a challenge for this type of study, and hampers conclusions on the effect of physical activity interventions.

Secondly, Harris et al (2009) postulate that dietary modifications alone or in combination with physical activity possibly have greater influence on body mass than does physical activity. As the present study did not examine variables of nutrition, I am not able to answer this question. However, one could speculate that the lack of observed differences in ΔBMI could be caused by the I-school children increasing their energy intake to compensate for the increased energy expenditure caused by physical activity, thereby balancing out the BMI. This notion is supported by Sollerhed and Ejlertsson (2007) where both the I-school and the C-school had the same mean change in BMI ratio, which was calculated as the ratio between the individual BMI and the cut-off points for overweight according to Cole et al (2000). Sollerhed and Ejlertsson (2007) speculate that the intervention dose of physical activity was probably not enough to compensate for increased energy intake and/or lack of natural physical activity, and that the weekly dose of physical activity must be higher than 40 minutes per day. Brown and Summerbell (2009) compared studies that were either: a) only physical activity intervention,

b) only nutrition intervention or c) a combined physical activity and nutrition intervention. Brown and Summerbell (2009) concluded that there is insufficient evidence to assess the effectiveness of dietary interventions or diet vs. physical activity interventions and that longer and more intense interventions are needed.

Thirdly, it is possible that there may have been a small effect (change in BMI or WC) in a subset of children, but the effect was attenuated in the assessment of the entire population due to the fact that the majority of subjects in the present study and those included in the aforementioned review papers were healthy growing children with “normal” BMI, and thus had a limited potential for change. Analyses of subsets of children, e.g. quartiles or percentiles, might reach different conclusions. Also, interventions that focus solely on e.g. overweight or obese children might result in other conclusions. For instance, Marcus et al (2009) showed no difference between intervention and control groups in Δ BMI. However, the proportion of children who were initially overweight or obese and who reached normal body mass was larger in the I-school. The same pattern was observed in the present study, as the percent of overweight/obese children was reduced from 20% to 16% in the I-school children, whereas the number of overweight/obese C-school children increased from 13% to 17%. This suggests that important information is available beyond the mean data.

Finally, it may be unreasonable to expect that a school-based physical activity intervention can, in isolation, change BMI when the majority of children have a normal BMI at baseline. It may be more sensible to target children with a high BMI for body mass alteration, while children with a normal BMI could be targeted solely for physical activity. A physically active lifestyle in a long-term perspective might ultimately turn out to be a solid approach to regulate BMI regardless of initial BMI status.

4.2.4 HOMA-IR

There was no significant difference when comparing Δ HOMA-IR between the I-school and C-school children. Both the I-school and C-school children significantly increased their HOMA-IR scores from baseline to post-intervention. A likely explanation for this increase is that a transient increase in insulin resistance occurs in puberty (Bloch and Clemons, 1987; Moran et al., 1999; Goran and Gowan, 2001). The physiological mechanism behind changes in pubertal insulin sensitivity has not been clearly determined (Goran and Gowen 2001), but it

is associated with a compensatory increase in insulin secretion (Capri et al., 1989). Increased insulin secretion might be to provide a mechanism for increasing the anabolic effects of insulin and growth hormone during a period of rapid somatic growth (Caprio and Tamborlane 1994; Caprio et al., 1994).

Few interventions have investigated the relationship between physical activity and insulin resistance in young people. Those few available studies are not comparable to the present study because they examine subjects who are either overweight/obese, adolescents or include an intervention combination of physical activity and nutrition (Ritenbaugh et al., 2003; Reinehr et al., 2004; Nassis et al., 2005; Balagopal et al., 2005; Kim et al., 2007). Still, it is noteworthy that most of these studies report a beneficial reduction in insulin sensitivity combined with significant weight loss in the subjects. Obesity seems to be the single most important cause of insulin resistance in young people (Caprio, 2002), and it has been suggested that adiposity accounts for 55% of the variance in insulin sensitivity in children (Arslanian et al., 1996). Baseline analyses in the present study support this conclusion, as a significant correlation between HOMA and body mass ($r=0.45$), BMI ($r=0.45$) and WC ($r=0.48$) was shown. Furthermore, those 58 children (both I-school and C-school) that lowered their HOMA during the intervention period also had a significantly lower Δ body mass, Δ BMI, and Δ WC compared to the 160 children who increased their HOMA.

McMurray et al. (2000) is one of the few intervention studies investigating the effect of exercise on insulin levels in children. Although their intervention period was relatively short, they concluded that: a) the exercise program must improve VO_{2peak} to obtain a positive change in insulin level, and b) the greatest change occurred in those children with the highest initial resting insulin levels. In McMurray et al (2000), those children ($n=60$) whose VO_{2peak} improved ($\geq 3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) had a significantly greater reduction in insulin than the children ($n=204$) whose VO_{2peak} did not increase. In the present study this was not the case, as there was no difference in Δ HOMA between the 84 children in the I-school whose VO_{2peak} improved ($\geq 3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and the 43 children in I-school who had a decrease in VO_{2peak} . The same conclusion was reached for the C-school children. However, when singling out those I-school children who both increased their VO_{2peak} ($\geq 3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and were in the least beneficial quartile of HOMA at baseline ($n=16$), and comparing them to the other I-school children ($n=92$), a significant difference in Δ HOMA occurred. This suggests that the

present intervention had a positive impact on Δ HOMA in a subset of children, and again underlines the need for analyzing the data beyond the mean.

4.3 Cardiorespiratory fitness and CVD risk factors (cross-sectional data)

Clustering of CVD risk factors is the coexistence of elevated levels in several risk factors in the same subject, and a composite risk factor score is now viewed as a good method for assessing children's cardiovascular health (Steele et al., 2008).

There are a few studies that have investigated the association between CRF and cardiovascular risk factor clustering in children (Brage et al., 2004; Anderssen et al., 2007; Eisenmann et al., 2007 (1); Rizzo et al., 2007; Ruiz et al., 2007; Kriemler et al., 2008; Steene-Johannessen et al., 2009), and there seems to be a clear trend that low CRF is strongly associated with clustered metabolic risk. The present study supports this conclusion, as both boys and girls with three, four or five risk factors had a significantly lower VO_{2peak} than the children with two or fewer risk factors. Moreover, the children in the least fit quartile had significantly poorer CVD risk factor values than all children in the other quartiles. The association between CRF and the clustered risk score was weakened, but still significant, when WC was excluded from the clustered risk score. It is difficult to determine whether adiposity confounds, mediates, or modifies the association between CRF and metabolic health (Steele et al., 2008). Furthermore, children with clustered risk were significantly heavier than children without clustered risk. CRF in the present study, and in most other studies addressing this problem, is expressed in relation to whole body mass ($ml \cdot kg^{-1} \cdot min^{-1}$). As CRF is strongly related to body mass, I also performed an analysis where CRF was scaled to body mass^{0.67}. Results showed a weaker but still significant relationship for both sexes. This conclusion is similar to that drawn by Ekelund et al. (2007) analyzing data from the EYHS. Ekelund et al. (2007) removed adiposity from the outcome by normalizing CRF by fat-free mass, but still found a significant though tenuous association between CRF and CVD risk factors. Andersen et al. (2008), also analyzing data from the EYHS, found that removing the fatness parameter from the Z-score attenuated the association, and further adjustment for fatness weakened it, but the association between CRF and clustered risk still remained significant. These findings indicate that confounding is unlikely to explain all of the association, or alternatively that some of the effects of CRF on clustered metabolic risk are mediated by adiposity. However, even if fatness may mediate part of the association between clustered risk and CRF, the lower fatness in the more fit individuals may still be caused by lack of exercise/physical activity,

and it may be very difficult to train a fat subject without a change in abdominal fat mass. The findings of the present study, therefore, support the hypothesis that CRF is independently associated with clustered CVD risk in nine-year-old children. If future studies continue to confirm this trend, it might be warranted that CRF should be included as one of the variables in the clustered metabolic risk score for children.

Two recent studies (Eisenmann et al., 2007 (2); Andersen et al., 2008) showed that the highest levels of CVD risk factors were found in children who were both overweight and had a low CRF. DuBose et al. (2007) reported similar results. Based on these findings, different fit/fat groups were compared to CVD risk factors by sex in the present study. For girls, *the unfit & overweight/obese group* had significantly poorer values than *the fit & normal body mass group* in all five CVD risk factors. The same strong pattern was not shown in boys, as only two risk factors, WC and SBP, were significantly higher among *the unfit & overweight/obese*. A possible explanation could be the small sample size for boys, as only 9 subjects were classified as *unfit & overweight/obese*, compared to the 20 subjects for the girls. However, when analyzing the CVD risk factors as a clustered risk, I found that for both sexes *the unfit & overweight/obese group* had a significantly higher CVD risk factor clustering Z-score than *the fit and normal weight group*. Our findings add to the body of evidence that the combination of being unfit (low CRF) and fat (overweight/obese) in children could be regarded as unhealthy and that this condition could potentially pose a health hazard in the long term for these individuals.

4.4 Study strengths

The study's main strengths were the length (19 months) and the daily volume (60 minutes) of the intervention, *direct* measurement of VO_{2peak} and the accuracy of the CVD risk factor measurements. Regarding the measurement of VO_{2peak} , the high mean HR_{peak} (*baseline: 204±7, post-intervention: 203±7*) suggests that a reliable VO_{2peak} was obtained. Furthermore, both the baseline and the post-intervention measurements for each variable were carried out by the same experienced test leaders, removing any inter-rater reliability bias.

Another strength in this study was the mandatory nature of the intervention, which guarantees for adherence since all eligible children took part in the intervention, including those who might have dropped out if given a free choice. There is reason to believe that such children

would benefit the most from an intervention program. Therefore, high participation and completion rates made our sample representative of the nine-year-olds in these two rural communities where testing was performed. Furthermore, trained PE teachers were responsible for the planning, implementation and evaluation of the physical activity. Additionally, the intervention was thoroughly monitored by the teachers, and every physical activity lesson was saved into a physical activity database. This database, which is easily accessible to all teachers at the I-school, might lower the threshold for all teachers to be involved in physical activity/PE lessons after the intervention period is completed. Also, since this was a low cost intervention approach the I-school was not supported with extra resources which would have increased costs. Such support could easily have put an end to the physical activity focus after the intervention period. Instead, the school found a cost-effective way to carry out the intervention. This might be one of the reasons the I-school continued with daily physical activity lessons after the intervention period was completed (see epilogue) and this approach might increase the possibility that other schools copy the physical activity program from the I-school.

4.5 Study limitations

Regarding limitations, one cannot exclude the possibility that our observations could partly be explained by several confounding factors that were not controlled for. These factors will now be discussed in a point-by-point fashion.

4.5.1 Design

A controlled intervention was performed, but the study was not a RCT. This is an obvious weakness, and I recognize that a RCT is the most appropriate study design for a school intervention study. I also recognize that the next most significant threat to validity after not using an RCT design is the allocation of the two schools to either the intervention or control arm, and that the study would have been strengthened if the pair of participating schools had been selected prospectively and if it had then been determined which one would receive the intervention. However, it was a challenging task to get one school to commit to the two-year 60-minute daily physical activity intervention. Furthermore, the choice of the I-school was based on its proximity to our institution (Sogn og Fjordane University College, located in Sogndal, Norway). This had practical implications with respect to monitoring the adherence to the intervention protocol and interaction with the staff and administrators at the school.

However, the choice of the I-school and the C-school was made prior to any collection of data and therefore removed some of the selection bias from the study.

A non-RCT design introduces a potential regression towards the mean (RTM) effect. To correct this statistical challenge, I first used a formula suggested by Beach and Baron (1998). The analysis showed that the potential RTM effect was only minor in those four variables that showed a significant difference in Δ between the children in the I-school and C-school (SBP: 0.05 mm Hg, TC:HDL ratio: 0.04, TG: 0.01 mmol·l⁻¹ and VO_{2peak}: 0.3 ml·kg⁻¹·min⁻¹). Secondly, I also included the respective baseline value for each of the CVD risk factors as a covariate in the linear multiple regression analysis. Still, the same conclusions were upheld regarding significant differences between the children in the I-school and C-school, suggesting no RTM effect.

4.5.2 Objective measurement of the children's physical activity outside of school

Unfortunately it was not practically possible at the time of the intervention to assess physical activity objectively during the school day or physical activity levels outside of school, including the summer break. This is an obvious weakness, and I recognize that. However, the significant increase for the I-school children compared to the C-school children in VO_{2peak} strongly suggests that the I-school children really increased their physical activity levels. Furthermore, I believe that I had reasonable control over the intervention. I was in regular dialogue with the I-school regarding the content of the daily physical activity lessons, including the duration, frequency and the intensity of the lessons. Theoretically, the intervention could have affected the physical activity levels of the I-school children outside of school. However, I believe that it would still be an effect of the intervention if this had occurred, and the beneficial changes observed in the I-school children would still be attributed to the intervention.

4.5.3 Maturation status

I did not assess puberty status, and I recognize that is a flaw as children of the same chronological age can vary considerably in puberty status (Malina et al., 2004). The reason for not assessing puberty status was the potential concern to cause discomfort to the children. However, there were no significant differences between the children from the I-school and C-school in Δ body mass or Δ height. Maturation development is unlikely to differ in two

municipalities in such close proximity, and maturation should therefore not confound the analysis of change in CRF or change in CVD risk factors.

4.5.4 Nutrition status

It is indeed useful to document the nutritional intake in an intervention such as this, as the nutrition element could affect the CVD risk factors. Therefore, the lack of nutrition information is a limitation of this study.

4.5.5 Limitations regarding the generalization of the results

The study sample includes only rural Norwegian children, raising questions about the generalizability of the results.

4.5.6 Limitations to the clustering of CVD risk factors analyses (cluster Z-score approach)

There are some limitations to the Z-score approach. Firstly, it is based upon the assumption that each selected variable is equally important in defining CVD risk. Secondly, the risk is specific to this sample only. Even though a child has been defined as at risk, this does not necessarily mean that the child has high levels of CVD risk factors *per se*. The child could simply be located in the unfavorable quartile because of genetics or normal biological variations. Still, even in this group of apparently healthy rural children, clustering is not a desirable condition.

4.5.7 Limitations to cross-sectional analysis pertaining to the baseline data

All analyses in paper IV are performed based on cross-sectional data. The cross-sectional design does not allow conclusions based on causal inferences.

4.6 Obstacles to the intervention

A number of obstacles were encountered during the implementation of the physical activity intervention. The four major obstacles were; 1) getting all relevant stakeholders to accept the intervention, 2) time constraints, 3) space constraints and (4) ensuring that staff with the relevant PE training were included in the intervention on a daily basis.

(1) Several measures were taken to ensure that all relevant stakeholders in the I-school accepted the intervention. The teachers and administrative personnel were introduced to the positive outcomes of equivalent programs both in their native country and abroad by traveling to the relevant schools. All teachers and the administration went to visit Rosenlund School in Copenhagen, a school with long experience of physical activity. Additionally, to reinforce their awareness and knowledge regarding the merits of the physical activity program, I instituted several educational sessions which were conducted by experts. In addition, these educational sessions were aimed at motivating and inspiring the teachers. The parents at both the I-school and the C-school also received the same type of lectures. Parents were informed that they could contact the school and the *P.I.* if they had any inquiries regarding the intervention. A major reason for the school and parents accepting the intervention was the documentation showing a strong association between academic performance and physical activity in school (Sibley and Etnier, 2003).

(2) The lack of a large physical activity-specific indoor area at most education centers limits the effective implementation size at any one time. There was not a large physical activity-specific indoor area at the I-school, and I therefore utilized an outdoor physical activity regime which necessitated compliance from the pupils and their parents to ensure that correct outdoor apparel was available, particularly during colder, adverse weather conditions.

(3) Time constraints were addressed by reducing all other subjects by an equivalent margin. In addition, school starting times were brought forward by five minutes each day which resulted in a cumulative gain of 25 minutes a week.

(4) It is crucial that the teachers who plan, organize and carry out the daily physical activity are expert PE teachers. In the present intervention, two teachers with relevant PE training did most of the planning of the physical activity lessons, and one of them was always present in the daily physical activity. The classroom teachers involved, having no relevant PE education, were given specific tasks and contributed in an important but thus not in a crucial way.

In conclusion, this study has shown that these obstacles can be overcome, and I believe that this type of physical activity intervention is expandable to larger schools and larger group sizes. However, it is important to underline that this project was carried out in an elementary

school (students from 1st to 7th grade). The literature suggests that it is easier to implement a physical activity intervention in this age-group than with older students (8th to 10th grade). This is due mainly to the holistic approach and flexibility in the primary curriculum.

4.7 Perspectives and implications

The Sogndal school-intervention study has shown that a two-year school-based teacher-led 60-minute daily physical activity intervention can beneficially modify children's CVD risk profile if the intervention is of sufficient length and includes substantial daily MVPA, and if the physical activity is planned, organized and led by expert PE teachers. Therefore, this intervention has shown that physical activity can positively modify CVD risk factors at an early age, and thus might be an important tool in the primary prevention of CVD. The central message regarding children's CVD risk factors is that all risk factors are important (McMahan et al., 2008) and that the presence of one or multiple risk factors should be a cause for concern (Steele et al., 2008). An elevated CVD risk factor status in children may provide an early warning for later metabolic health risk, and this is especially important in children with low physical activity and/or low CRF levels, as there appears to be an independent association between both physical activity and CRF *and* metabolic health in children (Ekelund et al., 2007). Childhood, a time when these CVD processes are most likely highly reversible, might be an advantageous time to undertake preventative action.

The school setting might be the most viable arena in which to increase all children's physical activity levels. It is of the utmost importance that the children experience the MVPA in school as varied and enjoyable, as their doing so could contribute positively to increasing their interest and skills in physical activity and thereby stimulate their motivation to participate in such activity. Many skills used to maintain physical activity in adulthood are learned while engaging in physical activity during childhood. This may be important because it could be anticipated that it becomes increasingly difficult to change to a more physically active lifestyle with increased age. There are minimal costs and side effects associated with school-based physical activity interventions, and if the beneficial changes observed in the present study could translate into benefits of a similar magnitude in adults, this could be of major public health significance. Furthermore, if the positive findings observed in the present study period (19 months) were to continue during adolescence and young adulthood, this would translate into even greater long-term CVD health benefits which would be clinically

significant. Finally, the average initial CRF level was quite high and greater improvements were found in the less fit children, which may indicate that the intervention could be even more effective in a less fit population. Taking all these factors together, daily physical activity carried out by qualified teachers should be given due consideration in the design of school policies.

5. CONCLUSIONS

This two-year school-based teacher-led 60-minute daily physical activity intervention demonstrated that the I-school children improved their CRF significantly more than the C-school children. The intervention, primarily carried out at moderate intensity, had the biggest impact on those children with low initial CRF levels. Furthermore, this study showed that the I-school children had a significantly greater beneficial development in SBP, DBP, TC:HDL ratio and TG than the C-school children. Those children in the I-school with the least favorable starting point experienced the most beneficial effect of the intervention. No significant differences in changes were observed in WC, BMI and HOMA-IR between the two groups. Our cross-sectional data suggested that low CRF, *and* low CRF and fatness combined were highly associated with clustered CVD risk.

6. EPILOGUE

The daily physical activity intervention program was established as part of the school curriculum for all participating children from the I-school, thus the physical activity was mandatory. However, an important question is: What will happen to the physical activity in the I-school *after* the physical activity-project is completed?

The I-school, Trudvang School in Sogndal, Norway, based on their experience in *the Sogndal school-intervention study*, has decided to continue its commitment to the physical activity program, and expand the program to all students. The program consists of 30 minutes of daily teacher-led *physical activity*. Trudvang School considers the 30 minutes of daily *physical activity* as a subject with the same status and financial resources as the traditional subjects. Additionally, the children are given the possibility of a minimum of 30 minutes of daily free play in recess. At Trudvang School, there is no conflict between PE and *physical activity*. The former is a subject with defined goals which teachers and pupils work together to accomplish, while the latter has a public health perspective. For both PE and *physical activity*, trained PE teachers are responsible for the planning and organizing of lessons, and they also lead the *physical activity* lessons together with classroom teachers when appropriate. In this way, the students receive *physical activity* lessons of high quality.

According to Trudvang School, all obstacles have now been overcome, and daily *physical activity* is a natural part of the school day. Finally, questions remain as to whether the favorable changes observed in the I-school children are temporary or will lead to beneficial long-term effects. In order to answer this question, we plan to conduct follow-up studies.

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PAPER I-IV

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Effects of a 2-year school-based daily physical activity intervention on cardiorespiratory fitness: the Sogndal school-intervention study

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The aim of this study was to describe changes in children's cardiorespiratory fitness (CRF) following a school-based physical activity (PA) intervention. In total, 259 children (age 9.3 ± 0.3 years) were invited to participate, of whom 256 participated. The children from the intervention school (63 boys, 62 girls) carried out 60-min PA over 2 school years. The children from the control school (62 boys, 69 girls) had the regular curriculum-defined amount of physical education in school, i.e. 45 min twice weekly. One hundred and eighty-eight children (73.4%) successfully completed both the baseline and the post-intervention peak oxygen uptake (VO_{2peak}) test. VO_{2peak} was measured directly

during a continuous progressive treadmill protocol where the children ran until exhaustion. The children from the intervention school increased their mean VO_{2peak} (95% confidence interval) 3.6 (2.5–4.6) mL/kg/min more than the children from the control school. This VO_{2peak} value was adjusted for both sex and baseline VO_{2peak} . Boys and girls demonstrated similar VO_{2peak} responses. The intervention, primarily carried out at a moderate intensity, had the biggest impact in children with low initial CRF levels. In conclusion, a 2-year school-based 60-min daily PA intervention significantly improved CRF in children.

Conflicting results exist concerning the effect of increased physical activity (PA) levels on cardiorespiratory fitness (CRF) in children. On the one hand, it has been suggested that an increase in daily PA cannot be expected to substantially alter children's peak oxygen uptake (VO_{2peak}) (Rowland, 2005). This view is mainly explained by the fact that children generally have a relatively high initial level of both PA and CRF, and that their PA pattern is typically sporadic and non-continuous, all of which may make it difficult to alter their CRF levels. On the other hand, Yoshizawa et al. (1997) showed that prepubertal girls performing a 915 m run 6 days a week for 18 months had a significantly greater increase in VO_{2peak} than the control group. Yet, this difference reached statistical significance only after 12 months. Hansen et al. (1991) performed a school intervention where 67 children received three extra physical education (PE) lessons weekly for an 8-month period. A CRF test after 3 months showed no difference between the intervention group and the control group. However, the intervention group showed a significantly greater increase in VO_{2peak} compared with the control group after 8 months. Although

these two studies have methodological weaknesses, they raise the intriguing possibility that, to affect children's CRF levels with PA, a lengthy intervention period is needed, and the PA needs to be frequent. Furthermore, a recent cross-sectional study (Dencker et al., 2006) showed a positive relationship between *directly* measured CRF and PA assessed *objectively* in children by accelerometers, suggesting that previous studies, mostly using a subjective assessment of PA and indirect or field-based CRF tests, might have failed to find a link because of methodological weaknesses.

Schools provide an advantageous setting in which to enhance levels of PA, and thereby possibly increase CRF. A large number of school-based PA interventions are undertaken at present (van Sluijs et al., 2008; Brown & Summerbell, 2009). However, few studies focus on CRF as the main outcome and most assess CRF indirectly. Given the methodological limitations of previous studies of PA and CRF, the present study's aim was to examine the effects of a school-based intervention, involving 60 min of daily PA over 2 years on VO_{2peak} measured directly among 9-year-old children in two Norwegian rural towns.

Materials and methods

Population

A total of 259 children, all corresponding to fourth-grade schoolchildren enrolled in 2004 (born 1995) and 2005 (born 1996) in two elementary schools from two rural municipalities in Western Norway, were invited to participate. The municipalities, Sogndal (total population 6836) (according to the Statistics Norway on January 1, 2006) and Førde (11 327), are located 105 km apart. All children (boys $n = 63$ and girls $n = 62$) in the intervention school (I-school) agreed to participate in the study. In total, 55 children [I-school: 23, the control school (C-school): 32] were excluded from the study, mainly because of chronic diseases, injuries occurring outside school time during the intervention period, injury/sickness on test day, an unacceptable CRF test or equipment failure at either baseline or post-intervention test. Of the remaining 204 children, 188 (I-school, $n = 102$, C-school, $n = 86$) successfully completed both the baseline and post-intervention $\text{VO}_{2\text{peak}}$ test. Those 16 children not accounted for (all from the C-school) were unable or unwilling to travel to the test venue.

Body mass and height were collected from 256 of the 259 children at baseline, and there were no significant differences between those 188 that performed both an acceptable baseline and post-intervention test, and the 68 other children at baseline in body mass, height or body mass index (BMI). Also, of those children not completing successfully both the baseline and post-intervention $\text{VO}_{2\text{peak}}$ test, 57 successfully completed either a baseline ($n = 39$) or a post-intervention ($n = 18$) $\text{VO}_{2\text{peak}}$ test. No significant differences existed in baseline $\text{VO}_{2\text{peak}}$ between those 39 excluded at baseline and the 188 included children, and no significant differences existed in the post-intervention $\text{VO}_{2\text{peak}}$ between those 18 excluded at post-intervention and the 188 included children.

The administration at the I-school systematically recorded the children's absence from school, and any child who had a substantial absence was excluded. This only applied to one child. On average, the mean absence from school was 11.9 [standard deviation (SD): 8.6] days over 2 years, corresponding to 3.7% absence yearly.

Ethics

Procedures and methods used in the present study conform to the ethical guidelines defined by the World Medical Association's Declaration of Helsinki and its subsequent revisions. The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Services. After information meetings and written explanation of the study, a written consent was obtained from the children's parents/guardians before all testing. Participants were free to withdraw from all measurements at any time, without explanation.

Intervention

The intervention consisted of a 60-min daily PA lesson and was implemented over two school years for each of the two age groups in the I-school. Children from the C-school had the curriculum-defined amount of PE in school, i.e. 45 min twice weekly including time for teachers to organize activities, and for the children to change clothes and shower.

The 60-min daily PA did not include time for changing clothes before or after PA, shower after PA or active play in recess or before or after school. The teachers were always present and were instructed to be as efficient as possible regarding the time used for PA. However, it proved impossible

to avoid spending approximately 5 of the 60 min on teachers' explanations, organizing the children and various other low-intensity activities. For the remaining 55 min, the teachers were told to carry out moderate to vigorous-intensity PA, of which 15 min was planned to be at vigorous intensity, meaning that the children should be sweating and out of breath. The vigorous PA component was tried and accomplished by selecting a variety of activities such as running, relay racing, obstacle courses and various forms of active play of high intensity. Nevertheless, most activities were non-competitive. *Ballgames* (accounting for 19.4% of the PA time over the 2 intervention years) were the most frequent activity, with football and basketball as the two most dominant. *Brisk walking* (13.1%) was usually carried out every school day, and often at a relatively fast pace. *Active play* (12.1%) included a variety of fun activities and games. *Skiing* (10.7%) was mainly cross country, and the children spent 11 full school days skiing and thereby compensating for the 5 min lost every day to explanations, organizing, etc., in the other activities. *Gymnastics* (9.6%) included a variety of gymnastics exercises. *Relay race* (8.5%) also included completing obstacle courses. The term *others* (10.7%) describes miscellaneous activities, such as orienteering, cycling, jumping rope and ice skating.

PA lessons were planned by two expert PE teachers at the I-school in collaboration with the first author, and carried out by teachers at the I-school. Each lesson was planned so the activities would be varied and be enjoyable, exciting and pleasurable, and stimulate to the children's "feeling of mastery." PA lessons were organized in a variety of ways. Most often, all children in one grade (approximately 60 children) had PA together, where they were divided into four groups of 15 children that rotated between four activity stations every 15 min. Regular visits from Geir K. Resaland ensured that the intentions of the intervention were fulfilled.

Measurements

The procedures for body mass and height measurements and the methodology of $\text{VO}_{2\text{peak}}$ testing have been presented in detail elsewhere (Resaland et al., 2009a, b). Briefly, body mass and height were measured by the study nurse according to standardized procedures. $\text{VO}_{2\text{peak}}$ was directly measured with a MetaMax I analyzer (Cortex Biophysics GmbH, Leipzig, Germany) during a continuous progressive treadmill protocol. The analyzer was fully calibrated on each test day. Between each test, calibration of volume and a two-point gas calibration were performed, as well as a measurement of ambient air.

The reliability of the $\text{VO}_{2\text{peak}}$ tested directly in children is shown to be approximately 4%, which compared favorably with the reliability of adults' $\text{VO}_{2\text{max}}$ (Welsman et al., 2005). The MetaMax I system used in this study was validated against the Douglas Bag technique (Medbø et al., 2002). The validation showed a systematic overestimation by the MetaMax. This trend was confirmed in the later internal validation tests. Hence, the data presented are adjusted accordingly. This pattern of overestimation in the VO_2 measurements was confirmed in a recent study (Kolle et al., 2009).

The methodology differed slightly for the baseline and post-intervention $\text{VO}_{2\text{peak}}$ tests. In the baseline test, the extra workload per minute was either an increase in treadmill speed by 1 km/h or a 1.5% increase in inclination depending on how the subject was performing, until a maximum speed of 10 km/h was reached. Thereafter, the workload was increased through inclination, which was raised by 1.5% each minute until exhaustion. In the post-intervention test, there was a fixed protocol, whereby speed was increased every minute until a

maximum speed of 11 km/h was reached. After this point, the load was increased by elevating the treadmill's gradient by 1.0% every minute until exhaustion. The primary consideration for an acceptable test was that the subject demonstrates signs of intense effort and clear symptoms of fatigue. The objective criteria of respiratory exchange ratio (≥ 1.0) and peak heart rate (HR_{peak}) (≥ 200 beats/min) were also taken into consideration.

All $VO_{2\text{peak}}$ tests were performed at the Human Physiology Laboratory, Sogn og Fjordane University College, in Sogndal. The same two experienced test leaders carried out all baseline and post-intervention tests. One monitored safety and urged subjects on, trying to ensure that they gave a maximum effort. The second controlled measurements and treadmill speed and inclination. Baseline data were collected in the September–October period in both 2004 and 2005. Post-intervention data were collected in the May–June period in both 2006 and 2007.

Statistics

All statistical analyses were performed using SPSS software, version 16.0 (SPSS Inc., Chicago, Illinois, USA). Sample-size calculations for the main outcome, $VO_{2\text{peak}}$ (mL/kg/min), were performed before the study (SigmaStat 3.1 Systat Software GmbH, Erkrath, Germany). Variables were tested for normality before the analyses, and only those children ($n = 188$, 98 boys and 90 girls) with an acceptable $VO_{2\text{peak}}$ test both at baseline and post-intervention were included in the final analyses. A power calculation was performed after testing to ensure that the power still was sufficient (SigmaStat 3.1 Systat Software Inc.). The least detectable difference at the 5% significance level between the I-school ($n = 102$) and the C-school ($n = 86$) with a power of 0.90 and a SD of 5.0 was 2.4 mL/kg/min. Differences in baseline means between the I-school and the C-school were determined by an independent sample t -test. Differences-in- Δ between the I-school and the C-school were analyzed with a linear multiple regression that was adjusted for sex and baseline value. ANCOVA, with Tukey's *post hoc* test, was used to compare the $\Delta VO_{2\text{peak}}$ between quartiles in the I-school and in the C-school. Significance level was set at $P < 0.05$.

Results

The main finding is that the I-school children improved their $VO_{2\text{peak}}$ [mean, 95% confidence interval (CI)] 3.6 (2.5–4.6) mL/kg/min more than then the children from the C-school ($P < 0.001$). This finding is based on values that are adjusted for sex and $VO_{2\text{peak}}$ baseline. The unadjusted difference-in- $\Delta VO_{2\text{peak}}$ (mL/kg/min) was 3.9 (2.8–5.0) mL/kg/min ($P < 0.001$). Sub-group analyses between the I-school and the C-school by sex, adjusting for $VO_{2\text{peak}}$ baseline, showed a $VO_{2\text{peak}}$ difference-in- Δ of 3.8 (2.4–5.3) mL/kg/min for boys and 3.5 (2.0–5.1) mL/kg/min for girls (both $P < 0.001$). Expressed as a percentage, the difference-in- $\Delta VO_{2\text{peak}}$ was 8.0% higher in the I-school children than in the C-school children (8.8% vs 0.8%).

Table 1 shows baseline values (mean, SD), post-intervention values (mean, SD), changes from baseline to post-intervention value (Δ -value) (mean, SEM) and difference-in- Δ with 95% CI between I-school and C-school. No significant differences

Table 1. Baseline values, post-intervention values, Δ values both absolute and in percent, and difference-in- Δ values for children in the I-school and C-school

	I-school ($n = 102$)				C-school ($n = 86$)				Adjusted difference-in- Δ (95% CI)	P for adjusted difference-in- Δ
	Baseline (SD)	Post-intervention (SD)	Δ (SEM)	$\Delta\%$	Baseline (SD)	Post-intervention (SD)	Δ (SEM)	$\Delta\%$		
Age (years)	9.2 (0.3)	10.9 (0.3)	1.7 (0.01)	18.6	9.2 (0.3)	10.8 (0.3)	1.6 (0.01)	17.4	0.10 (0.07–0.12)	< 0.001
Body mass (kg)	32.9 (6.7)	39.3 (8.2)	6.4 (0.3)	19.5	32.1 (6.3)	37.9 (8.0)	5.8 (0.3)	18.1	0.4 (–0.3–1.1)	0.230
Height (cm)	137.8 (6.0)	146.8 (6.6)	9.1 (0.2)	6.6	136.6 (5.4)	145.2 (6.2)	8.6 (0.2)	6.3	0.4 (0.0–0.9)	0.069
BMI (kg/m ²)	17.2 (2.6)	18.1 (3.0)	0.9 (0.1)	5.2	17.1 (2.7)	17.9 (3.1)	0.8 (0.1)	4.7	0.1 (–0.2–0.4)	0.367
$VO_{2\text{peak}}$ (L/min)	1.58 (0.23)	2.06 (0.28)	0.48 (0.02)	30.4	1.60 (0.23)	1.90 (0.28)	0.31 (0.02)	19.4	0.17 (0.12–0.22)	< 0.001
$VO_{2\text{peak}}$ (mL/kg/min)	49.1 (7.3)	53.4 (6.8)	4.3 (0.4)	8.8	50.7 (6.9)	51.1 (7.5)	0.4 (0.4)	0.8	3.6 (2.5–4.6)	< 0.001
$VO_{2\text{peak}}$ (mL/kg ^{0.67} /min)	153.8 (18.4)	177.4 (17.1)	23.6 (1.3)	15.3	157.9 (18.5)	168.0 (20.3)	10.1 (1.2)	6.4	12.3 (9.1–15.5)	< 0.001
Running time (min)	10.95 (1.44)	11.32 (1.69)	0.38 (0.1)	3.5	11.21 (1.44)	10.69 (1.61)	–0.50 (0.1)	–4.5	0.82 (0.49–1.15)	< 0.001
HR_{peak} (beats/min)	203.6 (6.6)	202.5 (6.7)	–1.2 (0.3)	–0.6	203.7 (7.6)	203.1 (7.6)	–0.5 (0.5)	–0.2	–0.6 (–1.6–0.4)	0.230

All data presented are for sexes combined.

Δ is the post-intervention value minus the baseline value. Adjusted difference-in- Δ is the net effect of the intervention, which is I-school Δ minus C-school Δ . All difference-in- Δ values are adjusted for both sex and their respective baseline value. $\Delta\%$ represents the effect size, and is the difference between the baseline and the post-intervention test in percent. Significant differences between the I-school children and C-school children are marked with bold and italics.

existed between children from the I-school and C-school in any of the variables at baseline. Children from the I-school had a significantly higher absolute (L/min) and scaled ($\text{mL}/\text{kg}^{-0.67}/\text{min}$) $\Delta\text{VO}_{2\text{peak}}$ compared with children from the C-school (all $P < 0.001$). The difference-in- Δ data presented are adjusted for sex and baseline values. Also, Δ running time was significantly higher for I-school children ($P < 0.001$).

Figure 1 shows the unadjusted relative $\text{VO}_{2\text{peak}}$ at baseline and post-intervention (95% CI) for both sexes combined for the I-school and the C-school children. The I-school children increased their $\text{VO}_{2\text{peak}}$ (mean, SD) from 49.1 (7.3) $\text{mL}/\text{kg}/\text{min}$ to 53.4 (6.8) $\text{mL}/\text{kg}/\text{min}$ ($P < 0.001$). The C-school children increased their $\text{VO}_{2\text{peak}}$ (mean, SD) from 50.7 (6.9) $\text{mL}/\text{kg}/\text{min}$ to 51.1 (7.5) $\text{mL}/\text{kg}/\text{min}$ ($P = 0.300$).

Table 2 shows $\Delta\text{VO}_{2\text{peak}}$ ($\text{mL}/\text{kg}/\text{min}$) by quartiles of $\text{VO}_{2\text{peak}}$ baseline. $\Delta\text{VO}_{2\text{peak}}$ in both quartiles 1 (Q1) and 2 (Q2) in the I-school was significantly higher than in all quartiles in the C-school (all $P < 0.001$, except for Q2 in the I-school vs Q1 in the C-school, $P = 0.002$). Furthermore, $\Delta\text{VO}_{2\text{peak}}$ for Q3 in the I-school was significantly higher than $\Delta\text{VO}_{2\text{peak}}$ in all quartiles in the C-school (all $P < 0.05$) except Q1. $\Delta\text{VO}_{2\text{peak}}$ for Q4 in the I-school was not significantly different from the $\Delta\text{VO}_{2\text{peak}}$ in any of the quartiles in the C-school. The difference-in- Δ in $\text{VO}_{2\text{peak}}$ between the Q1 in the I-school and the Q1 in the C-school was 5.2 (3.3–7.1) $\text{mL}/\text{kg}/\text{min}$. For the three other quar-

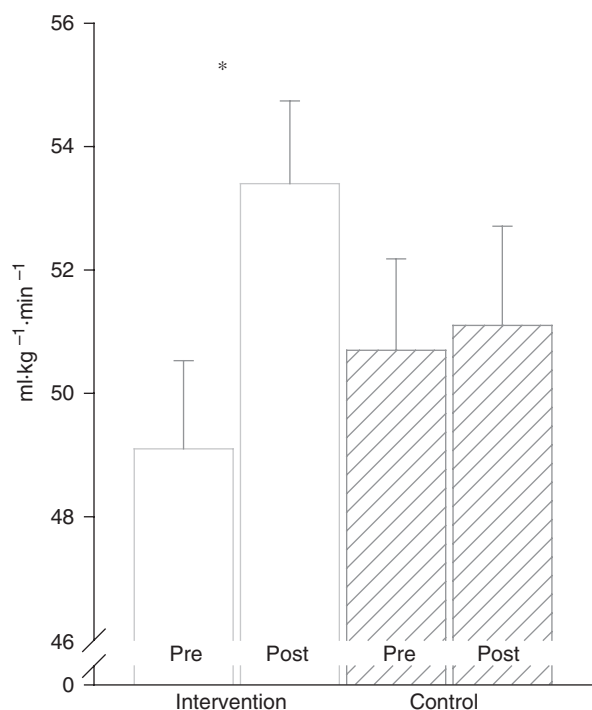


Fig. 1. Unadjusted baseline and post-intervention relative $\text{VO}_{2\text{peak}}$ (95% confidence interval) for I-school and C-school, sexes combined. *Significant difference from baseline to post-intervention test ($P < 0.001$).

tiles, the differences were 5.4 (3.7–7.2), 3.4 (1.3–5.5) and 1.7 (–0.8 to –4.3) $\text{mL}/\text{kg}/\text{min}$, for Q2 vs Q2, Q3 vs Q3 and Q4 vs Q4, respectively.

Discussion

To our knowledge, the present study breaks new ground by being the first multi-year daily PA intervention with *direct* measurement of $\text{VO}_{2\text{peak}}$ as main outcome. The principal finding is that a 2-year school-based teacher-controlled 60-min daily PA intervention significantly improves CRF in children. Boys and girls demonstrated similar $\text{VO}_{2\text{peak}}$ responses. The intervention, primarily carried out at moderate intensity, had the biggest impact in those children with low initial CRF levels.

A potential explanation for the significantly higher $\Delta\text{VO}_{2\text{peak}}$ in the I-school children, could be a lower Δ body mass compared with the C-school children. This was not the case, however, as the I-school children in fact tended to gain more body mass during the intervention than did the C-school children. Possible explanations for this gains could be that the extra PA resulted in a higher energy intake, and/or that the I-school children gained more muscle mass than the C-school children. The C-school children showed a significant decrease in running performance on the treadmill. At the same time, they did not improve their $\text{VO}_{2\text{peak}}$. On the other hand, the I-school children's increase in $\text{VO}_{2\text{peak}}$ was accompanied by a significant improvement in the running performance on the treadmill. The majority of this improvement is most likely a function of cardiovascular adaption.

When considering the effect on CRF of a PA intervention in school, one should consider that the distribution might be uneven, and it is therefore important to not only to investigate the changes in mean, but also to examine the changes in sub-groups. We therefore divided the subjects into quartiles based on their baseline $\text{VO}_{2\text{peak}}$ values. The least fit children from the I-school increased their $\Delta\text{VO}_{2\text{peak}}$ significantly more than the children in the upper quartile of CRF, whereas there was no such finding regarding the children in the C-school. This conclusion was supported when $\Delta\text{VO}_{2\text{peak}}$ was analyzed as a continuous variable in simple correlations. The $\Delta\text{VO}_{2\text{peak}}$ were highly inversely related to baseline $\text{VO}_{2\text{peak}}$ for the I-school children but not for the C-school children (–0.39, $P < 0.001$ and –0.008, $P = 0.47$, respectively), and this difference shows that the potential for improvement in $\text{VO}_{2\text{peak}}$ is highest for those children with low initial $\text{VO}_{2\text{peak}}$. This potential for improvement is also shown in adults (Wenger & Bell, 1986).

Table 2. Baseline values, post-intervention values, Δ values both absolute and in percent for VO_{2peak} (mL/kg/min) by quartiles of VO_{2peak} baseline for children in the I-school and C-school

	I-school ($n = 102$)					C-school ($n = 86$)				
	n	Baseline (SD)	Post-intervention (SD)	Δ (SEM)	$\Delta\%$	n	Baseline (SD)	Post-intervention (SD)	Δ (SEM)	$\Delta\%$
Quartile 1	26	40.3 (5.2)	46.4 (5.1)	6.1 (0.7)*	15.1	22	43.2 (6.1)	44.1 (5.7)	0.9 (0.6)	2.0
Quartile 2	26	47.0 (2.2)	52.2 (4.3)	5.2 (0.6)**	11.1	22	49.0 (3.9)	48.9 (5.2)	-0.1(0.6)	-0.2
Quartile 3	25	51.9 (2.0)	55.7 (4.2)	3.8 (0.8)***	7.3	21	53.2 (3.2)	53.6 (5.5)	0.4 (0.8)	0.7
Quartile 4	25	57.5 (3.0)	59.5 (5.6)	2.1 (0.8)	3.7	21	57.7 (3.8)	58.1 (5.5)	0.3 (1.0)	0.5
Mean	25.5	49.2 (3.1)	53.5 (3.9)	4.3 (0.7)	9.3	21.5	50.8 (4.3)	51.2 (5.5)	0.4 (0.8)	0.8

Δ represents difference between baseline and post-intervention values. $\Delta\%$ is the difference between the baseline and the post-intervention test in percent. Children in the fourth quartile (Q4) are the fittest. The 25% least fit boys in the I-school ($n = 14$) and the 25% least fit girls in the I-school ($n = 12$) constitute Q1 for the I-school. Hence, these results are not adjusted for sex. For Q1 in the C-school, the numbers are boys = 11 and girls = 11. Q2, Q3 and Q4 for the I-school were boys = 14 and girls = 12, boys = 13 and girls = 12, boys = 13 and girls = 12, respectively. Q2, Q3 and Q4 for the C-school were: boys = 11 and girls = 11, boys = 11 and girls = 10, boys = 11 and girls = 10, respectively. There is a minor difference between the VO_{2peak} (mL/kg/min) result in Table 2 and those presented in the paper. This is due to the fact that the data in Table 2 are not adjusted for sex, as there were approximately the same number of boys and girls in each quartile.

All data presented are for sexes combined.

*Significantly higher than in all quartiles in the C-school ($P < 0.001$).

**Significantly higher than in all quartiles in the C-school ($P < 0.003$).

***Significantly higher than Q2, Q3 and Q4 in the C-school ($P < 0.05$).

Results from the present study suggest that a daily dose of PA over a relatively long period might be essential to affect CRF in children. This conclusion is supported by several recent large-scale studies on children. In Sweden, 132 children participated in a 3-year daily PA intervention, where the time for PA was expanded from one or two lessons to four lessons weekly, with every lesson lasting at least 40 min (Sollerhed & Ejlertsson, 2008). CRF was assessed by a 6-min running test and the multi-stage 20 m shuttle run test (MSSRT). Post-intervention tests showed a significant effect on the endurance test for the children from the I-school compared with the children from the C-school. In Germany, 615 children participated in the CHILT Project, a 4-year PA intervention where the teachers were asked to give one extra health education lesson weekly lasting 20–30 min (Graf et al., 2008). Additionally, the children were given small PA breaks, in which they were physically active, during the school day. Fitness was assessed by a 6-min running test. In contrast to the study of Sollerhed and Ejlertsson (2008), no statistical difference existed in Δ CRF between the I-school and the C-school children. Seemingly, the increased PA in this intervention was not sufficient to affect CRF. The same conclusion was reached in the Copenhagen school child intervention study ($n = 383$), where the twice weekly PA classes were doubled from 45 to 90 min for 3 years (Jago et al., 2009). The findings of the present study, together with the conclusions from these studies, suggest that the volume of PA performed and its frequency, preferably on a daily basis, are both crucial to changing children's CRF levels.

Baquet et al. (2003) reviewed the literature regarding endurance training and CRF in children and adolescents, and suggested that children's VO_{2peak} can be increased with training, albeit not as much as for adults. Generally, aerobic training for children leads to a mean improvement of 5–6% in VO_{2peak} , and two training sessions weekly might be sufficient to increase VO_{2peak} . They also suggested that the intensity needs to be at 80% of HR_{peak} to increase VO_{2peak} , and that both session frequency and session duration appear to be key factors in training programs for children. The 22 studies that formed the basis for these conclusions had relatively few subjects, ranging from seven to 37, and the majority of these studies had training programs lasting <3 months. Obviously, a school-based intervention is not the same as a regular training program. Still, the present study's results suggest that children's VO_{2peak} can be significantly increased by PA that is, for the most part, of moderate intensity. This conclusion is supported by Sundberg (1982) who showed, in a cross-sectional study, that blind children, whom we can expect generally to have lower PA levels than sighted children, had significantly lower CRF values than their sighted counterparts did. Also, other studies have shown that CRF of visually impaired children is lower than that of age-matched sighted counterparts (Seelye, 1983; Hopkins et al., 1987; Liberman & McHugh, 2001).

According to a recent Cochrane Review (Dobbins et al., 2009) that considered school-based interventions promoting PA and CRF in children and adolescents, and included only prospective randomized-controlled trials and controlled clinical trials,

few school-based studies reporting children's CRF results are of a high quality. In fact, only one study for children was considered to be of sufficient quality. This study (Trevino et al., 2004), a 7-month intervention, aimed to prevent diabetes in more than 1200 low-income Mexican-American 9-year olds. There was a significant positive effect on CRF, measured indirectly using a modified Harvard Step Test. Most school interventions aim to increase habitual PA and/or prevent or treat overweight and obesity (Katz et al., 2008; Shaya et al., 2008; Brown & Summerbell, 2009), and few assess VO_{2peak} directly. Those testing CRF instead often use indirect tests, and the most frequently applied is the MSSRT (Léger et al., 1988). A possible explanation for why so few intervention studies test VO_{2peak} directly could be that highly trained test leaders and sophisticated, technical and expensive equipment are required. Furthermore, as each test is carried out individually, the testing is time consuming. Indirect tests, often performed simultaneously on a large number of subjects, therefore have great practical advantages compared with a direct measurement of VO_{2peak} , but have a wider margin of error and are less accurate in predicting CRF. Validation studies in children and adolescents comparing the predicted VO_{2peak} in MSSRT to directly measured VO_{2peak} vary in results and use different statistical methods (e.g. van Mechelen et al., 1986; Léger et al., 1988; Boreham et al., 1990; Liu et al., 1992; McVeigh et al., 1995).

A number of obstacles were encountered during the implementation of the PA promotion intervention. The four major obstacles were (i) getting all relevant stake-holders to accept the intervention, (ii) time constraints, (iii) space constraints and (iv) ensuring that staff that have the relevant PE education were included in the intervention on a daily basis. (i) One of the key aspects of the positive outcome is the requirement that all relevant stakeholders accept the intervention. To ensure this, the teachers and administrative personnel in the school were physically introduced to the positive outcomes of equivalent programs both in their native country and abroad by travelling to these centers. Additionally, to re-enforce their awareness and knowledge about the merits of the PA program, we instituted several educational sessions, which were conducted by experts. In addition, these educational sessions were aimed at motivating and inspiring the teachers. The parents at both the intervention and control schools also received the same type of lectures. Parents were also informed that they could contact the school and Geir K. Resaland if they had any inquiries regarding the intervention. A major reason for the school and parents accepting the intervention was the documentation that shows a strong association between academic performance and PA in school (Sibley &

Etnier, 2003). This has also been confirmed in several review papers (Ahamed et al., 2007; Trudeau & Shephard, 2008). (ii) The lack of a large PA-specific indoor area at most education centers limits the effective implementation size at any one time. We therefore utilized an outdoor PA regime, which necessitated compliance from the pupils and their parents to ensure that correct outdoor apparel was available, particularly during colder, aversive weather conditions. In addition, this required a creative attitude from teachers with respect to novel PA routines when traditional exercise programs were not feasible. (iii) Time constraints were addressed by reducing all other subjects by an equivalent margin. In addition, school starting times were changed by 5 min each day, which resulted in a cumulative gain of 25 min each week. (iv) It is crucial that the teachers who plan, organize and carry out the daily PA have relevant PE education. In the present intervention, two teachers with relevant PE education did most of the planning of the PA lessons, and one of them was always present in the daily PA. The classroom teachers (without any relevant PE education) involved were given specific tasks and contributed in an important but, thus, not in a crucial way. In conclusion, we have shown that these obstacles can be overcome, and we believe that this type of PA intervention is expandable to larger schools and larger group sizes. However, skilled and motivated staff remains the cornerstone of effective implementation. The feasibility of a successful PA intervention of this type in an older group of students, where compliance may be lower, needs to be evaluated by further studies.

The main strengths in the present study were the length of the intervention (19 months), the amount of daily PA (60 min) and the *direct* measurement of VO_{2peak} . Furthermore, high participation and completion rates make this a representative population of the 9-year olds in these two rural municipalities. Finally, both baseline and post-intervention measurements were carried out by the same test leaders. Regarding limitations, we cannot exclude the possibility that several confounding factors that were not controlled for, such as energy intake, PA outside of school, pubertal status and genetic variation, could partly explain our observations. Furthermore, we did not objectively measure the PA either in lessons during school or the children's PA outside of school. On the other hand, these factors would apply to the children in both the I-school and C-school. Regarding puberty status issues, there were no differences between the children from the intervention and control schools with respect to Δ body mass or Δ height, and maturational development is unlikely to differ in two municipalities with such close proximity. Maturation should therefore not confound the

analysis of changes in fitness. Also, although a randomized control trial would be considered the optimal design for a school intervention study, we chose the intervention school for reasons pertaining to practical limitations. However, the choice of the intervention and control schools was made before any collection of data and therefore avoided any selection bias. Still, existing baseline differences for boys between I-school and C-school in VO_{2peak} became evident. In addition, there is always a potential for regression toward the mean (RTM) in longitudinal studies comparing two different groups. These statistical challenges were solved by analyzing ΔVO_{2peak} for both sexes combined in a linear multiple regression adjusted for sex and baseline VO_{2peak} . To further investigate for RTM, we removed baseline VO_{2peak} as an independent variable in the linear multiple regression analyses (but kept sex), and used a formula suggested by Beach and Baron (1998) to correct any potential RTM effect on the ΔVO_{2peak} value. The analysis showed that the potential RTM effect was 0.3 mL/kg/min, which is the same as the result we observed when we adjusted for baseline VO_{2peak} in the linear multiple regression analysis. Finally, the present study includes only rural Norwegian children, raising questions about the generalizability of the results. However, the average initial CRF level was quite high and we found larger improvements in less fit children, which may indicate that the intervention could be even more effective in a less fit population.

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Perspectives

The present study's findings suggest that a school-based PA intervention can significantly improve children's CRF, provided it is of sufficient length, includes substantial daily moderate-to-vigorous PA and that the PA is planned, organized and controlled by skilled teachers. The present study suggests that increased PA levels and increased CRF in children should be given due consideration when designing school policies. Establishing a lifestyle of regular exercise, and thereby possibly contributing to a higher level of CRF in children, has many important benefits, including short- and long-term health benefits (Malina, 2001; Andersen et al., 2004; Ferreira et al., 2005; Anderssen et al., 2007). The most advantageous approach to decrease the incidence of lifestyle diseases, such as the metabolic syndrome in adults, might well be through such preventive strategies. Substantial amounts of daily moderate-to-vigorous PA over a long period of time, and thereby increased CRF levels, may be particularly beneficial.

Key words: physical activity, fitness, VO_{2peak} , children, school, intervention.

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Cardiovascular risk factor clustering and its association with fitness in nine-year-old rural Norwegian children

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This paper describes cardiovascular disease (CVD) risk factor levels in a population-representative sample of healthy, rural Norwegian children and examines the association between fitness and clustering of CVD risk factors. Final analyses included 111 boys and 116 girls (mean age 9.3 ± 0.3). To determine the degree of clustering, six CVD risk factors were selected: homeostasis model assessment score, waist circumference, triglycerides, systolic blood pressure, total cholesterol to high-density lipoprotein ratio and fitness (VO_{2peak}). Clustering was observed in 9.9% of the boys and 13.8% of the girls. In a different analysis, fitness was omitted as a CVD risk factor and analyzed

against the five remaining CVD risk factors. Low fitness was a strong predictor for clustering of CVD risk factors, and children in the least-fit quartile had significantly poorer CVD risk factor values than all of those in the other quartiles. Finally, subjects were cross-tabulated into different fat-fit groups. For both sexes, the unfit and overweight/obese group had a significantly higher CVD risk factor score than the fit and normal weight group. Clustering of CVD risk factors was present in this group of rural children. Low fitness, and low fitness and high fatness combined, were highly associated with a clustered CVD risk.

The clustering of atherosclerotic cardiovascular disease (CVD) risk factors, often referred to as the metabolic syndrome, increases the risk of both CVD and type 2 diabetes in adults (Wilson et al., 2005). Although the clinical endpoints for CVD are almost non-existent in children, precursors of atherosclerosis, known as fatty streaks, do develop in children (Benson et al., 1998). Additionally, CVD risk factors have been shown to cluster in children as young as nine (Andersen et al., 2003). Furthermore, this sort of clustered risk often tracks from childhood to adulthood (Twisk et al., 1997; Raitakari et al., 2003), creating a lifetime of exposure to and an elevated risk of CVD. From a public health perspective, it is particularly important to identify children with a clustered risk at the earliest opportunity so that primary preventive strategies can be put in place to prevent later onset of disease. In Norway, data on children's CVD risk factors are sparse, and the little data available on children's CVD risk factor profiles are mainly from urban Oslo. However, many children live in rural settings, and so it is important to gather data on these children, particularly as their lifestyles may differ from those of their urban counterparts.

Recently, it was shown that low cardiorespiratory fitness (fitness) is a strong predictor for clustering of

CVD risk factors (Anderssen et al., 2007), and that fitness and physical activity are separately and independently associated with clustered metabolic risk in children (Ekelund et al., 2007). Additionally, it was shown that high fitness is associated with a healthier cardiovascular profile (Brage et al., 2004; Ruiz et al., 2007). Still, limited research exists on 9-year-old children, and therefore the association between fitness and clustering of CVD risk factors remains uncertain.

This paper, therefore, has two main aims. Firstly, it seeks to describe the CVD risk factor levels for a population-representative sample of 9-year-old, apparently healthy, rural Norwegian children and secondly, to examine the association between fitness and clustering of CVD risk factors.

Materials and methods

The participants were part of a school-based physical activity intervention study, and the presented data are baseline data. The sample included all fourth graders (age 9.3 ± 0.3 , $n = 259$) in two consecutive years (born in 1995–1996) in two rural elementary schools in Sogn og Fjordane County, western Norway. The communities, Sogndal (population 6836)¹ and

¹According to Statistics Norway on January 1, 2006.

Førde (11 327), are 105 km apart. The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate. The Norwegian Directorate of Health also approved the study in accordance with the Biobank Act. Participation was voluntary; a child could withdraw from the study at any time, without giving a reason. Written consent was obtained from the children's parents or guardians. Data were collected in the September–October period in both 2004 and 2005. The children from Førde travelled to the *Sogn og Fjordane University College* in Sogndal, where their body mass and height, waist and hip circumference, blood pressure and $\text{VO}_{2\text{peak}}$ were measured at the Human Physiology Laboratory. The Sogndal group's $\text{VO}_{2\text{peak}}$ was measured at the same laboratory, while their body mass and height, waist and hip circumference and blood pressure were measured at their school. All blood sampling was carried out at the schools on a different day than all the other testing. The same nurse carried out all the body mass, height, blood pressure and waist and hip circumference measurements. A phlebotomist carried out all the blood sampling tests. The same two test leaders carried out all fitness tests.

Blood sampling, treatment and analysis

After an overnight fast, intravenous blood samples were taken from each child antecubital vein in the morning between 09:00 and 10:30 hours 1 h after the application of an anesthetic band-aid (lidocaine/prilocaine Emla cream, Astra, Albertslund, Denmark). Blood samples were mechanically agitated for 30 min to prevent clotting, and were then aliquoted and separated. The samples were spun for 10 min at 2500 g. Two samples were obtained from each child. One sample per subject was analyzed at the FÜRST Medical Laboratory (Oslo, Norway) for glucose, total cholesterol, high-density lipoprotein cholesterol (HDL) and triglycerides (TG). Low-density lipoprotein cholesterol (LDL) was estimated from total cholesterol, HDL and TG by the Friedewald formula (Friedewald et al., 1972). The ratio of total cholesterol to HDL (total cholesterol:HDL ratio) was calculated. The other sample was frozen immediately after sampling and stored at -80°C . These samples were later analyzed for insulin using a radioimmunoassay kit (Linco Research Inc., St. Charles, Missouri, USA) at the Hormone Laboratory, Aker University Hospital (Oslo, Norway). Insulin resistance was estimated according to the homeostasis model assessment (HOMA) using the formula $[(\text{glucose} \times \text{insulin})/135]$ (Matthews et al., 1985). Both laboratories are subject to external quality assessment and are internationally accredited.

Resting blood pressure

Resting systolic (systolic BP) and diastolic (diastolic BP) blood pressure were measured using the Omron HEM-907 automated blood pressure monitor (Omron Healthcare Inc., Vernon Hills, Illinois, USA). The device was validated according to the AAMI validation protocol (White & Anwar, 2001) and the validation criteria of the published proposal of the international protocol for the validation of blood pressure measuring devices (El Assaad et al., 2002). Our own reliability study showed that there was no significant difference between the Omron HEM-907 compared with the manual measurement (systolic BP, $P = 0.163$ and diastolic BP, $P = 0.816$). Children rested quietly for 10 min in a sitting position with no distractions before measurements. During the test, each child sat still in a quiet room, and blood pressure was measured from his or her right arm, using the appropriate-sized cuff. The blood

pressure monitor was programmed to take four measurements with a 2-min break between each measurement. For all tables and analyses, the mean value of the last two measurements was used. Measurements were carried out between 09:00 and 15:00 hours for the children from Sogndal and between 12:00 and 18:00 hours for the children from Førde.

Fitness

$\text{VO}_{2\text{peak}}$ was directly measured during a continuous progressive treadmill protocol, whereby speed was increased every minute until a maximal speed of 10 km/h was reached. After this, the load was increased by elevating the gradient of the treadmill by 1.5% every minute until voluntary fatigue. The primary consideration for an acceptable test was that the subject demonstrated signs of intense effort and clear symptoms of fatigue. The objective criteria of respiratory exchange ratio (≥ 1.0) and peak heart rate (HR_{peak}) (≥ 200 beats/min) were also taken into consideration. The $\text{VO}_{2\text{peak}}$ tests were carried out between 15:00 and 20:00 hours for the children from Sogndal and between 12:00 and 19:00 hours for the children from Førde.

Waist and hip circumference

Waist circumference (waist) was measured at the level of the umbilicus to the nearest 0.5 cm with the child abdomen relaxed at the end of a gentle expiration. The child was standing with the arms hanging slightly away from the body. Hip circumference was measured at the point of maximum protrusion of the buttocks.

Body mass and height

Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Seca 770, SECA GmbH, Hamburg, Germany) with children wearing light indoor clothing and shoeless, for which an allowance of 0.2 kg was subtracted from results. Height, without stretch, was measured to the nearest 0.1 cm, with children standing shoeless facing forward.

Statistics

All statistical analyses were performed using SPSS software, version 15.0 (SPSS Inc., Chicago, Illinois, USA). Variables were tested for normality of distribution before the analyses, and skewed variables were logarithmically transformed (natural log) for all statistical analyses. Significant differences between the means of the sexes were determined by an independent-sample *t*-test. To determine the degree of clustering in the study sample, six biological CVD risk factors were selected: HOMA, waist, TG, systolic BP, total cholesterol:HDL ratio and fitness. Clustering was analyzed by dividing each sex into quartiles for each risk factor. Being in the least favorable quartile for each CVD risk factor was defined as being at risk. Children in the unfavorable quartiles were given the value 1, and children in the three other quartiles were given the value 0. The cumulative number of risk factors for each child was calculated for the six risk factors, and the children were then assigned to seven risk-factor categories, 0–6, according to their number of risk factors. Clustering was defined as a child having four, five or six CVD risk factors. To analyze the association between fitness and clustering of CVD risk factors, another clustered risk variable was constructed. This time, fitness was omitted. Clustering was defined here as a child having three, four or five risk factors. The mean differences in fitness, body mass, height and body mass index (BMI) between sexes were determined by an independent-

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Table 1. Participants' characteristics

	Boys		Girls		P for sex
	n	Mean ± SD or median (Q3–Q1)	n	Mean ± SD or median (Q3–Q1)	
Age (years)	125	9.2 ± 0.3	131	9.3 ± 0.3	0.085
Body mass (kg)	125	32.1 ± 5.2	131	33.0 ± 7.7	0.271
Height (cm)	125	137.7 ± 5.4	131	136.6 ± 6.2	0.172
BMI (kg/m ²)	125	16.9 ± 2.2	131	17.6 ± 3.1	0.054
Systolic BP (mm Hg)	119	108.9 ± 8.4	125	109.0 ± 7.5	0.921
Diastolic BP (mm Hg)	119	61.3 ± 6.7	125	63.0 ± 6.0	0.040
Waist circumference (cm)	119	60.9 ± 5.3	125	61.9 ± 7.7	0.276
*Waist circumference (cm) skewed	119	59.5 (63.0-57.5)	125	59.5 (66.0-56.5)	0.374
Hip circumference (cm)	119	63.4 ± 6.4	125	66.8 ± 8.8	0.001
*Hip circumference (cm) skewed	119	62.0 (66.0-59.0)	125	64.5 (71.3-60.0)	0.001
Total cholesterol (mmol/L)	121	4.63 ± 0.70	126	4.76 ± 0.74	0.152
HDL cholesterol (mmol/L)	121	1.75 ± 0.38	126	1.62 ± 0.32	0.004
LDL cholesterol (mmol/L)	121	2.57 ± 0.63	126	2.78 ± 0.69	0.010
Total cholesterol:HDL ratio	121	2.73 ± 0.57	126	3.02 ± 0.71	P < 0.001
*Total cholesterol:HDL ratio skewed	121	2.73 ± 0.57	126	2.88 (2.60-3.40)	P < 0.001
Triglyceride (mmol/L)	121	0.69 ± 0.27	126	0.80 ± 0.44	0.023
*Triglyceride (mmol/L) skewed	121	0.62 (0.78-0.51)	126	0.72 (0.93-0.59)	0.008
Insulin (pmol/L)	121	52.8 ± 15.9	126	66.4 ± 30.6	P < 0.001
*Insulin (pmol/L) skewed	121	52.8 ± 15.6	126	61.5 (75.3-49.8)	P < 0.001
Glucose (mmol/L)	121	4.74 ± 0.34	126	4.62 ± 0.36	0.004
*Glucose (mmol/L) skewed	121	4.70 (4.90-4.50)	126	4.62 ± 0.36	0.006
HOMA	121	1.87 ± 0.60	126	2.29 ± 1.1	0.003
*HOMA skewed	121	1.87 ± 0.60	126	2.10 (2.64-1.69)	0.001
VO _{2peak} (ml/kg/min)	111	52.8 ± 6.5	116	46.9 ± 7.2	P < 0.001

All variables are presented as mean ± SD. In addition, skewed variables* are also presented as median (Q3–Q1). P-value for sex is presented after adjustment for location. Significant values are given in **bold**.

BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; HOMA, homeostasis model assessment.

sample *t*-test. To further investigate the relationship between fitness and CVD risk factors, a *z*-score [$z = (\text{value} - \text{mean}) / \text{SD}$] by sex was computed for the same five risk factors. *Z*-scores of the individual risk factors were summed up to obtain a clustered risk score for each quartile of fitness. Pearson correlation analysis was performed to investigate the association between fitness and the CVD risk factors. Finally, four fitness/BMI groups (fit/normal BMI; unfit/normal BMI; unfit/overweight or obese; and fit/overweight or obese) were compared in relation to CVD risk factors by sex. Weight status was defined by the BMI classification from the International Obesity Task Force (Cole et al., 2000). High fitness was defined as being in the highest (best) quartile of fitness and unfit in the lowest (worst) quartile. Differences across fitness/BMI groups and these groups' clustered risk (*z*-score) were assessed by one-way analysis of variance (ANOVA) and Tukey's *Post hoc* comparison. Only children ($n = 227$) with valid measurements in all six selected risk factors were included in the analyses. Power calculations (SigmaStat 3.1 Systat Software GmbH, Erkrath, Germany) were performed before the study and also with the remaining subjects ($n = 227$) to ensure that power was still sufficient. Significance level was set at $P < 0.05$.

Results

A total of 259 children were invited to participate in the study. Three children were excluded because they had a chronic disease; the remaining 256 children were apparently healthy and able to participate.

Twelve children were unable or unwilling to travel to the research center, hence, their blood pressure and VO_{2peak} data were not obtained. Nine of these 12 children did not consent to have their blood drawn; the remaining 247 children completed the blood test. Of the 244 children who volunteered for the VO_{2peak} test, 17 subjects' tests were rejected because of either sickness on the test day ($n = 1$), poor compliance ($n = 4$) or equipment failure ($n = 12$). In total, body mass and height data were collected for all 256 children; 96.5% of the 256 eligible children completed the blood test and 95.4% completed both the blood pressure test *and* waist and hip circumference measurements. Finally, 87.6% successfully completed the VO_{2peak} test. There was no statistical difference between the children who were either included or excluded from the data analysis, with respect to age, body mass and height (data not shown). In a general linear model including sex and location, only LDL ($P = 0.013$), glucose ($P < 0.001$) and VO_{2peak} ($P = 0.032$) were significantly different between the two rural communities.

Table 1 shows the descriptive characteristics of the participants by sex. The mean age, body mass, height, systolic BP, waist and total cholesterol were not different between sexes. Girls had a higher BMI ($P = 0.050$) and diastolic BP ($P = 0.041$) than boys.

Table 2. Observed number of children with the different number of CVD risk factors by sex

CVD risk factors	0	1	2	3	4	5	6	At risk: 4,5 and 6 CVD risk factors combined
Boys (n)	28	38	23	11	6	5	0	11 (9.9%)
Girls (n)	41	31	14	14	8	6	2	16 (13.8%)
Total	69	69	37	25	14	11	2	25 (11.9%)

The degree of clustering of risk factors in those 227 children (111 boys and 116 girls) who had valid measurements in all six selected risk factors; HOMA, waist, TG, total cholesterol:HDL ratio, fitness and systolic BP. For each CVD risk factor, a child being in the least favorable quartile was defined as being at risk. Clustering (being at risk) was defined as a child having four, five or six CVD risk factors by sex.

CVD, cardiovascular disease; HOMA, homeostasis model assessment; TG, triglycerides; HDL, high-density lipoprotein; BP, blood pressure.

Table 3. Fitness (relative VO_{2peak} and scaled VO_{2peak}), body mass, height and BMI for those children with and without clustering of CVD risk factors

	Mean \pm SD		<i>P</i> boys	Mean \pm SD		<i>P</i> girls
	Non-clustering boys (<i>n</i> = 99)	Clustering boys (<i>n</i> = 12)		Non-clustering girls (<i>n</i> = 94)	Clustering girls (<i>n</i> = 22)	
Relative VO_{2peak} (mL/kg/min)	53.7 \pm 6.1	46.0 \pm 5.9	<i>P</i> < 0.001	48.3 \pm 6.5	40.8 \pm 7.3	<i>P</i> < 0.001
Scaled VO_{2peak} (mL/kg ^{0.67} /min)	166.6 \pm 15.5	152.5 \pm 14.2	0.004	148.8 \pm 17.1	137.8 \pm 18.0	0.009
Body mass (kg)	31.5 \pm 4.6	38.8 \pm 7.2	0.005	30.8 \pm 4.8	42.0 \pm 9.6	<i>P</i> < 0.001
Height (cm)	137.2 \pm 5.2	140.9 \pm 5.8	0.023	136.0 \pm 5.7	139.7 \pm 7.0	0.028
BMI (kg/m ²)	16.7 \pm 2.0	19.5 \pm 3.1	<i>P</i> < 0.001	16.6 \pm 2.1	21.3 \pm 3.6	<i>P</i> < 0.001

Clustering is defined as a child having three, four or five of the following risk factors: HOMA, waist, TG, total cholesterol:HDL ratio and systolic BP. Significant values are given in *bold*.

CVD, cardiovascular disease; BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; HOMA, homeostasis model assessment.

Girls also had a wider hip circumference ($P < 0.001$). Furthermore, girls showed a less favorable lipid profile, with higher levels of TG ($P = 0.007$), LDL ($P = 0.013$), lower concentrations of HDL ($P = 0.004$) and a more unfavorable total cholesterol:HDL ratio ($p < 0.001$) compared with boys. Girls also had a higher HOMA score ($P < 0.001$). Finally, girls had a lower relative VO_{2peak} ($P < 0.001$).

Table 2 shows the observed number of children with the different number of biological CVD risk factors by sex. Clustering was found in 9.9% of the boys and 13.8% of the girls.

Table 3 shows fitness (relative and scaled VO_{2peak}) by sex for those with and those without clustering of CVD risk factors. Body mass, height and BMI were also included to describe the two groups. The analysis includes the same risk factors as in Table 2 minus fitness. Children with three, four or five risk factors (boys $n = 12$, 10.8%; girls $n = 22$, 19.0%) had a lower relative VO_{2peak} ($P < 0.001$ for both boys and girls) compared with children with two or fewer risk factors (boys $n = 99$, 89.2%; girls $n = 94$, 81.0%). When VO_{2peak} was scaled (mL/kg^{0.67}/min¹), there was a less pronounced but still significant difference in means between the two groups (boys $P = 0.004$, girls $P = 0.009$).

Figure 1 shows the summed z-score as a continuous variable by sex-specific quartiles of fitness of the same five CVD risk factors as shown in Table 3. The

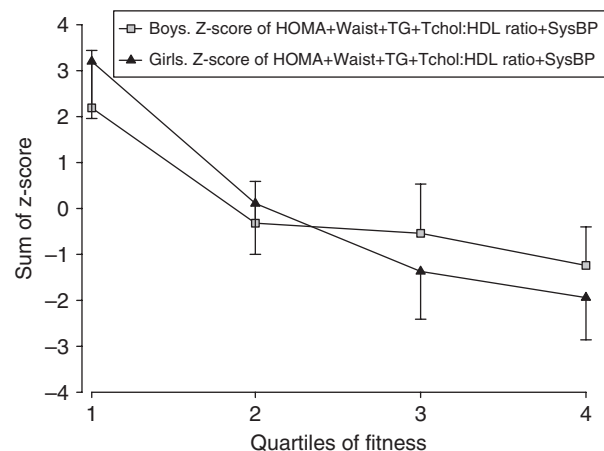


Fig. 1. Z-score and 95% confidence interval for the composite risk score for quartiles of fitness for boys and girls. A higher sum of the z-score indicates a less favorable metabolic profile. Children in the fourth quartile of fitness are the fittest.

differences in the z-score between the upper and the lower quartiles of fitness were 3.43 for boys and 5.14 for girls. One-way ANOVA analysis including a Tukey *post hoc* test showed significant differences for both boys ($F = 8.8$) and girls ($F = 18.9$). For both sexes, the children in quartile 1 (the least fit children) had significantly poorer values than the children in all other quartiles (boys: $P = 0.003$, $P = 0.001$,

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Table 4. Relationship between fitness and weight status *and* single CVD risk factors

	<i>n</i>	HOMA	Waist	Systolic BP	TG	Total cholesterol:HDL ratio
Boys						
Fit and normal weight	28	1.79 ± 0.63	57.5 ± 3.0	106 ± 7	0.67 ± 0.23	2.76 ± 0.54
Unfit and normal weight	18	2.11 ± 0.67	63.3 ± 4.7*	109 ± 9	0.81 ± .043	3.02 ± 0.77
Unfit and overweight/obese	9	2.17 ± 0.54	71.7 ± 5.2 ^{†,‡}	119 ± 7 ^{†,‡}	0.65 ± 0.21	2.62 ± 0.39
Girls						
Fit and normal weight	28	1.93 ± 0.58	56.6 ± 3.3	105 ± 6	0.71 ± 0.27	2.81 ± 0.40
Unfit and normal weight	9	2.26 ± 0.72	59.8 ± 3.3	109 ± 6	0.76 ± 0.06	3.14 ± 0.57
Unfit and overweight/obese	21	3.00 ± 1.56 [†]	74.2 ± 6.9 ^{†,‡}	115 ± 7 [†]	0.94 ± 0.26 [†]	3.47 ± 0.83 [†]

Mean ± SD values for three fitness-BMI groups: *fit and normal weight*, *unfit and normal weight*, *unfit and overweight/obese* and CVD risk factors. Because of uneven group sizes, the harmonic mean was used instead of the arithmetic mean.

*Unfit and overweight/obese is significantly different than fit and normal weight ($P < 0.05$).

[†]Unfit and overweight/obese is significantly different from unfit and normal weight ($P < 0.05$).

[‡]Unfit and normal weight is significantly different from fit and normal weight ($P < 0.05$).

CVD, cardiovascular disease; BMI, body mass index.

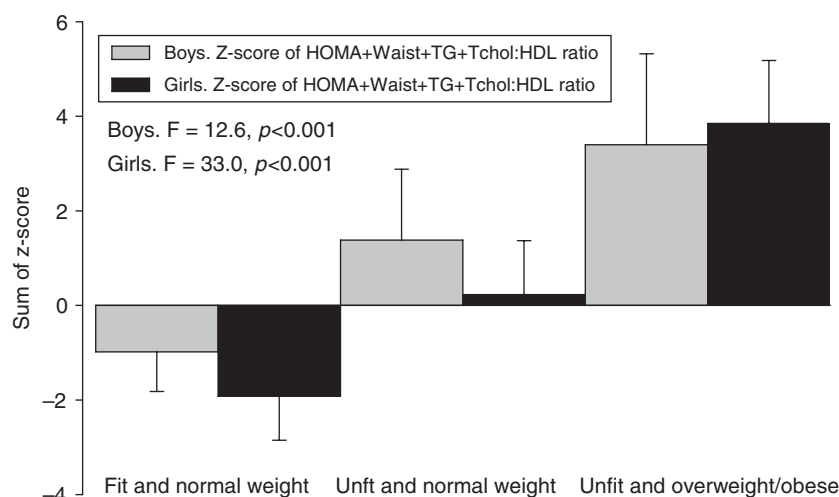


Fig. 2. Z-score and 95% confidence interval for the composite risk score for three fitness-body mass index groups: fit and normal weight; and unfit and normal weight; unfit and overweight/obese. A higher sum of the z-score indicates a less favorable metabolic profile.

$P < 0.001$; girls: $P < 0.001$, $P < 0.001$, $P < 0.001$) for quartiles 2, 3 and 4, respectively). Additionally, for girls, the second quartile had significantly poorer values ($P = 0.035$) than the fittest quartile. If waist was excluded from the clustered risk score, the association attenuated for boys ($P = 0.030$, 0.080 , 0.016) and remained strong for girls ($P = 0.009$, $P < 0.001$, $P < 0.001$) for quartiles 2, 3 and 4, respectively. For boys the difference between the least-fit boys (Q1) and Q3 was no longer significant. For girls, the difference between Q2 and Q4 was no longer significant.

Among the CVD risk factors, fitness was most closely associated with waist. Pearson's correlation coefficient showed a strongly negative correlation between the two variables (boys: $r = -.62$, $P < 0.01$; girls: $r = -.74$, $P < 0.01$).

Table 4 shows the relationship between fitness and weight status *and* the same five CVD risk factors used in Table 3 and Figure 1. Children were divided into four groups by sex according to their fitness and BMI

status. One-way ANOVA analysis including a Tukey *post hoc* test showed significant differences in HOMA (girls, $F = 5.2$), waist (boys, $F = 43.8$ and girl, $F = 69.6$), systolic BP (boys, $F = 9.7$ and girls, $F = 12.9$), TG (girls, $F = 4.9$) and total cholesterol:HDL ratio (girls, $F = 7.3$). For girls, the unfit and overweight/obese group had significantly poorer values than the fit and normal body mass group in all five CVD risk factors (HOMA $P = 0.006$, waist $P < 0.001$, systolic BP $P < 0.001$, TG $P = 0.009$, total cholesterol:HDL ratio $P = 0.001$). The unfit and overweight/obese girl group also had significantly poorer values than the unfit and normal body mass group in waist ($P < 0.001$). For boys, the unfit and overweight/obese group had significantly poorer values than the fit and normal body mass group in waist ($P < 0.001$) and systolic BP ($P = 0.005$). Also, in waist and systolic BP, the unfit and overweight/obese group had significantly poorer values than the unfit and normal body mass group. Finally, in waist, the unfit and normal body mass had significantly poorer

values than the fit and normal body mass group ($P < 0.001$).

Figure 2 shows z -score and 95% CI for the composite risk score for the same three fit-fat groups used in Table 4. For boys, the fit and normal weight group had a significantly lower z -score than did both the unfit and normal weight ($P = 0.002$) and the unfit and overweight/obese groups ($P < 0.001$). For girls the unfit and overweight/obese group was significantly different from both the fit and normal weight group ($P < 0.001$) and the unfit and normal weight ($P = 0.001$).

If waist was excluded from the clustered risk score in boys, the significant association between the fit and normal-weight group and the unfit and normal-weight group was weakened ($P < 0.031$), while the difference between the fit and normal-weight group and the unfit and overweight/obese group no longer significant ($P < 0.069$). For girls, the association between the unfit and overweight/obese group and the fit and the normal-weight group was unchanged ($P < 0.001$). However, there was no longer a significant difference between the unfit and overweight/obese group and the unfit and normal-weight group ($P = 0.124$).

Discussion

Clustering of CVD risk factors was present in this group of rural children. Low fitness, *and* low fitness and high fatness combined, were highly associated with clustered CVD risk.

There is a lack of CVD risk factor reference values for Norwegian children, making comparisons difficult. The only available relevant data are serum lipid data taken from non-fasting children aged 8–12 (Tonstad et al., 1996), and BMI, waist and blood pressure data from the Norwegian part of The European Youth Heart Study (EYHS) (Klasson-Heggebø, 2003). The Norwegian EYHS data were compiled for 9-year-olds in Oslo City. Compared with these city children, the rural children in the present study had similar waist values for both sexes, while BMI was similar for boys and slightly higher for girls. The rural children also had registered substantially higher systolic BP, while diastolic BP was approximately the same. The few other domestic studies on record focused on older Norwegian children (Tell et al., 1981, 1985; Tell & Vellar, 1988; Johnsen et al., 1991; Resellmo & Nielsen, 1998). However, several international studies, such as EYHS, have described CVD risk factor levels in 9 year-olds (Wennlöf et al., 2005; Andersen et al., 2006). Compared with their Swedish, Danish, Portuguese and Estonian counterparts, both boys and girls in the present study appear to have approximately

the same values in BMI and TG, substantially lower values in glucose and substantially higher values in total cholesterol, HDL and systolic BP. It is difficult to explain why Norwegian children register higher values of systolic blood pressure and also the considerable variation between different countries in blood pressure. The differences could stem from cultural factors, genetics or measurement technique variations. Norway (the present study) and Denmark (Andersen et al., 2006), which are geographically close, had similar systolic BP values (Norway: boys: 108.9 ± 8.4 and 61.3 ± 6.7 ; girls: 109.0 ± 7.5 and 63.0 ± 6.0 . Denmark: boys: 106.0 ± 7.3 and 63.3 ± 5.8 ; girls: 104.6 ± 7.8 and 62.60 ± 5.6).

Clustering of CVD risk factors is the coexistence of elevated levels in several risk factors in the same subject, and a composite risk factor score is now considerable as a good method for assessing children's cardiovascular health (Steele et al., 2008). This is mainly due to the fact that health outcomes are not well defined in children and that cut-off points for single risk factors are not established in children, with the exception of BMI (Cole et al., 2000). Additionally, there is a weak association between fitness and single CVD risk factors (Andersen et al., 2006). Finally, clustered risk can, to some extent, compensate for the day-to-day fluctuation in the single risk factors. It is therefore reasonable to investigate a composite CVD risk factor score rather than single variables. In the present study, clustering was defined as a child having four, five or six CVD risk factors by sex, and 11.9% ($n = 27$) of the children displayed this clustered risk. This percentage level is similar to the results reported elsewhere (Andersen et al., 2006). The children thus defined as being *at risk* were evenly distributed in the normal BMI group ($n = 12$) and the overweight/obese group ($n = 15$), indicating that BMI status alone is not an ideal method to define a CVD risk factor profile in children.

Recently, it was shown that low fitness is a strong predictor for clustering of CVD risk factors in children (Anderssen et al., 2007). The present study supports this conclusion, as both boys and girls with three, four or five risk factors had a significantly lower VO_{2peak} than the children with two or less risk factors ($P < 0.001$; Table 3). Moreover, the children in the least fit quartile had significantly poorer CVD risk factor values than all of those in the other quartiles. In the present study, the associations between fitness and the clustered risk score were weakened when waist circumference was excluded from the clustered risk score. It is difficult to determine whether adiposity confounds, mediates or modifies the association between fitness and metabolic health (Steele et al., 2008). In the present study, children with a clustered risk (those with three, four

or five risk factors) were significantly heavier than children without clustered risk ($P < 0.000$). Fitness in the present study, and in most other studies addressing this problem, is expressed in relation to whole body mass (mL/kg/min). As fitness is strongly related to body mass, we also performed an analysis where fitness was scaled to body mass^{0.67}. The results showed a weaker but still significant relationship for both sexes (boys $P = 0.004$, girls $P = 0.009$). This conclusion is similar to that drawn by Ekelund et al. (2007) analyzing data from the EYHS. Ekelund et al. (2007) removed adiposity from the outcome by normalizing fitness by fat-free mass, but still found a significant although tenuous association between fitness and CVD risk factors. Andersen et al. (2008) analyzed the association between quartiles of fitness and sum of the z -score in a much larger sample of 9-year-old children. They found that removing the fatness parameter from the z -score attenuated the association, and further adjustment for fatness decreased the association more, but the association between fitness and clustered risk still remained significant. These findings indicate that confounding is unlikely to explain all of the association, or alternatively that some of the effects of fitness on clustered metabolic risk are mediated by adiposity. However, even if fatness may mediate part of the association between clustered risk and fitness, the lower fat in the more fit individuals may still be caused by exercise, and it may be very difficult to train a fat subject without a change in abdominal fat mass. The findings of the present study, therefore, support the hypothesis that fitness is independently associated with clustered CVD risk in 9-year-old children.

Although there are a limited number of solid studies investigating the association between cardiorespiratory fitness and cardiovascular risk factor clustering in children (Brage et al., 2004; Anderssen et al., 2007; Eisenmann et al., 2007; Ekelund et al., 2007; Rizzo et al., 2007; Ruiz et al., 2007; Kriemler et al., 2008), there seems to be a clear trend in which low fitness is strongly associated with clustered metabolic risk, and that high fitness is strongly associated with a healthy metabolic profile in children. If future studies continue to confirm this trend, it might be warranted that cardiorespiratory fitness become part of the definition of the metabolic syndrome in children.

Two recent studies (Eisenmann et al., 2007; Andersen et al., 2008) showed that the highest levels of CVD risk factors were found in children who were both overweight and had a low fitness. DuBose et al. (2007) reported similar results. Based on these findings, different fit-fat groups were compared with CVD risk factors by sex. We were not able to perform the same analysis as Eisenmann et al.

(2007) due to an inadequate sample size, as our *fit and overweight/obese group* was excluded because there was only one boy and no girls in this group. For girls, the unfit and overweight/obese group had significantly poorer values than the fit and normal body mass group in all five CVD risk factors. The same strong pattern was not shown in boys, as only two risk factors, waist and systolic BP, were significantly higher among the unfit and overweight/obese. A possible explanation could be the small sample size for boys, as only nine subjects were classified as unfit and overweight/obese, compared with the 20 subjects for the girls. However, when analyzing the CVD risk factors as a clustered risk, we found that for both sexes the unfit and overweight/obese group had a significantly higher CVD risk factor clustering z -score than *the fit and normal-weight group*. Our findings add to the body of evidence that the combination of unfit (low fitness) and fat (overweight/obese) in children could be regarded as unhealthy and that this condition could pose a health hazard in the long term for these individuals.

The main strengths of the present study were its accurate and high-quality measurements including insulin resistance and blood lipids and *direct* measurement of VO_{2peak} . The high mean HR_{peak} (204.3 ± 7.2) suggests that a reliable VO_{2peak} was obtained. Additionally, the high participation and completion rates made our sample highly representative of the 9 year-olds in these two rural communities where testing was performed. There are limitations regarding the generalization of these results, and the data from the present study may not be representative for the whole country. Also, pubertal status was not assessed. Especially for girls, this factor cannot be excluded, as some of the girls tested most likely had started puberty. Dietary status was not registered. The cross-sectional design does not allow conclusions based on causal inferences. There are also limitations to the z -score approach. First, it is based on the assumption that each selected variable is equally important in defining CVD risk. Second, the risk is specific to this sample only. Although a child may be defined as at risk (being in the most unfavorable quartile) it does not necessarily mean that the child has high levels of CVD risk factors *per se*. The child could simply be placed in the unfavorable quartile because of genetics or normal biological variations. Still, even in this group of healthy rural children, clustering is not a desirable condition.

Perspectives

In conclusion, the results show that clustering of CVD risk factors exists in apparently healthy rural

Norwegian children. From a public health perspective, the existence of clustering highlights the need to develop more effective strategies to prevent CVD in childhood, as clustering of CVD risk factors could be viewed as a forewarning for CVD. The present study also shows that low fitness alone, *and* low fitness and high fatness combined, are highly associated with clustered CVD risk. These results support the hypothesis that fitness is an important health marker in children. Additionally, the results indicate that fitness status could define target populations for intervention. Finally, the strong association between fitness and CVD risk factors adds to the argument

for increasing health-related fitness testing among children.

Key words: BMI, VO_{2peak}, z-score.

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APPENDIX 1-7

APPENDIX 1:

Physically activity and physical education in the Norwegian school system

Physically activity and physical education in the Norwegian school system

In the Norwegian school system today there are three main opportunities for children to be physically active: A) *PE* (kroppsøving) (478 school-hours over the first seven years and 228 school-hours in 8th to 10th grade). In total, over the ten school-years, 706 school-hours, which translates into 9.2% of all time used for school-subjects. B) *Physical activity*; introduced in the school-year 2009/2010 for 5th to 7th grade (76 school-hours á 60 minutes over the three years). C) Free play in recess. In addition, schools offer physical activity in after-school programs (skulefritidsordning). There is a need to distinguish between *PE* and *physical activity*. On the one hand, *PE* is a standardized part of the school curriculum, and therefore a school subject that has defined educational objectives which place demands on the competence of the teachers. On the other hand, *physical activity*, which is not a part of *physical education*, does not have defined educational objectives and therefore does not demand formally qualified teaching staff. Therefore, the school leaders in Norway are now free to decide whether they want to use PE teachers, regular class-room teachers or school-assistants in the planning and carrying out of the *physical activity*-classes. Obviously, with this freedom, in a pressured financial situation, school-leaders overburdened with various curriculum mandates due to the emphasis on basic academic standards might opt to use school-assistants, or even define that the *physical activity*-classes should be carried out as a part of an extended recess. From a physical activity perspective, this downgrading of *physical activity* is unacceptable.

APPENDIX 2

Statement from Bjarte Ramstad; Principal at Trudvang School.

(bjarte.ramstad@sogndal.kommune.no). November 2009.



TRUDVANG SKULE
BOKS 01
6851 SOGNDAL
Bjarte.Ramstad@sogndal.kommune.no
Tlf. 57 02 97 80, 95 00 58 83

Dagleg lærerstyrt fysisk aktivitet på Trudvang skule

I perioden 2004 til 2007 var skulen med på eit prosjekt: 60 minutt dagleg fysisk aktivitet. Det var ulike elevar som var med på dette (eitt og eitt trinn, til saman 6 klassar). I 2005 starta skulen opp med 25 minutt dagleg fysisk aktivitet for alle klassane. I tillegg kom fruktpausen inn med 10 minutt. Fram til prosjektperioden enda i 2007 dreiv me dette opplegget vidare på litt ulike måtar.

Sommaren 2007 måtte skulen bestemme framhald på satsinga sjølve. Lokalt engasjement og sentrale retningslinjer måtte takast ned i vår lokale modell. Skulen og lærarane er eintrådige på at dagleg fysisk aktivitet har vore kvalitetshevande i forhold til fysisk helse (folkehelse), sosialt samhald, nye meistringsarenaer og mange av oss ser og koplinga mot faglege resultat. Det skulen såg på som svært viktig var at dersom me skulle gå for dagleg fysisk aktivitet var kvalitet viktig. I tillegg med dei sentrale betraktningane gjorde dette til at det å gå vidare med lest i den opphavlege modellen var svært lett for oss.

Modellen skulen driv etter i dag er 30 minuttar dagleg lærerstyrt fysisk aktivitet med fokus på aktivitet og fagleg innhald. For å få til dette har me implementert fysisk aktivitet i fag- og timefordelinga ved skulen. Me omfordeler 6% av timetalet i faga (inkludert kroppsoving) til fysisk aktivitet, samstundes som me nyttar fysisk aktivitet til måloppnåing i alle fag. Dette betyr at fysisk aktivitet er å rekne som eit "fag" med innhald frå dei vanlege faga og gjev fagleg føre- og etterarbeid frå læraren som har det. I tillegg kjem minst 35 minutt uregulert friminutt per dag. Elevane ved skulen har dermed tilbod om minst 65 minutt dagleg fysisk aktivitet, der mykje er kvalitetssikra gjennom lærarstyring. Fysisk aktivitet er lagt opp klassevis, men er oftast lagt samstundes på dei tre klassane skulen har på same trinn for å gje mogelegheit til felles aktivitetar på trinnet. Den sosiale gevinsten med å gjere det på denne måten er svært framtrudende. I tillegg er øktene med fysisk aktivitet etterfølgt av ein fruktpause.

I prosjektperioden var foreldra involvert frå første stund. Etter grundige gjennomgangar frå mellom anna doktorgradsstipendiat Geir Kåre Resaland var foreldra utehukkande positive til prosjektet.

Eg ser at skulen i dag har eit press frå mange ulike aktørar om å få innpass i skulekvardagen, døme på dette kan vere kulturskulen, skulemåltid og fysisk aktivitet. Fysisk aktivitet er for oss noko som i dag er ein heilt normal del av skuledrifta vår. Både dei tilsette, lærarane og elevane er einige om at dette er med på å gje oss ein kvalitativ betre skule, dette både heilskapleg og særleg overfor dei elevane / familiane som fell utanom regulert trening / kosthaldsproblematikk. Dei sentrale rammene som ikkje er komne har gjort til at me har måtta valt vår modell, me er i dag glade for å ha valt slik me har gjort. Implementeringa av 2 veketimar til fysisk aktivitet som kom hausten 2009 vil me leggje inn i denne modellen. Det er for oss uaktuelt å gå tilbake til bruk av ufaglært kompetanse på dette.

Ein av suksessfaktorane er at kompetansen på fysisk aktivitet og kroppsoving er tilstades på huset. Me har 12 tilsette med vidareutdanning i faget. Desse er med på å halde fagrykket oppe, både opp mot førebuing, utval av aktivitetar og samkøyring mellom klassar. Me ser og ein tydeleg link mellom fysisk-aktivitet og det at elevane dreg med seg eit rikare aktivitetsutval til dei frie friminutta. Modellen vår fører og til eit unikt eigarskap til fysisk aktivitet der kontaktlærar ofte er den som har aktiviteten og kan knytte den mot resten av klassedrifta.

Forholdet mellom fysisk aktivitet og faget kroppsoving er hjå oss klårt. Fysisk aktivitet har eit folkehelseperspektiv, faget kroppsoving er å nå måla sette for faget i Kunnskapsløftet 2006. Det er mi oppfatning at desse to delane av skuledagen er nær likestilte når det gjeld status og tidsbruk frå dei ansvarlege lærarane.

I tillegg gjev Trudvang skule tilbod om både aktivitets-SFO og idretts-SFO.

Bjarte Ramstad

Rektor Trudvang skule

23. november 2009

Sogndal kommune
Postboks 153
6851 SOGNDAL

Tlf: 57 02 98 00
Faks: 57 02 98 01
E-post: post@ogndal.kommune.no

APPENDIX 3

Informed consent



Førespurnad om deltaking i forskingsprosjektet; *Verknad av dagleg fysisk aktivitet i skulen.*

Dette er eit informasjonsskriv til deg som foreldre/føresette med førespurnad om deltaking for ditt barn i prosjektet *Verknad av dagleg fysisk aktivitet i skulen*. Prosjektet er del av eit doktorgradsarbeid av høgskulelektor Geir Kåre Resaland ved Høgskulen i Sogn og Fjordane.

Prosjektet vil bli gjennomført i skuleåra 2004/05-2006/07, og vil føregå på to barneskular i Sogn og Fjordane.

Ved den eine skulen (Trudvang skule i Sogndal) vil alle 4. klassingane gjennomføre 60 minutt dagleg fysisk aktivitet. Trudvang skule ved rektor Aud Marion Larsen har takka ja til å delta i prosjektet, og inkludert fysisk aktivitet som ein del av skulen sin utviklingsplan for perioden 2003-2005.

Den andre skulen (Flatene skule i Førde) vil fungere som kontrollskule, og gjennomføre vanleg kroppsøving to gangar i veka. Flatane skule ved rektor Åge Stafsnes har skriftleg takka ja til å delta i prosjektet.

Det vil bli gjennomført testar før prosjektet startar og etter at prosjektet er avslutta. Dette vil vere fysisk form, blodtrykk, midjeomkrins, vekt og høgde. Det vil òg bli teke ei blodprøve for å undersøke insulin, kolesterol, blodfeitt og fastande blodsukker hjå forsøkspersonane.

Det vil under all testing bli lagt vekt på barnet sitt beste, og forsøksleiarane er svært medviten om at forsøkspersonane er barn, og dermed sårbare. Alle moglege førhandsreglar vil bli tekne for å minimalisera eventuelle situasjonar som kan opplevast som ubehaglege for barna. Til dømes vil alle blodprøvar bli tekne i trygge lokale (barneskulen) av helsepersonell som har erfaring med barn. Foreldre/føresette vil få tilbod om å vere med barnet ved alle testar.

Det er frivillig å delta i alle testane. Ein kan trekke seg frå testing når som helst og utan å oppgi grunn, og utan at det får negative konsekvensar. Dersom foreldre/føresette ynskjer å trekke sitt barn frå testinga, vil allereie innsamla data ikkje bli sletta, og informasjon som er samla inn om ditt barn vil fortsatt nyttast i samband med dette prosjektet. Foreldre/føresette har imidlertid rett til å vite kva informasjon som blir oppbevara.

Prosjektleiari vil informere munnleg om prosjektet ved foreldremøte. Foreldre/føresette vil få tilgang til opplysningar om sitt barn undervegs og etter at prosjektet er avslutta. All data vil bli behandla konfidensielt og oppbevara i sikre lokale ved Høgskulen i Sogn og Fjordane. Skulane registrerar elevane sitt fråver. Dette vil bli nytta i datamateriale, og bli behandla på same konfidensielle måte som anna sensitiv data.

Foreldre/føresette vil bli bedt om å fylle ut eit spørjeskjema som omhandlar vaner og haldningar til fysisk aktivitet, sosioøkonomisk status samt opplysningar om alder osv. Det er eit mål å publisere resultatane i form av fire engelskspråklege artiklar i internasjonal faglitteratur. Det er òg eit mål å formidle resultatane til det norske fagmiljøet i form av populærvitenskaplege artiklar og faglege føredrag. I den samanheng ynskjar me å presisere at opplysningar som kjem fram i publikasjonar og føredrag ikkje kan førast tilbake til enkeltpersonar.

HSF er oppdragsgivar for prosjektet og finansierer løn til Resaland samt driftsutgifter. I tillegg vil delar av testingane finansierast av eksterne kjelder. HSF er ansvarleg for å dekke forsøkspersonane ved eventuelle uhell eller komplikasjonar.

Studien er vurdert og klarert av Regional komité for medisinsk forskningsetikk, Vest-Noreg (REK Vest) og personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste.

Prosjektet vil i utgangspunktet verte avslutta i august 2008. Det kan bli aktuelt med oppfølgingsundersøkingar, i så fall vil prosjektleiari ta kontakt med foreldre/føresette innan prosjektet avsluttast. Dersom ikkje vil datamaterialet på dette tidspunkt anonymiserast. Fordi det er moglegheit for at det vil bli gjennomført oppfølgingsundersøkingar vil blodprøver oppbevarast til prosjektslutt.

Teoretisk bakgrunn for prosjektet:

Det er vist at regelbunden fysisk aktivitet har ei rad gunstige påverknadar for vår helse. Det er òg data som indikerar at barn og unge i Noreg i dag er mindre fysisk aktive og i dårlegare fysisk form enn barn og unge i tidlegare generasjonar, samtidig som vekta til barn og unge går opp. Det er òg vist at regelbunden fysisk aktivitet hjå barn er viktig for normal vekst og utvikling, og for normal utvikling av ulike organ i kroppen. Det er òg generelt akseptert at mange kroniske tilstandar startar tidleg i tidleg barndom, og at strategiar for å førebygge bør starte så tidleg i livet som mogleg.

Dei vitenskaplege bevisa som danner grunnlag for anbefalingar i forhold til fysisk aktivitet for barn er relativt svake, og at det i dag ikkje er gode nok rettingslinjer for anbefalingar. Me veit lite om effekten av tiltak for barn. Der er derfor behov for vitenskapleg baserte undersøkingar omkring meir fysisk aktivitet i skulen, slik at tiltak som settast inn er basert på forskning og utprøving.

Seniorforskar ved Norges Idrettshøgskole Lars Bo Andersen vil vere hovudrettleiarar, og førsteamanuensis/forsker ved Norges Idrettshøgskole Sigmund Anderssen vil vere birettleiar. Dei har begge lang erfaring frå tilsvarande undersøkingar, til dømes frå European Youth Heart Study, der over 4000 barn har gjort liknande testar som me ynskjer å gjere i dette prosjektet.

Dersom de på noko tidspunkt har spørsmål, ta gjerne kontakt på telefon (41621333 eller 57676097) eller e-post (geir.kare.resaland@hisf.no).

Vennleg helsing

Geir K. Resaland
Høgskulen i Sogn og Fjordane

August 2005, Sogndal

Prosjektet;

Verknad av dagleg fysisk aktivitet i skulen

Erklæring om samtykke

Eg har motteke skriftleg og munnleg informasjon og aksepterar at mitt barn deltek i prosjektet.

Signatur _____

Signatur _____

Dato _____

APPENDIX 4

Approval letter from the Regional Committees for Medical Research Ethics

UNIVERSITETET I BERGEN

Det medisinske fakultet

Harald Hårfagresgt. 1,
Postboks 7800, 5020 BERGEN
Tlf: 55 58 20 84/86
Fax: 55 58 96 82
E-post: Rek-3@uib.no



UNIVERSITY OF BERGEN

Faculty of Medicine

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Fax: +47 55 58 96 82
E-mail: Rek-3@uib.no

<http://www.etikkom.no/REK/>

*Regional komité for
medisinsk forskningsetikk
Vest-Norge (REK Vest)*

Bergen, 15.09.04
Sak nr: 04/6235

Høgskulelektor Geir Kåre Resaland
Høgskulen i Sogn og Fjordane
Kjyrkjebakken 37B
6856 SANDANE

Ad prosjekt: Verknad av dagleg fysisk aktivitet i skulen (REK Vest nr. 143.04)

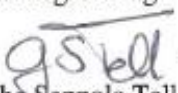
Ein syner til ditt brev dagsett 28.07.04 med svar på komiteen sine merknader, søknad om oppretting av forskingsbiobank og revidert førespurnad om deltaking..

REK Vest v/leiar har vurdert saka. Overskrift på førespurnad bør vera "Førespurnad om deltaking i forskningsprosjekt Verknad av dagleg fysisk aktivitet i skulen".

Då ein ventar dette vert teke til fylgje er studien, inklusiv søknad om oppretting av forskingsbiobank, endeleg klarert frå denne komité sin side. En ber om å få tilsendt retta skriv for vårt arkiv.

Ein ynskjer deg lukke til med gjennomføringa og minner om at komiteen setter pris på ein sluttrapport, eventuelt ein kopi av trykt publikasjon når studien er fullført.

Vennleg helsing


Grethe Seppola Tell
leiar


Arne Salbu
sekretær

APPENDIX 5

Approval letter from the Norwegian Social Science Data Service

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES



Hans Holmboes gate 22
N-5007 Bergen
Norway
Tel: +47/ 55 58 21 17
Fax: +47/ 55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org. nr. 985 321 884

Geir Kåre Resaland
Avdeling for lærerutdanning
Høgskolen i Sogn og Fjordane
Postboks 133
6852 SOGNDAL

Vår dato: 16.07.2004

Vår ref: 200400783 SM /RH

Deres dato:

Deres ref:

KVITTERING FRA PERSONVERNOMBUDET

Vi viser til melding om behandling av personopplysninger, mottatt 24.06.2004. Meldingen gjelder prosjektet:

11223 Verknad av dagleg fysisk aktivitet i skulen - Ein eksperimentell oppfølgingstudie på barnesteget

Norsk samfunnsvitenskapelig datatjeneste AS er utpekt som personvernombud av Høgskolen i Sogn og Fjordane, 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:

- førstegangskontakt opprettes på grunnlag av offentlig tilgjengelige registre eller gjennom en faglig ansvarlig person ved virksomheten der respondenter er registrert,
- respondenten, eller dennes verge dersom vedkommende er umyndig, har samtykket i alle deler av undersøkelsen,
- prosjektet skal avsluttes på et tidspunkt som er fastsatt før prosjektet settes i gang,
- det innsamlede materialet anonymiseres eller slettes ved prosjektavslutning,
- prosjektet ikke gjør bruk av elektronisk sammenstilling av personregistre.

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

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, 31.08.2008, rette en henvendelse angående arkivering av data benyttet i prosjektet.

Vennlig hilsen


Atle Alvheim



Siv Midthassel

Kontaktperson: Siv Midthassel tlf: 55588334

Vedlegg: Prosjektbeskrivelse

APPENDIX 6

The Norwegian Directorate of Health; the Biobank Act.



Geir Kåre Resaland
Høgskulen i Sogn og Fjordane
Postboks 133
6856 SOGDAL

Deres ref:
Saksbehandler: pre
Vår ref: 04/4816 TSP/PRE
Arkivkode:
Dato: 26.11.2004

Melding om opprettelse av forskningsbiobank i forbindelse med prosjektet: Verknad av daglig fysisk aktivitet i skulen

Vi viser til brev av 29. september 2004 vedrørende ovennevnte, samt til direktoratets foreløpige svar av 11. november 2004.


Sosial- og helsedirektoratet er delegert å vurdere meldinger om opprettelse av forskningsbiobanker i henhold til biobankloven § 4. Direktoratet har ingen innsigelser til at forskningsbiobanken opprettes i henhold til biobankloven.

Direktoratet forutsetter at opprettelsen av den planlagte forskningsbiobanken oppfyller nødvendige krav til godkjenning, konsesjon m.v. i henhold til annet relevant regelverk, herunder biotekn loven, helseregisterloven og legemiddel loven.

I informasjonsskrivet/samtykkeerklæringen avsnitt 8 sies det at allerede innsamlede data ikke vil bli slettet, og informasjon som er samlet inn fortsatt vil bli benyttet i prosjektet. Dette er i strid med utgangspunktet i biobankloven § 14 om tilbakekall av samtykke, hvor det slås fast at en i så fall kan kreve det biologiske materialet destruert og innsamlede helse- og personopplysninger slettet eller utlevert (såfremt de ikke er anonyme eller har gått inn i analysen). Direktoratet forutsetter at informasjonsskrivet/samtykkeerklæringen rettes slik at det ikke er i strid med loven.

Meldingen om forskningsbiobanken vil bli sendt til Nasjonalt folkehelseinstitutt som har fått ansvaret for å føre et offentlig tilgjengelig register over landets biobanker, jf. biobankloven § 6.

Med vennlig hilsen


Hans Petter Aarseth e.f.
avdelingsdirektør


Pål Rune Etterlid
rådgiver

Sosial- og helsedirektoratet
Avdeling for spesialisthelsetjenester

Postadr: Pb 7000 St Olavs plass, 0130 Oslo • Besøksadr: Universitetsgaten 2, Oslo
Tel: 24 16 30 00 • Faks: 24 16 30 08 • Org.nr.: 983 544 622 • postmottak@shdir.no • www.shdir.no/is

APPENDIX 7

Trudvang School has published a report on its website summarising the school's experience with the *the Sogndal school-intervention study*. The report is called “Physical activity as a natural part of the school day at Trudvang School”:

Go to:

http://www.trudvang.skule.no/filer/trudvang_skule_dagleg_fysisk_aktivitet.pdf