PHYSICAL ACTIVITY FROM ADOLESCENCE TO ADULTHOOD AND HEALTH-RELATED FITNESS AT AGE 31

Cross-sectional and longitudinal analyses of the Northern Finland birth cohort of 1966

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Abstract in Finnish

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Abstract

Regular physical activity, a high level of cardiorespiratory fitness and the maintenance of normal weight are strongly associated with several positive health outcomes across the lifespan. The aim of this study was to evaluate how physical activity and social status in adolescence are associated with physical activity in adulthood, and how a change in the level of physical activity from adolescence to adulthood is associated with overall and abdominal obesity in adulthood. This study also evaluated the relationship between occupational physical activity and physical fitness and produced reference values of cardiorespiratory fitness for males and females aged 31 years.

The study population consisted of the Northern Finland birth cohort of 1966 (N = 12,058). Data on physical activity and social situation at 14 and 31 years were collected by postal inquiries in 1980 and in 1997–1998, respectively. Cardiorespiratory fitness, muscular fitness and obesity were measured at medical examination at age 31.

Participation in sports twice a week or more after school hours, being a member in a sports club and a high grade in school sports at age 14 were associated with a high level of physical activity at age 31. Adolescent participation in rather intensive endurance sports, and some sports that require or encourage diversified sports skills appeared to be the most beneficial with respect to the enhancement of adult physical activity. Low social class and poor school achievements were associated with physical inactivity at age 14. Poor school achievements at age 14 were also associated with physical inactivity at age 31. Becoming inactive during the transition from adolescence to adulthood was associated with overall obesity in both genders and abdominal obesity in females at 31 years.

A linear dose-response relationship was observed between the frequency of participation in brisk exercise and cardiorespiratory fitness. The mean peak oxygen uptake was 43 $ml \cdot kg^{-1} \cdot min^{-1}$ in males and 34 $ml \cdot kg^{-1} \cdot min^{-1}$ in females. Very low levels of cardiorespiratory fitness were associated with a combination of infrequent participation in brisk exercise and increased body mass index. High level of occupational physical activity was associated with a high level of physical fitness, but low level of leisure-time physical activity at age 31.

The enhancement of regular participation in physical activity across the lifespan is an important challenge for public health promotion. The present results that define the predictors and correlates of physical activity can be used to identify the target groups for interventions to enhance continuous participation in physical activities. New information on physical fitness of young adults is useful in physical activity counseling when fitness test results are interpreted and the need for health-enhancing or fitness-improving physical activity is evaluated.

Keywords: adolescent, adult, exercise, leisure activities, longitudinal studies, obesity, physical fitness, social class, sports, work

Tammelin, Tuija, Liikunta-aktiivisuus nuoruudesta aikuisikään sekä fyysinen kunto ja lihavuus 31-vuotiaana. Pohjois-Suomen vuoden 1966 syntymäkohortin seuranta-tutkimus
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2003
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Tiivistelmä

Säännöllinen liikunta, hyvä fyysinen kunto ja normaali paino ovat yhteydessä hyvään terveyteen. Tämän tutkimuksen tavoitteena oli selvittää, miten liikunta-aktiivisuus ja sosiaaliset tekijät nuoruusiässä ovat yhteydessä liikunta-aktiivisuuteen aikuisena, sekä miten liikunta-aktiivisuuden muutos nuoruudesta aikuisikään on yhteydessä lihavuuteen ja keskivartalolihavuuteen aikuisena. Lisäksi selvitettiin raskaan ruumiillisen työn yhteyttä fyysiseen kuntoon nuorilla työntekijöillä ja luotiin aerobisen kunnon väestöpohjaiset viitearvot 31-vuotiaille.

Tutkimusaineiston muodosti Pohjois-Suomen syntymäkohortti 1966 (N = 12058). Liikunta-aktiivisuus selvitettiin postikyselyin 14- ja 31-vuotiaana vuosina 1980 ja 1997–1998. Aerobinen kunto, lihaskunto, lihavuus ja keskivartalolihavuus mitattiin 31-vuotiaana terveystarkastuksessa.

Urheilun harrastaminen kaksi kertaa viikossa tai useammin kouluajan ulkopuolella, kuuluminen urheiluseuraan ja hyvä liikuntanumero 14-vuotiaana olivat yhteydessä aktiiviseen liikkumiseen 31-vuotiaana. Intensiivisten kestävyyslajien sekä tiettyjen monipuolisia taitoja vaativien tai kehittävien lajien harrastaminen nuorena oli voimakkaimmin yhteydessä aktiiviseen liikkumiseen aikuisena. Heikko sosioekonominen asema ja heikko koulumenestys olivat yhteydessä liikkumattomuuteen 14-vuotiaana. Heikko koulumenestys 14-vuotiaana ennusti liikkumattomuutta myös 31-vuotiaana. Muutos liikunnallisesti aktiivisesta inaktiiviseksi 14 ja 31 ikävuoden välillä oli sekä miehillä että naisilla yhteydessä lihavuuteen ja naisilla keskivartalolihavuuteen 31-vuotiaana.

Maksimaalinen hapenottokyky oli kohortin 31-vuotiailla miehillä keskimäärin 43 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ ja naisilla 34 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$. Ripeän liikunnan harrastaminen oli positiivisesti ja lineaarisesti yhteydessä maksimaaliseen hapenottokykyyn. Erittäin matala maksimaalinen hapenottokyky havaittiin niillä 31-vuotiailla, jotka harrastivat harvoin ripeää liikuntaa ja olivat ylipainoisia tai lihavia. Raskas ruumiillinen työ oli yhteydessä hyvään fyysiseen kuntoon mutta vähäiseen vapaa-ajan liikuntaan 31-vuotiailla työntekijöillä.

Liikunta-aktiivisuuden tukeminen elämänkulun eri vaiheissa on tärkeä haaste terveyden edistämisessä. Tämän tutkimuksen tuloksia liikkumattomuuteen liittyvistä nuoruusiän ja aikuisiän tekijöistä voidaan hyödyntää, kun määritellään kohderyhmiä interventioihin elinikäisen liikunnan edistämiseksi. Tuloksia nuorten aikuisten fyysiseen kuntoon liittyvistä tekijöistä voidaan hyödyntää käytännön liikuntaneuvonnassa, kun tulkitaan kuntotestien tuloksia ja määritellään tarvetta terveyttä edistävän ja fyysistä kuntoa kohottavan liikunnan lisäämiseksi.

Asiasanat: aikuisuus, fyysinen kunto, lihavuus, liikunta, nuoruus, pitkittäistutkimus, ruumiillinen työ, sosiaalinen asema

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Oulu, November 2003 Tuija Tammelin

Abbreviations

β	regression coefficient (table 10)
BMI	body mass index, kg/m^2
CI	confidence interval
HR	hazard ratio (in figure 8)
HR	heart rate after step test, beats/min (in prediction models)
OR	odds ratio
PA	physical activity (in appendix tables)
PA	frequency of participation in brisk physical activity, times/week (in prediction models)
R^2	multiple correlation squared, the proportion of the variation explained by the model
SE	standard error of the estimation model (table 10)
SEE	standard error of the coefficient (table 10)
$\dot{V}O_{2max}$	maximal oxygen consumption, maximal aerobic power, $ml \cdot kg^{-1} \cdot min^{-1}$
$\dot{V}O_{2peak}$	peak oxygen consumption, $ml \cdot kg^{-1} \cdot min^{-1}$
WC	waist circumference, cm

List of original articles

I Tammelin T, Näyhä S, Hills AP & Järvelin M-R (2003) Adolescent participation in sports and adult physical activity. American Journal of Preventive Medicine 24, 1: 22–28.

II Tammelin T, Näyhä S, Laitinen J, Rintamäki H & Järvelin M-R (2003) Physical activity and social status in adolescence as predictors of physical inactivity in adulthood? Preventive Medicine 37, 4: 375–381.

III Tammelin, Laitinen & Näyhä. Continued physical activity from adolescence into adulthood and obesity and abdominal obesity at the age of 31 years. Submitted.

IV Tammelin T, Näyhä S, Rintamäki H & Zitting P (2002) Occupational physical activity is related to physical fitness in young workers. Med Sci Sports Exerc, 34, 1: 158–166.

V Tammelin T, Näyhä S & Rintamäki H. Cardiorespiratory fitness of males and females of Northern Finland birth cohort of 1966 at age 31. Int J Sports Med. In press.

Original articles are referred to in the text by the Roman numerals I–V.

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1 Introduction

Physical inactivity, a low level of cardiorespiratory fitness and obesity are related to many chronic diseases (U.S. Department of Health and Human Services 1996, WHO 1998). Therefore, the enhancement of regular participation in physical activity across the lifespan is an important challenge for public health promotion.

The trends in physical activity have been positive and promising in Finland during the last 20 years, but at the same time the trends in physical fitness and obesity have been alarming. Among adolescents, participation in sport club activities has increased and the proportion of very active individuals increased in 1977–1999 (Hämäläinen *et al*. 2000). In adult population, the proportion of completely sedentary individuals has decreased, and participation in leisure-time physical activity has increased during the last 25 years (Barengo *et al.* 2002).

At the same time, however, the prevalence of obesity has increased in Finland among both adolescents (Kautiainen *et al.* 2002) and adults (Lahti-Koski 2001). This increasing trend in obesity suggests that increase in leisure-time physical activity does not counterbalance the decrease observed in occupational and commuting physical activity among adults (Fogelholm *et al.* 1996). The reported increase in leisure-time physical activity is not in line with the decrease in cardiorespiratory fitness among Finnish young men. This decline has been observed in the results of the 12-minute running test performed during compulsory military service in 1975–2002 (Vasankari *et al.* 2003). A similar declining trend has also been observed in the test results of cardiorespiratory fitness in Finnish schools in 1976–2001 (Nupponen & Huotari 2002). Maybe the modes of leisure-time physical activity have changed, and the types of physical activity are not brisk enough to improve and maintain a high level of cardiorespiratory fitness.

The total amount of physical activity declines dramatically during the adolescent years (Telama *et al.* 1997, Hämäläinen *et al*. 2000). Therefore, the time period from adolescence into adulthood is an important and interesting target for research. It would be useful to evaluate the types of participation in youth that are most beneficial in terms of lifelong participation in physical activity. It also seems useful to identify the groups that are at risk of dropping out from a physically active lifestyle and therefore need some special support.

A longitudinal study of the Northern Finland birth cohort of 1966 enabled us to provide new information about the factors associated with these topical items: physical activity, health-related fitness and obesity during the transition from youth to adulthood. This study evaluated how physical activity and social status in adolescence are associated with physical activity in adulthood, and how a change in the level of physical activity from adolescence to adulthood is associated with overall and abdominal obesity in adulthood. The relationship between occupational physical activity and physical fitness in young workers was also evaluated. In addition, population-based reference values of cardiorespiratory fitness were produced for young adults.

2 Review of the literature

2.1 Definitions of physical activity, fitness and health

Physical activity is most often defined in the context of energy expenditure as any bodily movement produced by skeletal muscles that substantially increases energy expenditure over the resting level (Bouchard & Shephard 1994). The dose or volume of physical activity can be calculated from the frequency, duration (time), intensity and type of physical activity. Although physical activity is often evaluated in terms of energy expenditure, it can be seen as a biocultural *behavior:* energy is expended in active behaviors that occur in different forms and cultural contexts (Malina 2001a).

Leisure-time physical activity can be defined as a broad descriptor of activities one participates in during free time, based on one's personal interests and needs. These activities include formal exercise programs as well as participation in informal activities such as walking, hiking, gardening and dancing etc. (Howley 2001.) *Exercise* is a subcategory of leisure-time physical activity and can be defined as planned, structured and repetitive physical activity, performed in oder to improve or maintain one or more components of physical fitness (Caspersen *et al.* 1995). The term *sport* is used in North America and it refers to a form of physical activity that involves competition, but in Europe, the term sport may also embrace exercise and recreation (Bouchard & Shephard 1994).

Occupational physical activity is physical activity that is associated with the performance of a job. The relatively new terms *health-related physical activity* and *health-enhancing physical activity* are sometimes used when the health effects of physical activity are in the focus. *Habitual physical activity* may be defined as the level and pattern of energy consumption during the usual activities of life, including both work and leisure (Andersen *et al.* 1978).

Physical fitness is an adaptive *state* which can be defined as a set of attributes that people have or achieve which relate to the ability to perform physical activity (Howley 2001). Physical fitness can be divided into performance and health-related fitness. *Performance-related fitness* is linked to the attributes related to performance outcomes in various sports or in certain occupations. *Health-related fitness* consists of those

components of physical fitness that are affected by habitual physical activity and that are related to health status. Health-related fitness has been defined as a state of being able to perform daily activities with vigor, and traits and capacities that are associated with a low risk of premature development of hypokinetic diseases and conditions (Bouchard & Shephard 1994).

According to the Toronto model presented by Bouchard & Shephard (1994), the components of health-related fitness are defined as morphological, muscular, motor, cardiorespiratory and metabolic fitness (Fig. 1). *Morphological fitness* refers to body composition and bone strength (Skinner & Oja 1994). Body composition describes the amount of fat mass and fatfree mass and considers also whether body fat is peripherally or abdominally distributed (Howley 2001). *Muscular or musculoskeletal fitness* refers to muscular strength, muscular endurance and flexibility, and motor fitness refers to postular control (Skinner & Oja 1994). *Cardiorespiratory fitness* reflects the ability of cardiovascular and respiratory systems to supply oxygen to the working muscles during heavy dynamic exercise (Howley 2001), and direct measurement of maximal oxygen uptake ($\dot{V}O_{2max}$) during a maximal exercise test is regarded as the gold standard for the evaluation of cardiorespiratory fitness. *Metabolic fitness* refers to carbohydrate and lipid metabolism usually defined usually by glucose tolerance, insulin sensitivity, lipid profile and the ratio of lipid to carbohydrate oxidized at rest of during steady-state exercise (Bouchard & Shephard 1994).

Childhood refers to the period until the start of puberty, *adolescence* to the period between the beginning of puberty and adulthood, and *youth* to the period between childhood and adulthood. *Adulthood* denotes the time when a person has reached maturity and is fully developed. (Sinclair *et al.* 1987.)

2.2 Relationships between physical activity, fitness and health

The relationships between physical activity, health-related fitness and health in adult population can be examined and understood by a model presented in Figure 1 (Bouchard & Shephard 1994). Physical activity may influence fitness, which in turn may modify the level of physical activity. With increasing fitness, people tend to become more active, and the fittest persons tend to be the most active. The association between fitness and health is also reciprocal. Fitness influences health, but health status also influences both physical activity and fitness. (Bouchard & Shephard 1994.)

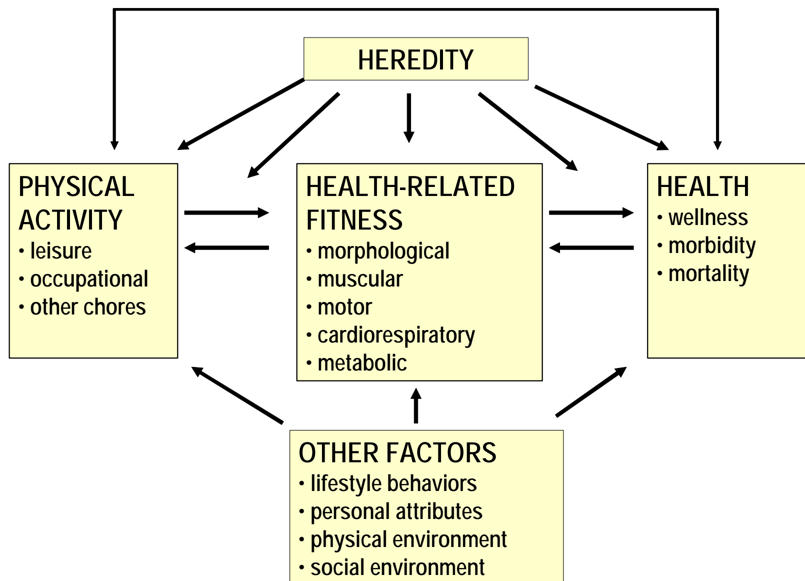

Fig. 1. A model describing the relationships between physical activity, health-related fitness and health (Bouchard & Shephard 1994).

There are also other factors that influence physical activity, fitness and health: lifestyle factors other than physical activity, personal attributes, physical environment and social environment (Fig. 1). Lifestyle behaviors include for instance smoking, diet, alcohol consumption and sleeping patterns. Several personal attributes, such as age, gender, socioeconomic status, personality, motivation and attitude toward physical activity and other health habits may shape a person's lifestyle pattern. Social environment combines social, cultural, political, and economic conditions that affect physical activity, fitness and health. Environmental conditions such as temperature, humidity, air quality, altitude and climatic changes, may influence physical activity, health-related fitness and health. (Bouchard & Shephard 1994.)

Heredity has an impact on all three components of the model: physical activity, fitness and health. There are inherited differences in the levels of physical activity and in the components of health-related fitness. Interaction between the genes and the environment is largely responsible for the variability in the health-related phenotypes in response to physical activity. Different genotypes may be at different risk for diseases associated with physical inactivity and a low level of health-related fitness. (Bouchard & Pérusse 1994.) There are marked individual differences in responsiveness to a certain dose of physical activity. Although the results of physical activity intervention studies are usually presented as the average effects of the observed groups, individual responses to a certain training program may vary between no change to 100% increase in $\dot{V}O_{2max}$ among sedentary persons. (Bouchard & Rankinen 2001.)

2.2.1 Leisure-time and occupational physical activity in relation to fitness

Increase in the volume and intensity of leisure-time physical activity is associated with increase in physical fitness in adults (Oja 2001). Exercise recommendations to improve and maintain cardiorespiratory fitness suggest exercise that uses large muscle groups, is performed three to five times a week, at intensity of 60–90% of maximum heart rate and for 20–60 minutes at a time (ACSM 1998). These latest fitness recommendations (ACSM 1998) also include guidelines for enhancing muscular fitness and flexibility.

Associations between occupational physical activity and fitness are not so clear in the light of earlier studies. Studies on the association between occupational physical activity and physical fitness are summarized in Appendix 3. In middle-aged workers, heavy physical work has been related to poor physical fitness (Era *et al.* 1992, Nygård *et al.* 1987, Torgen *et al.* 1999), although the findings have varied from a weak positive association (Sobolski *et al.* 1988, Torgen *et al.* 1999) to no association at all (Ilmarinen *et al.* 1991, Rantanen *et al*. 1993, Sobolski *et al.* 1988, Tuxworth *et al.* 1986). Two previous studies have reported a higher level of muscular strength in young manual workers than in their white-collar counterparts (Era *et al.* 1992), and better cardiorespiratory fitness in young men who daily sweat visibly at work, compared with others (Jonsson & Åstrand 1979). However, both studies mentioned above contained only small numbers of young subjects and used rather inaccurate measurements of occupational physical activity.

2.2.2 Physical inactivity, low level of cardiorespiratory fitness and obesity as risk factors

The favorable effects of regular physical activity on health are nowadays well recognized. The dose-response relationships between physical activity and health varies for different health outcomes (Kesäniemi *et al.* 2001). The general physical activity recommendation to enhance health suggests 30 minutes of moderate-intensity physical activity on most days of the week (Pate *et al.* 1995). This can be interpreted as a minimal dose of physical activity to guarantee most of the health benefits. However, the prevalence of physically inactive persons is relatively high in most western countries, emphasizing the significance of inactivity as a public health hazard (U.S. Department of Health and Human Services 1996).

A low level of physical activity is known to be associated with an increased rate of all-cause mortality (Lee & Skerrett 2001), increased incidence of cardiovascular diseases (Kohl 2001), obesity (Ross & Janssen 2001), type-2 diabetes (Kelley & Goodpaster 2001), colon cancer (Thune & Furberg 2001), osteoporosis (Vuori 2001) and depression symptoms (Dunn *et al.* 2001). Physical inactivity is also associated with an unfavorable profile of cardiovascular risk factors, such as high level of blood pressure (Fagard 2001) and blood lipids (Leon & Sanchez 2001). Among the oldest adults long-term physical activity is related to postponed disability and independent living (Spirduso & Cronin 2001).

A low level of cardiorespiratory fitness is associated with an increased risk of cardiovascular diseases and mortality (Blair *et al.* 2001, Laukkanen *et al.* 2001, Talbot *et al.* 2002), and the least fit 20% of the population is reported to be at special risk compared with moderately (the next 40%) or highly fit groups (the highest 40%) (Blair *et al.* 1989, Blair *et al.* 2001). Overall obesity is associated with an increased risk of cardiovascular diseases and type-2 diabetes (WHO 1998). The major health risks of obesity are more related to the abdominal distribution of body fat than to its total amount (Samaras & Campbell 1997). Obesity is related to physical activity and cardiorespiratroy fitness. Physical activity is a means of controlling weight by increased energy expenditure, but obesity may also influence motivation to participate in physical activities (DiPietro 1995). An increase in body fat decreases cardiorespiratory fitness, especially when cardiorespiratory fitness is expressed in relation to body weight.

2.3 Physical activity and health-related fitness – pathways from adolescence into adulthood

Physical activity may influence health-related fitness in youth and throughout life. Figure 2 illustrates potential relationships between physical activity and health-related fitness during youth and adulthood. The potential pathways from youth to adulthood are numbered as 1–6. In this chapter the pathways 1 and 5 are discussed more in depth than the others because these two potential pathways are tested in the articles I, II and III. Summary of the longitudinal studies on physical activity from youth and from youth to adulthood is presented in Appendix 1. In these summarized studies, age of the subject at baseline was less than 25 years and the follow-up time was at least two years.

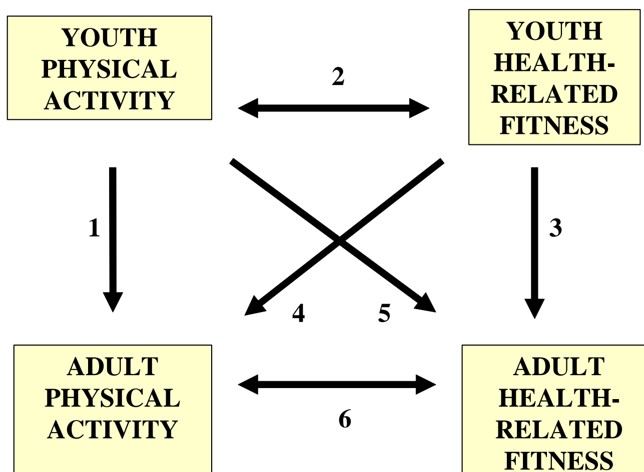

Fig. 2. A model describing the relationships between physical activity and health-related fitness in youth and adulthood and potential pathways from youth to adulthood (modified after Blair *et al.* 1989, Malina 2001a and Twisk *et al.* 2002a).

2.3.1 Pathway 1: Youth physical activity and adult physical activity

The potential relationship between youth and adult physical activity assumes that physical activity tracks from youth to adulthood (Malina 2001b). Tracking or stability refers to the tendency of individuals to maintain their rank or position within a group over time. Interage correlations between the repeated measurements are most often used to estimate tracking. The age at first observation and the time span between the measurements influences the correlations. Correlations < 0.30 are considered low, 0.30–0.60 moderate and > 0.60 high. (Malina 2001b). Correlations indicate only the association between the two measurements, but nothing about causality or determining factors. Stability of physical activity can be described by the maintenance of a given rank (e.g. active vs. inactive) over time. The association between youth and adult physical activity can also be approached by percentile or risk analyses. The prevalence (%) or probability (risk or odds) of being physically active or inactive in adulthood can be presented for different groups of adolescent physical activity or related variables.

The amount of physical activity declines with inreasing age from youth to adulthood (Campbell *et al.* 2001, Kemper *et al.* 2001b, Kimm *et al.* 2000, Telama *et al.* 1997). The decline in physical activity is steeper in males than in females after age 12 and the steepest at age 12–15 in males and at age 15–18 in females in Finland (Telama & Yang 2000). Decline in physical activity is observed especially in participation in vigorous physical activity (Barnekow-Bergkvist *et al.* 1996, Engström 1986, van Mechelen *et al.* 2000).

2.3.1.1 Youth physical activity as predictor of adult physical activity

A high level of physical activity in childhood and adolescence has been reported to be associated with a high level of physical activity in adulthood (Barnekow-Bergkvist *et al.* 1998, Engström 1986, Pietilä *et al.* 1995, Telama *et al.* 1997). Of the different physical activity variables in adolescence, frequent participation in sports (Barnekow-Bergkvist *et al.* 1996, Pietilä *et al.* 1996, Telama *et al.* 1997), participation in organized sports after school hours (Dennison *et al.* 1988), membership in a sports club (Barnekow-Bergkvist *et al.* 1996), participation in sport club training (Telama *et al.* 1997), playing sport in a school team (Dovey *et al.* 1988) and participation in competitive sports (Hirvensalo *et al.* 2000, Telama *et al.* 1997) have been associated with a high level of adult physical activity.

Being a top-level athlete in young adulthood was associated with a high physical activity level 20 years later (Fogelholm *et al.* 1994). All different athlete groups, endurance, mixed and power athletes, were more active than the controls, and the former endurance athletes were physically the most active 20 years later (Kujala *et al.* 2000). In a retrospective study of middle-aged males there was no significant difference in physical activity between former athletes and nonathletes ($p>0.05$), although former athletes were shown to be slightly more active in adulthood (Dishman *et al.* 1988). In a retrospective study of Taylor *et al.* (1999) the type of sports (team, individual, both or none) in childhood was not associated with males' physical activity level at 45 years.

Only few studies have evaluated physical inactivity as an outcome. Frequent participation in sports at age 16 was associated with a decreased risk of being inactive at age 34 (Barnekow-Bergkvist *et al.* 1996). Males who were inactive at age 17 were more likely to be inactive at age 30 than their active counterparts (Vanreusel *et al.* 1997).

There are several other factors related to adolescent physical activity which are associated with adult physical activity. High marks in physical education at school (Barnekow-Bergkvist *et al.* 1996, Glenmark *et al.* 1994, Kuh & Cooper 1992, Telama *et al.* 1997), a high level of self-rated skills in physical activity (Taylor *et al.* 1999), being satisfied with ones's own sports perfomance (Barnekow-Bergkvist *et al.* 1996) and a positive attitude towards aerobic training in males (Barnekow-Bergkvist *et al.* 1996) in adolescence have been associated with a high level of physical activity in adulthood. Being forced to exercise in childhood was negatively (Taylor *et al.* 1999), and parental and spousal encouragement of exercise in childhood was positively (Dennison *et al.* 1988, Taylor *et al.* 1999) associated with physical activity level in adulthood. Parental physical activity and fitness at age 13 did not markedly predict physical activity level at age 25 (Campbell *et al.* 2001).

2.3.1.2 Tracking of physical activity from youth to adulthood

Tracking of physical activity during adolescence and from youth to adulthood have varied from low to moderate. The closer the time span between the measurements, the higher the correlation. Over a span of 3 to 4 years, the tracking of physical activity has been moderate (Aarnio *et al.* 2002b, Janz *et al.* 2000, Raitakari *et al.* 1994, Telama *et al.* 1996, van Mechelen & Kemper 1995, Vanreusel *et al.* (1997), but over longer spans of 5 years or more, the tracking correlations have generally been lower (Andersen *et al.* 1993, Campbell *et al.* 2001, Fortier *et al.* 2001, Raitakari *et al.* 1994, Telama *et al.* 1996, van Mechelen & Kemper 1995, Vanreusel *et al.* 1997).

The tracking correlations are higher for males than for females between 9 to 21 years of age (Andersen *et al.* 1993, Raitakari *et al.* 1994, Telama *et al.* 1996) and tend to increase with age at first observation (Raitakari *et al.* 1994, Telama *et al.* 1996). Tracking for the frequency of participation in overall physical activity was lower than tracking of physical activity index or intensity of physical activity (Telama *et al.* 1996). Among these different physical activity variables, the frequency of participation in sports club training had the highest tracking correlations (Telama *et al.* 1996). In the study of Kemper *et al.* (2001a) the tracking for heavy physical activity was higher than for light physical activity. Rather intensive participation in sport seems to track better than less intensive physical activity, but an exception is a study of Vanreusel *et al.* (1997) in which the males who were very active in adolescence did not have a better chance of being active at 30 years than their moderately active counterparts, suggesting that a very active physical activity pattern is not necessary for guaranteeing an active adult life.

Sedentary behavior seems to have higher tracking in males than in females in some studies. In the study of Campbell *et al.* (2001), the tracking of physical inactivity between ages 13 and 25 years was higher in males than in females (0.25 vs. 0.06). In the study of Janz *et al.* (2002), 75% of males, but only 21% of females who were in the lowest

physical activity tertile at 11 years, remained so four years later. In the study of Andersen *et al.* (1993), 53% of males but only 8% of females were persistently inactive between ages 17 and 25 years.

2.3.1.3 Participation in different sports in youth and in adulthood

The decline in the total amount of physical activity with age has been reported to be related to the decline in the number of activities (Aaron *et al.* 2002, Dovey *et al.* 1988). Tracking correlations for participation in different types of sports have not been described earlier. Such an approach would demand a rather large study population. Aarnio *et al.* (2002b) reported that the proportion of those who were persistently active at all three annual surveys between 16 and 18 years was highest among those who at 17 participated in cross-country skiing, gym-training and ball games in both sexes, and jogging in males. This may indicate quite an active and stable physical activity pattern of the adolescents who are involved in these sports. Aaron *et al.* (2002) reported that the probability of maintaining participation in a specific activity between 14 and 18 years was low to moderate (4–71%), and the probability of not participating in a specific activity was high (70–100%), indicating that if one has not participated in some sport at 14 years, one most probably will not get involved in that sport by age 18 either.

2.3.1.4 Youth social and behavioral factors as predictors of adult physical activity

A high level of parental education (Kuh & Cooper 1992) and social class (Kuh & Cooper 1992, Pietilä *et al.* 1995) in youth have been associated with a high level of adult physical activity. As an exception for this, Barnekow-Bergkvist *et al.* 1998 reported that father's occupation as a manual worker at 16 years was associated with a high level of females' physical activity at 34 years. When own social class in adulthood was taken into account in multivariate analyses, the parental social class was not significantly associated with physical activity in adulthood (Blane *et al.* 1996). Being extrovert or extremely energetic in childhood was associated with a high level of physical activity at 34 years (Kuh & Cooper 1992).

2.3.2 Pathway 2: Youth physical activity and youth health-related fitness

The Toronto model on physical activity, fitness and health (Fig. 1) has mainly been developed based on research carried out in adult population. There is only weak evidence of the relationship between habitual physical activity and health-related fitness in youth, in contrast to a strong relationship in adulthood. Earlier results suggest that also other

factors besides physical activity have a strong impact on health-related fitness in youth. Several components of health-related fitness that respond to physical activity also change with normal growth, maturation and development from childhood to adulthood. It is thus difficult to separate the changes that are induced by enhanced physical activity from those that accompany normal maturation. More active youths have been found to be more fit in the tasks that demand good cardiorespiratory fitness, but the associations with the other components of health-related fitness are inconsistent. And reciprocally, youths classified as fit in health-related fitness tests are, on average, physically more active, but there is a lot of variability. (Malina 2001a.)

Although the health effects of physical activity in youth are less obvious than in adulthood, physical activity can have multiple beneficial health outcomes in youth as well. Physical activity can enhance psychological well-being, self-esteem, and if appropriately structured, physical activity may enhance social and moral development. Physical activity can reduce symptoms of depression and anxiety. Additionally, physical activity has small but beneficial effects on reducing body fat and beneficial associations with serum lipids, blood pressure and skeletal health in young people. (Biddle *et al.* 1998.)

2.3.3 Pathway 3: Youth health-related fitness and adult health-related fitness

Longitudinal data for different components of health-related fitness suggest generally better tracking for fitness than for physical activity. Data on tracking of fitness from youth to adulthood are limited but indicate higher interage correlations for flexibility and strength compared to cardiorespiratory fitness. Correlations for cardiorespiratory fitness and muscular fitness from youth to adulthood are moderate. Growth and maturity are linked to the tracking of physical performance. For instance, as males progress through adolescence, correlations between the measures of strength and flexibility in adolescence and at age 30 tend to increase with age. (Malina 1996, Malina 2001a.)

Obesity has been shown to track from youth to adulthood (Parsons *et al.* 1999, Laitinen *et al.* 2001). Fatter children are more likely to be obese later in life, although the prediction of adult obesity from child and adolescent adiposity measures is only moderate (Power *et al.* 1997). The evidence also suggests that obesity in adolescence is associated with chronic diseases that develop in adulthood, independently of adult obesity (Must & Strauss 1999).

2.3.4 Pathway 4: Youth health-related fitness and adult physical activity

Health and health-related fitness during childhood may be predictive of adult physical activity. Very good self-assessed health at 15 years predicted a high level of physical activity at 18 years (Dovey *et al.* 1998), and fewer health problems in childhood was associated with a high level of physical activity at 34 years (Kuh & Cooper 1992). Some data suggest that those who are more fit in youth, especially in terms of cardiorespiratory fitness, tend to be more active in adulthood. In a study of Dennison *et al.* (1988), males who were active at 24 years had had better scores in youth fitness tests than their inactive counterparts, and the result of the 548.6 m run was the best predictor of later physical activity. The proportion of inactive adults was higher among those who scored in the lowest quintile of the 548.6 m run, compared to those who scored higher (Dennison *et al.* 1988). In a study of Barnekow-Bergkvist *et al.* (1998), males' good results in a 9-minute run and females' good results in a two-hand lift at age 16 were associated with a high level of physical activity at age 34. Great aerobic potential at age 16, including good running performance, high $\dot{V}O_{2max}$ and high proportion of type I muscle fibers, was associated with a high level of physical activity at age 27 (Glenmark *et al.* 1994). In a study of Kemper *et al.* (2001a) cardiorespiratory fitness at 13 years predicted a high level of physical activity at 33 years, but this was true only in females, and muscular fitness tests did not have any predictive value. In a study of Beunen *et al.* (2001) good muscular fitness at 13, 15 and 18 years predicted a high level of physical activity in adulthood. However, some measures (arm pull and bent arm hang) were inversely related to adult physical activity level. Judgement of own fitness to be better than that of peers at 15 years predicted a high level of physical activity at 18 years (Dovey *et al.* 1998). Kemper *et al.* 1997 reported that those who maturated later in youth had a slightly higher activity pattern at 17–22 years than those who maturated early, and speculated that this may be due to an earlier change of the early maturers to physically inactive adults.

2.3.5 Pathway 5: Youth physical activity and adult health-related fitness

Evidence about the relationship between physical activity in youth and health or health-related fitness in adulthood is meager, except for the evidence for physical activity in youth and skeletal health in adulthood. Physical activity in youth can contribute to increased peak bone mass. Weight-bearing activities produce high-impact loading that stimulates bone formation effectively. Peak bone mass that is accumulated in youth and the subsequent rate of bone loss are thought to be equally important in determining bone mass in the elderly. Limited information suggests that much of the achieved peak bone mass may be lost during adult years, but this diminution can be deterred by substantially less physical activity than what was needed to gain it. (Vuori 2001.)

Twisk *et al.* (2002c) summarized the results of six longitudinal studies which evaluated the relationship between physical activity and fitness in youth and cardiovascular disease risk factors later in life. They concluded that a high level of physical activity in

adolescence and young adulthood did not seem to be predictive, but high physical fitness did seem to be predictive of a healthy cardiovascular disease risk profile later in life (Twisk *et al.* 2002c). The authors (Twisk *et al.* 2002c) also discussed the difficulties in measuring physical activity in large epidemiological studies and the possibility that the relationship between physical activity and cardiovascular diseases risk profile might be underestimated. Relatively small sample sizes of the reviewed studies was another problem under discussion. The relationship between physical activity in youth and obesity in adulthood, one of the five areas of the present study, is discussed more in depth in the following chapter.

2.3.5.1 Physical activity and obesity from youth to adulthood

Longitudinal studies on the association between physical activity and obesity from youth to adulthood are summarized in Appendix 2. The follow-up time in these studies has been at least two years. Previous follow-up studies have given inconsistent results regarding the association between youth physical activity and adult obesity, which may be explained by relatively small samples and methodological differences in these studies (Parsons *et al.* 1999, Raitakari *et al*. 1994, Twisk *et al.* 1997, Lefevre *et al*. 2002). Some studies have suggested a protective effect of adolescent physical activity on adult obesity defined by skinfold thickness (Parsons *et al.* 1999, Raitakari *et al*. 1994, Twisk *et al.* 1997). However, this protective effect was not confirmed when adult obesity was defined by body mass index (Kemper *et al.* 1999) or by measures of abdominal obesity (Twisk *et al.* 1997, Hasselstrom *et al.* 2002, Twisk *et al*. 2002b), and some studies have reported no association between adolescent physical activity and adult obesity (Lefevre *et al.* 2002, Twisk *et al*. 2002b). Only one of these studies (Hasselstrom *et al.* 2002) took into account the change in the level of physical activity between adolescence and adulthood and suggested that the change in physical activity from 17 to 25 years was negatively associated with males' waist circumference and fatness at 25 years.

Among adult population, Williamson *et al.* (1993) showed that the change in the level of physical activity, whether a decrease or an increase, was associated with greater weight gain compared with those who had been persistently active or inactive, and Haapanen *et al.* (1997) reported that the decrease in physical activity was more strongly associated with significant weight gain than being persistently inactive. Abdominal obesity was not evaluated in these two follow-up studies but in the study of Wing *et al.* (1991) the change in physical activity was negatively associated with the change in the waist to hip ratio after adjustment for body mass index in middle-aged females.

2.3.6 Pathway 6: Adult physical activity and adult health-related fitness

Associations between physical activity, health-related fitness and health are described in chapter 2.2.

2.4 Measurement of physical activity and health-related fitness in epidemiological studies

In large-scale studies there is a need to apply simple, low-cost and time-efficient methods to measure physical activity and fitness. Therefore, large population-based studies rely mostly on questionnaires and self-reports in the evaluation of frequency, intensity, time and type of physical activity. High costs may be one reason why health-related fitness, especially cardiorespiratory fitness has been quite rarely measured objectively in population-based studies, and population-based reference values for several components of health-related fitness have been rarely reported. For instance, the reference values of cardiorespiratory fitness have usually been formed on the basis of relatively small and, most probably, selected samples.

It has sometimes been suggested that cardiorespiratory fitness is a better indicator of regular physical activity than self-reported data. However, physical activity and fitness represent different characteristics, the former being a form of behavior and the latter a physiological state. Although physical activity is strongly associated with physical fitness in adults, the response in fitness to a certain amount of physical activity varies widely between individuals and is under genetic control (Bouchard & Pérusse 1994). In addition, other factors, such as obesity, health and smoking, affect cardiorespiratory fitness (Bouchard & Shephard 1994).

Studies measuring both cardiorespiratory fitness and physical activity have observed steeper dose-response gradients for the risk of cardiovascular diseases across the categories of objectively measured cardiorespiratory fitness than across the categories of self-reported physical activity (Blair *et al.* 2001). Both a low level of cardiorespiratory fitness and physical inactivity have been shown to be independently associated with several diseases (Blair *et al.* 2001), and this knowledge is a rationale for measuring the two separately in epidemiological studies.

Choosing the most appropriate way of measuring cardiorespiratory fitness in large population studies is problematic. Because direct measurement of $\dot{V}O_{2max}$ during a maximal exercise test is time-consuming, requires laboratory equipment and involves certain health risks for some subjects, short submaximal exercise tests have been developed to estimate $\dot{V}O_{2max}$. Researchers have also developed non-exercise models to estimate $\dot{V}O_{2max}$ from self-reported physical activity and anthropometric measures (Jackson *et al.* 1990).

2.5 Summary of the literature and justification for this study

The decreasing trend of cardiorespiratory fitness (Vasankari *et al.* 2003) and the increasing trend of obesity (Kautiainen *et al.* 2002, Lahti-Koski 2001) are alarming. An increase in habitual physical activity is one prescription for both of these problems. The amount of physical activity and the number of activities generally decrease during the transition from youth to adulthood. Adolescence seems to be a high-risk period for developing sedentary habits and is therefore of special interest in research. It would be

important to identify the elements associated with lifelong participation in physical activity and to find the target groups that are at risk to drop out from a physically active lifestyle and therefore need some special support.

2.5.1 Adolescent participation in different sports and adult physical activity

Large-scale studies of continuity of physical activity from adolescence to adulthood are rare (Appendix 1). Previous longitudinal studies have shown a significant but moderately low correlation between adolescent and adult levels of physical activity (Telama *et al.* 1996, van Mechelen & Kemper 1995). Detailed information about the continuity of different types of sports from adolescence into adulthood is still lacking. The types of physical activity that would be most beneficial in terms of lifelong participation in physical activity are unknown. Although the correlates of overall physical activity in youth have been reported (Sallis *et al.* 2000), the correlates of participation in different types of sports in youth are not clear.

2.5.2 Adolescent predictors of physical inactivity in adulthood

Several early life predictors of adult physical activity have been identified, but most of the earlier studies have relied on univariate analyses, and the effect of adulthood social circumstances has not been taken into account. Predictors of physical inactivity in adulthood have been rarely reported. A high grade in physical education at school and membership in a sports club have been associated with a high level of adult physical activity, but it is not known whether these factors are associated with adult physical activity independent of adolescent physical activity. Neither is it known whether low social class and poor school achievements in youth are independently associated with physical inactivity in adulthood, or whether they first lead to youth inactivity and thereby to adult inactivity as well.

2.5.3 Physical activity and obesity from youth to adulthood

In Finland the rising trend in obesity has been most pronounced among persons with the lowest levels of leisure-time physical activity (Lahti-Koski *et al.* 2002) and among persons aged 25–34 years (Lahti-Koski *et al.* 1997). The association between the change in physical activity from adolescence to adulthood and adult obesity would be an interesting issue for research because of a critical decline in physical activity during this period (Telama & Yang 2000) and a strong association between adolescence and adult obesity (Parsons *et al.* 1999, Laitinen *et al.* 2001). Previous follow-up studies have given

inconsistent results regarding the association between youth physical activity and adult obesity, which may be explained by relatively small samples and methodological differences in these studies. Only one of these studies focused on the change in the level of physical activity from youth to adulthood (Appendix 2). This study found that change in physical activity level from 17 to 25 years was negatively associated with waist circumference and body fat at 25 years in males, but not in females (Hasselstrom *et al.* 2002).

2.5.4 Occupational physical activity and physical fitness in young adults

In the light of earlier studies the association between occupational physical activity and fitness has remained elusive. Earlier studies in middle-aged workers have suggested that heavy physical work is associated with poor physical fitness (Era *et al.* 1992, Nygård *et al.* 1987, Torgen *et al.* 1999), but some sporadic findings among young workers suggest a positive association (Era *et al.* 1992, Jonsson & Åstrand 1979). These studies contained a small number of young workers and inaccurate measures of occupational physical activity, and the potential confounding factors were not taken into account.

2.5.5 Population-based reference values of cardiorespiratory fitness for young adults

The reference values for cardiorespiratory fitness have usually been formed on the basis of relatively small, and most probably, selected samples. Subjects who agree to participate in a maximal exercise test may be selected by their relatively high level of physical activity and fitness. Population-based reference values would be useful in fitness testing and physical activity counseling.

3 Aims of the study

The aims of the study were:

1. To evaluate how participation in different sports in adolescence is associated with the level and types of physical activity in adulthood. (I)
2. To examine how physical activity and social status in adolescence are associated with physical inactivity in adulthood. (II)
   Hypothesis: Infrequent participation in sports after school hours, a low grade in school sports, non-membership in a sports club, low social class of the family, and poor school achievements in adolescence are associated with physical inactivity in adulthood.
3. To evaluate how a change in the level of physical activity from adolescence into adulthood is associated with overall and abdominal obesity in adulthood. (III)
   Hypothesis: Being persistently inactive and becoming inactive between adolescence and adulthood are associated with overall and abdominal obesity at adult age.
4. To evaluate the association between the level of occupational physical activity and physical fitness among young workers. (IV)
   Hypothesis: Heavy physical work is associated with a high level of physical fitness in young workers.
5. To determine cardiorespiratory fitness and to produce reference values for 31-year-old males and females who were born in Northern Finland in 1966. (V)

The main associations evaluated in the present study are presented in Figure 3.

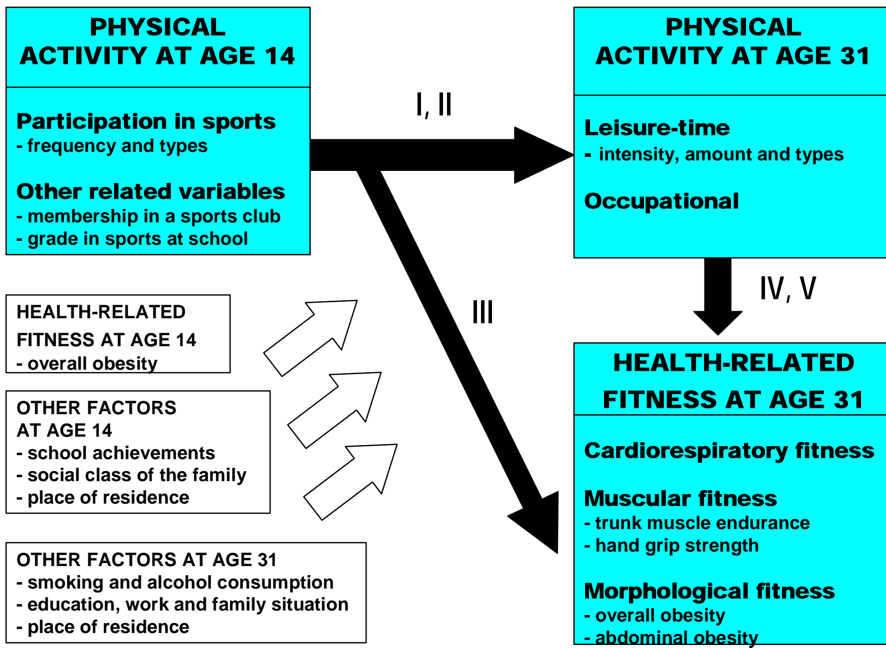

Fig. 3. The associations between physical activity and health-related fitness evaluated in the present study. Original articles are presented as I–V.

4 Material and methods

4.1 Study population and data collection

The study population consisted of the Northern Finland birth cohort of 1966 (NFBC 1966), originally including all 12,231 males and females whose expected year of birth was in 1966 in Finland's two northernmost provinces, Oulu and Lapland (Rantakallio 1988). This study focused on the follow-ups carried out in 1980 and 1997–1998, at the ages of 14 and 31. At both ages questionnaires were mailed to all subjects whose addresses were known. The response rate was 97% at age 14 (N = 11,399) and 75% at age 31 (N = 8,767). Study population and data collection are presented in Figure 4. The study samples in articles I–V are described in Table 1. Original questions are presented in Appendix 4.

At age 31, the 8,463 subjects who were still living in northern Finland, or had moved to the Helsinki capital area, were also invited to a medical examination performed at a local health center; 6,033 persons (71%) attended. Medical examinations were carried out by four teams of trained research nurses, who supervised the performance of the fitness tests and took the anthropometric measures.

A subsample was recruited to repeat the step test and to perform a maximal bicycle ergometer test with direct measurement of peak oxygen uptake ($\dot{V}O_{2peak}$) in the laboratory of the Oulu Regional Institute of Occupational Health. The subjects in this sample also kept diaries of their physical activity and food intake, and they were interviewed by a psychologist and a nutritionist. The sample was recruited in visiting order during the medical examinations carried out in the Oulu region. This sample was stratified in half by sex, urban or rural place of residence, and status of employment. Of the 252 persons invited, 134 agreed to participate and were able to perform the maximal exercise test. However, 11 of the tests were interrupted at the submaximal level, because the subjects felt uncomfortable during the test, technical problems developed, or there were abnormalities in the physiological reactions during the exercise. Therefore, the maximal exercise test was completed by 123 persons.

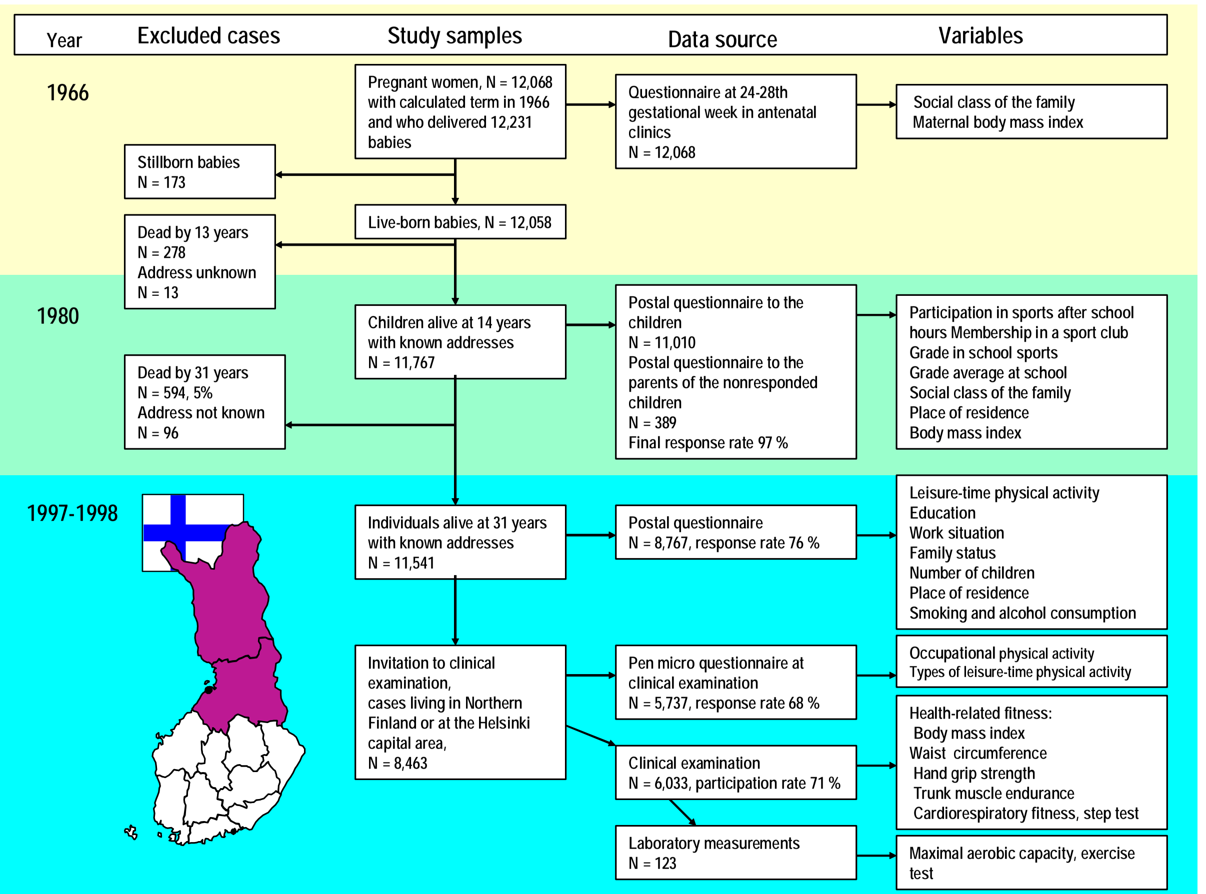

Fig. 4. Study population and data collection of the Northern Finland birth cohort of 1966 from 1966 to 1997–1998.

The ethics committee of the University of Oulu and the ethics committee of the Finnish Institute of Occupational Health approved this study. Written informed consent was obtained from all the subjects before participation in the study.

Table 1. Study samples in articles I–V.

Original article	Study sample
I and II	3,664 males and 4,130 females who responded to mailed questions about the level of leisure time physical activity at ages 14 and 31
III	2,834 males and 2,872 females whose body mass index and waist circumference were measured at medical examination at age 31, pregnant females were excluded
IV	2,188 males and 1,987 females who participated in medical examination at age 31 and were employed at the time of the survey
V	4,073 males and 4,368 females who participated in a step test at medical examination or provided data on their physical activity in a postal inquiry at age 31, and a subsample of 63 males and 60 females who also performed a maximal bicycle ergometer test

4.1.1 Evaluation of the losses to follow–ups and representativeness of the study samples

The characteristics of the different study samples were compared to evalute the possible selection bias in this longitudinal study (Appendix 5, Tables 1–3). No difference was observed in the frequency of sports participation or body mass index at age 14 between those who participated and those who did not participate in the study at age 31. Those who did not participate at age 31 came more often from families of a low social class (IV, 27% vs. 22%) and had more often low grade average of all school subjects (≤ 6.9, 30% vs. 22%) than the whole cohort population based on the data obtained at age 14 (Appendix 5, Table 1). No difference was observed in the level of physical activity or self-reported body mass index at age 31 between those who participated and those who did not participate in medical examination at age 31 based on the data obtained from postal inquiry at age 31. Those who did not participate in the medical examination at age 31 had more often university-level education (15% vs. 11%) than the whole cohort population (Appendix 5, Table 2). The sample that volunteered to participate in the maximal exercise test (N=123) had a higher level of physical activity, a higher level of vocational education, a slightly lower body mass index and better cardiorespiratory fitness at age 31 compared to the whole cohort population (Appendix 5, Tables 2 and 3).

4.1.2 Study variables

The study variables are presented in Table 2. The variable may be used as an explanatory variable, a confounding variable or an outcome variable in different articles.

Table 2. The explanatory, confounding and outcome variables used in the original articles (I–V)

Variables and their categorization	Explanatory variable	Confounding variable	Outcome variable
Physical activity			
Frequency of participation in brisk exercise at 31 years	V	IV	IV
Level of leisure-time physical activity at 31 years			I, II
Participation in different types of leisure-time physical activity at 31 years			I
Occupational physical activity at 31 years	IV	III	
Frequency of participation in sports after school hours at 14 years	I, II		
Participation in different types of sports at 14 years	I		I
Change in the level of physical activity between adolescence and adulthood	III		
Health-related fitness			
Body mass index at 14 years (kg/m^2)		III	
Body weight and height at 31 years (kg, cm)		IV	
Body mass index at 31 years (kg/m^2)	V	III	III
Waist circumference at 31 years (cm)			III
Hand grip strength at 31 years (N)			IV
Time in trunk extension test at 31 years (s)			IV
Heart rate after step test at 31 years (beats/min)	V		IV
Peak oxygen uptake at 31 years (ml•kg^{-1}•min^{-1})			V
Other factors			
Membership in a sports club at 14 years	I, II		
Grade in school sports at 14 years	I, II		
Social class of the family at 14 years	I, II		
Grade average for all subjects at school at 14 years	I, II		
Place of residence at 14 years	I		
Vocational education at 31 years	II	III	
Work situation at 31 years	II		
Number of children at 31 years	II	III	
Place of residence at 31 years	II		
Smoking at 31 years		III, IV	
Alcohol consumption at 31 years		III	
Maternal body mass index (kg/m^2)		III	

4.1.3 Physical activity

Participation in sports at 14 years. At 14 years, the subjects were sent a questionnaire to request *how often* they participated in sports after school hours. Response alternatives were every day, every other day, twice a week, once a week, every other week, once a month and generally not at all. Those participating in sports less than once a week were

defined as physically *inactive*, and those participating once a week or more often were defined as at least moderately *active* in adolescence. Adolescents also reported the main *types of sports* they used to practice. The sports were coded to form 20 groups, i.e. ice hockey, soccer, volleyball, basketball, other ball games (squash, badminton, tennis, table tennis, bandy, Finnish baseball and ball games in general), cross-country skiing, running (and jogging), swimming, cycling, walking, orienteering (running in the forest with a map and a compass), skating, track and field, gymnastics, downhill skiing, riding, dancing, combat sports (judo, wrestling, boxing), strength training (weight lifting, body building, strength training) and other small sports (shooting, sailing, hiking, ski jumping and some other less common sports).

Level of leisure-time physical activity at 31 years. At 31 years, the subjects were requested how often and for how long at a time they participated in light and brisk physical activities. In the questionnaire, the term 'brisk' was defined as physical activity causing at least some sweating and getting out of breath, and the term 'light' as physical activity causing no sweating or getting out of breath. Response alternatives are presented in more detail in Appendix 4.

The subjects were classified into four groups (*very active, active, moderately active and inactive*) according to the frequency, intensity and duration of physical activity they had been engaged in. The very active group exercised briskly four times a week or more often, and the active group two to three times a week, at least 20 minutes at a time. The physical activity level in these groups roughly met the recommendation for the development and maintenance of cardiorespiratory fitness (ACSM 1998). The moderately active group exercised briskly once a week, or more often than once a week, but less than 20 minutes at a time, or participated in light physical activity at least four times a week. This group did not meet the recommendations for fitness but was not totally inactive either. The inactive group participated in brisk physical activity less often than once a week, and in light activity less often than four times a week. The inactive group did not meet the recommendation for enhancing either fitness (ACSM 1998) or health (Pate *et al.* 1995).

Types of leisure-time physical activity at 31 years. The subjects also reported how often they had participated in certain types of physical activity during the previous year in the season which was suitable for those activities. Those who participated in a certain sport once a week or more often were classified as participants in that particular sport. The activities were walking, cycling, cross-country skiing, swimming, running, ball games, aerobics or gymnastics, gym training and outdoor activities (including gardening, hunting, and hiking).

Change in the level of physical activity between adolescence and adulthood. The data obtained at ages 14 and 31 were used to classify the subjects into four groups on the basis of the change in the level of physical activity that had occured between adolescence and adulthood (at least moderately active vs. inactive): 1) *persistently active*: at least moderately active both at 14 and 31 years of age, 2) *having become active*: inactive at 14 but at least moderately active at age 31, 3) *having become inactive*: at least moderately active at 14 but inactive at age 31, and 4) *persistently inactive*: inactive both at 14 and 31 years of age.

Occupational physical activity. In the questionnaire at 31 years, subjects were asked to indicate the intensity of physical activity in their current work, using the following response alternatives: (1) light sedentary work (2) other sedentary work, (3) light standing or moving work, (4) medium heavy moving work, (5) heavy manual work, (6) very heavy manual work, detailed description of work content in these classes is presented in article IV (Article IV: Table 1). This question has previously been used in the population-based Mini-Finland Health Survey (Mälkiä *et al.* 1988) and its test-retest reliability has been stated to be reasonably good (kappa coefficient 0.69) (Mälkiä *et al.* 1996).

Test-retest reproducibility of the questionnaires at 31 years was studied by administering the test battery twice about one month apart to a small sample of 67 subjects. We compared the difference between the categories (re-test minus original test) and the results showed modest misclassification. The responses to the question about the frequency of brisk physical activity were exactly the same category in 62.7% of the cases (N=67). The difference between the answers was one category in 28.3%, two categories in 7.5% and three or more categories in 1.5% of the cases. The responses to the question about the level of occupational physical activity were exactly the same in 78.3% of the cases. The difference was one category in 13.3%, two categories in 6.6% and three or more categories in 1.7% of the cases (N=60).

4.1.4 Health-related fitness

4.1.4.1 Body composition at 14 and 31 years

Overweight and obesity at 14 years. Body weight and height were self-reported at 14 years. Body mass index (BMI) was calculated as weight/ height^2 (kg/m^2). Overweight at 14 years was defined as BMI between the 85th and 95th percentiles (21.45–23.41 kg/m^2 in males and 21.63–23.77 kg/m^2 in females) and obesity as BMI above the 95th percentile (23.42 in males and 23.78 in females) (Whitaker *et al.* 1997, Laitinen *et al.* 2001).

Overall and abdominal obesity at 31 years. Overall and abdominal obesity at age 31 were measured by BMI and waist circumference (WC) respectively. Data on body weight, height and WC were obtained at the medical examination. Body height and weight were measured to an accuracy of 0.1 cm and 0.1 kg. WC was measured at the level midway between the lowest rib margin and the iliac crest. Overall overweight was defined as a BMI of 25.0–29.9 kg/m^2 and overall obesity as a BMI of ≥ 30.0 kg/m^2. Mild abdominal obesity was defined as WC 94.0–101.9 cm in males and 80.0–87.9 cm in females. Severe abdominal obesity was defined as WC ≥ 102.0 cm in males and ≥ 88.0 cm in females. These cut-off points are recognized internationally as identifying individuals with increased risk of co-morbidities (WHO 1998). Waist to hip ratio has earlier been the most used measure of abdominal obesity (WHO 1998), but more recently, WC has been suggested to be a better indicator of abdominal fat than waist to hip ratio (Despres *et al.* 2001).

4.1.4.2 Muscular fitness at 31 years

Handgrip test. Maximal isometric handgrip strength of the dominant hand was measured with a hand dynamometer (Newtest, Oulu, Finland) based on the strain-gauge technique. Measurements were performed with the subject in standing position, holding the dynamometer, with the hand beside, but not touching, the trunk. The wrist and the elbow were extended. The width of the grip in the dynamometer was adjusted to the size of the hand. The highest value in Newtons (N) of the three trials, each lasting from two to four seconds, was accepted as the result.

Trunk extension test. During the trunk extension test (Biering-Sorensen 1984) the subject was in prone position, the lower body lying on the stand and the upper body unsupported from the level of the anterior superior iliac spine upwards. The legs were stabilized by the tester sitting on them and the arms were held beside the trunk. The isometric endurance capacity of the trunk extensor muscles was evaluated by holding the upper part of the body in a horizontal position as long as possible, but not exceeding four minutes, however. When the subject was no longer able to maintain the horizontal position, the test ended. The outcome measure of the test was the endurance time in seconds.

4.1.4.3 Cardiorespiratory fitness at 31 years

Step test. Cardiorespiratory fitness was measured by a submaximal single-step test, which lasted four minutes (Ryhming 1954). A stepping rate of 23 ascents per minute was paced by a metronome. Stepping was performed without shoes on a bench adjusted to a height of 33 cm for females and 40 cm for males. Heart rate was measured immediately after stepping by a heart rate monitor handle (Fitwatch, Polar Electro, Kempele, Finland), which displayed the value within five seconds after setting the handle on the chest.

Peak oxygen uptake during maximal exercise test. The laboratory subsample performed a maximal incremental exercise test on a bicycle ergometer (model 818E, Monark, Sweden) with direct measurement of oxygen consumption (M901 ergospirometer, Medikro, Finland). The test began at the workload of 20 W for the females and 25 W for the males. The workload was increased by 20 W (females) or 25 W (males) every two minutes until exhaustion. Blood pressure and 12-lead electrocardiography were monitored before the test and continuously during the test. The tests were conducted in the laboratory at a temperature ranging from 21 to 23 °C and at humidity levels of 30% to 40%. Maximal heart rate, maximal workload and the highest value of oxygen consumption, $\dot{V}O_{2peak}$, were measured during the test. The term $\dot{V}O_{2peak}$ was used instead of $\dot{V}O_{2max}$, because only 27% of the subjects fulfilled the tight criteria for $\dot{V}O_{2max}$, which demands a plateau in oxygen uptake of ≤ 2 ml·kg^{-1}·min^{-1} with an increase in work rate (Howley *et al.* 1995). However, 97% of the subjects fulfilled both criteria, and all the subjects exceeded at least one of the two criteria of maximality: a respiratory exchange ratio of ≥1.1 or a heart rate of >90% of the age-adjusted maximum during the test.

4.1.4.4 Reasons for not performing the fitness test

Less than 10% of all subjects were excluded from the analysis for various reasons. The share of employed subjects who declined or were unable to perform the tests was as follows: step test 6%, handgrip 2%, and trunk extension 6%. The corresponding figures were 9%, 4%, and 8%, respectively, for those who attended the medical checkup, including those who were unemployed at the time of the survey. The most common reasons for not performing step or trunk extension tests were ill health and pregnancy.

4.1.5 Other variables

Other variables at age 14 years. Membership in a sports club outside school (yes vs. no) was asked about in postal questionnaire. Grade in school sports at 14 years was evaluated based on skills, action, and attitude during physical education lessons on a scale from 4 to 10. Adolescents were divided into three groups: (1) 9–10 (high), (2) 8 and (3) ≤ 7 (low). The social class of the family at 14 years was categorized based on the father's occupation and its prestige, according to a social grouping frequently used for this purpose in Finland (social groups I–IV) (Rantakallio 1979, Finnish Bureau of Statistics 1954): (1) I and II skilled professionals, (2) III skilled workers, (3) IV unskilled workers and (4) farmers. If the father's occupation in 1980 was unknown, it was replaced with his occupation in 1966. If the mother was single, her occupation in 1980 or in 1966 was used. School achievement at 14 years was measured in terms of the average grade for all school subjects (scale from 4 to 10), grouped into four categories: (1) ≥ 9.0, (2) 8.0–8.9, (3) 7.0–7.9 and (4) ≤ 6.9. Family's place of residence at 14 years was classified into (1) urban (42%) or (2) rural, according to the type of municipality in 1980.

Other variables at age 31 years. The number of children was asked about by postal inquiry. The grouping was (1) no child, (2) one child, (3) two children, and (4) three or more children. The level of vocational education at 31 years formed four classes: (1) university degree, (2) high education (polytechnic or vocational college), (3) medium education (vocational school or course), and (4) no vocational education. Work situation at 31 years was coded to form six categories: (1) employed persons, (2) entrepreneurs, (3) full-time students, (4) unemployed persons, (5) persons on childcare or maternity leave and (6) others (e.g. long-term sick leave, housewife). The categories 5 and 6 were merged for the males, because only very few were on childcare leave. Place of residence at 31 years was coded according to the regional classification of municipalities in 1997, into (1) urban, (2) semi-urban, and (3) rural municipalities (Statistics Finland 1997). Those who smoked once a week or more often were classified as smokers (36% of males and 24% of females). The amount of alcohol consumed per day was estimated from the questions measuring the frequency and the usual amount of beer, wine and spirits consumed on one occasion (Laitinen *et al.* unpublished manuscript). The subjects were then assigned to four groups by quartiles of alcohol intake.

Maternal BMI. Mother's weight before pregnancy was questionned during her first visit to the antenatal clinic, which occured on average during the 16th week of gestation. Height was measured or self-reported.

4.2 Statistical methods

The associations between physical activity and social status at age 14 and physical inactivity at age 31 were evaluated by multivariable logistic regression. The association between participation in sports at age 14 and the level of physical activity at age 31 (active or very active vs. inactive) was examined by multinomial logistic regression. Multinomial logistic regression analyses were also used to explore how the change in physical activity level between adolescence and adulthood was associated with overall and abdominal obesity at age 31. Persistently active persons with normal weight or normal WC formed the reference group. The odds ratios (OR) and their 95% confidence intervals (95% CI) were calculated for the explanatory factors.

The associations between occupational physical activity and the results of the step and handgrip tests were assessed by analysis of variance. The heart rate after step test (beats/min) and handgrip strength (N) was compared between the different groups of occupational physical activity. The results of the trunk extension test in different groups of occupational physical activity were analysed by Cox regression. Many subjects exceeded the maximum time of four minutes, and the endurance time remained unknown for some, and they were defined as censored observations in the analyses. The result was expressed as a hazard ratio (HR), i.e. ratio of the probability of failure (hazard) in a given class of occupational physical activity divided by the corresponding hazard in the reference class. The analysis presupposes proportionality of the hazards, which was checked graphically using log/ -log functions of cumulative hazards. Leisure-time physical activity, body height and weight and smoking were taken into account as potential confounding factors.

The subsample who performed the maximal exercise test was used to calculate four linear regression models to estimate $\dot{V}O_{2peak}$ ($ml \cdot kg^{-1} \cdot min^{-1}$). The models included different combinations of selected explanatory variables: heart rate after a step test (HR), body mass index (BMI) and the frequency of brisk physical activity (PA). The combinations of the variables in the $\dot{V}O_{2peak}$ prediction models were for Model 1: HR, for Model 2: HR and BMI, for Model 3: BMI and PA, and for Model 4: HR, BMI and PA. Model 1 and model 2 represented objective methods for predicting cardiorespiratory fitness. Model 3 represented a non-exercise method. Model 4 combined the results of submaximal exercise test and self-reported physical activity. Multiple correlation coefficients, R^2 adjusted for the number of variables in the model, and standard errors of the estimated $\dot{V}O_{2peak}$ (SEE) were calculated for different models to compare their accuracy. The best fitting models were chosen to form cardiorespiratory reference values to the whole cohort population. Statistical analyses were performed using SPSS software (Versions 9.0 and 10.1).

5 Results

5.1 Leisure-time physical activity and the background variables at ages 14 and 31

At age 14, males participated in sports more frequently and were more often members of a sports club than females (Table 3). There was no essential gender difference in the grade in school sports, but males had a lower average grade for all school subjects (Table 3). At 14 years, the most common sports were cross-country skiing, running, ice hockey, skating, soccer and swimming (Fig. 5 and Article I: Table 1). At 14 years, 30% reported participation in one, 34% in two, and 21% in three or more types of sports.

At age 31, it was slightly more common for males than females to be physically inactive (30% vs. 24%) (Table 3). Most of the subjects had children by that age, and 16% of the females were on maternity or childcare leave. The females had a higher level of education than the males. The majority of the subjects were employed, while 12% of the males and 5% of the females were working as entrepreneurs, about 13% were unemployed and 4% were full-time students. About 58% lived in an urban area and 25% in a rural one (Table 3). At 31 years, walking, cycling and outdoor activities were the most commonly reported types of physical activity (Fig. 6 and Article I: Table 2).

Table 3. Characteristics of males (N = 3,664) and females (N=4,130) at age 14 and 31 years.

Variables	Males (%)	Females (%)
Participation in sports after school hours at 14 years		
Daily	22.5	12.6
Every other day	25.4	14.9
Twice a week	22.4	22.7
nce a week	12.0	20.1
Once a week	17.6	29.6
Membership in a sports club at 14 years		
Yes	40.8	31.3
No	59.2	68.7
Grade in school sports at 14 years (scale 4–10)		
9–10 (high)	27.8	29.2
8	43.9	46.4
≤ 7 (low)	28.3	24.5
Social class of family at 14 years (father's occupation)		
I and II, skilled professional	30.9	29.5
III, skilled worker	34.3	35.0
IV, unskilled worker	21.6	22.2
Farmer	13.2	13.3
Average grade at school at 14 years (scale 4–10)		
≥ 9.0 (high)	2.8	11.1
8.0–8.9	24.2	43.6
7.0–7.9	40.2	34.7
≤ 6.9 (low)	32.8	10.6
Physical activity at 31 years		
Very active	13.4	11.5
Active	28.0	28.8
Moderately active	28.7	35.3
Inactive	29.9	24.4
Children in family at 31 years		
No children	45.6	29.1
One or more	54.4	70.9
Education at 31 years		
University degree	10.7	12.7
High	26.9	41.7
Medium	55.2	39.9
None	7.1	5.7
Work situation at 31 years		
Employed	68.5	55.3
Entrepreneur	11.5	4.9
Full-time student	3.1	4.8
Unemployed	12.3	12.6
Child care leave	–	16.2
Other	4.7	6.2
Place of residence at 31 years		
Urban	55.5	59.3
Semi-urban	18.4	17.0
Rural	25.1	23.7

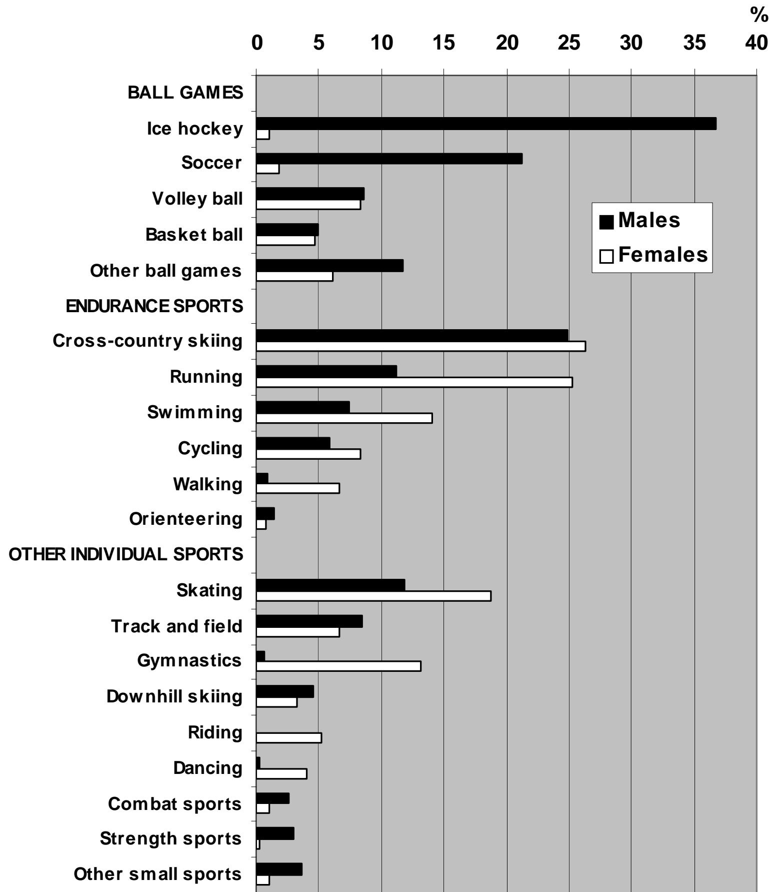

Fig. 5. Percentage of males and females who participated in a certain sport at age 14.

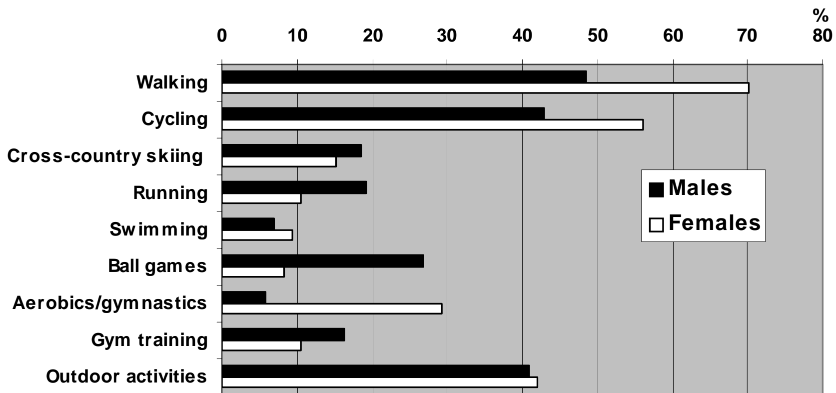

Fig. 6. Percentage of males and females who participated in different types of physical activity once a week or more often at age 31.

5.2 Participation in adolescent sports and adult leisure-time physical activity (I)

5.2.1 Association between adolescent sports and adult physical activity level

In males, participation in sports at least twice a week, and in females, at least once a week in adolescence was associated with being physically active or very active at leisure time in adulthood, compared to participation in sports less often than once a week (Fig. 7). Males' participation in ice hockey, soccer, volleyball, other ball games, cross-country skiing, running and track and field in adolescence was associated with a high level of leisure-time physical activity in adulthood (Table 4a). In females, the same applied to participation in running, cycling, track and field and gymnastics (Table 4b). Additionally, males' participation in soccer, volleyball, other ball games, running, orienteering, track and field, and combat sports, and females' participation in running, track and field, riding and orienteering in adolescence was associated with a very high level of adult physical activity.

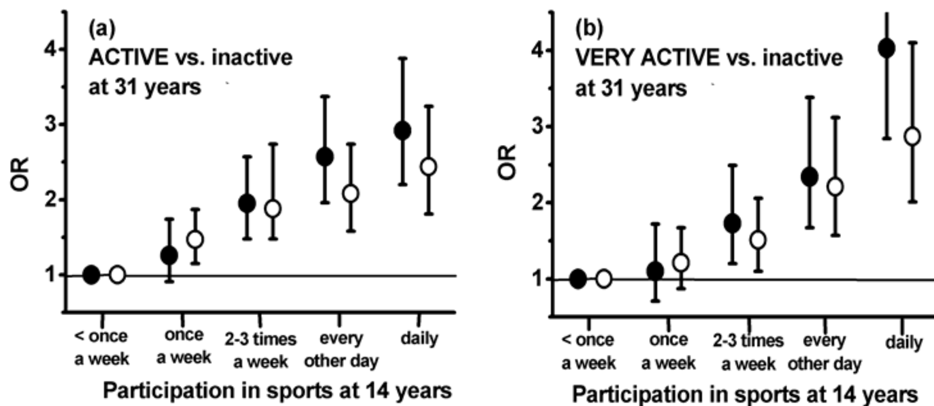

Fig. 7. Odds ratios (OR) and 95% onfidence intervals for being physically active (a) or very active (b) vs. inactive at leisure time at 31 years, according to the frequency of participation in sports after school hours at 14 years. Results are from multinomial logistic regression. ● = males and ○ = females.

Table 4a. Multinomial regression of physical activity level[a] at 31 years on types of sports at age 14 years in males. Odds ratios[b] (OR) and their 95% confidence intervals (CI).

Participation in sports at age 14 (yes vs. no)	Males at 31 years (N = 3,664)			
	Active vs. Inactive		Very active vs. Inactive	
	OR	CI	OR	CI
Ball games				
Ice hockey	1.43	1.18–1.74	1.05	0.82–1.34
Soccer	1.32	1.05–1.66	1.87	1.43–2.46
Volleyball	1.66	1.20–2.28	1.57	1.07–2.31
Basketball	1.27	0.85–1.89	1.07	0.65–1.76
Other ball games	1.80	1.36–2.36	1.45	1.03–2.04
Endurance sports				
Cross-country skiing	1.27	1.03–1.56	1.12	0.86–1.46
Running	1.50	1.13–2.00	1.43	1.00–2.04
Swimming	1.09	0.79–1.51	0.97	0.63–1.50
Cycling	0.86	0.58–1.25	0.74	0.44–1.25
Walking	1.25	0.47–3.30	1.00	0.27–3.81
Orienteering	1.00	0.40–2.51	3.64	1.60–8.23
Other individual sports				
Skating	1.00	0.76–1.32	0.83	0.58–1.20
Track and field	1.63	1.19–2.25	2.19	1.52–3.14
Gymnastics	0.93	0.31–2.81	0.93	0.24–3.68
Downhill skiing	1.10	0.72–1.67	1.33	0.80–2.20
Riding	–	–	–	–
Dancing	–	–	–	–
Combat sports	1.25	0.71–2.22	2.26	1.25–4.12
Strength sports	1.06	0.65–1.73	0.60	0.28–1.26
Other small sports	1.27	0.80–2.01	1.35	0.78–2.35

[a] Active = participation in brisk exercise at least two times a week, at least 20 minutes at a time, Very active = participation in brisk exercise at least four times a week, at least 20 minutes at a time, Inactive = participation in brisk exercise less than once a week and in light exercise less than four times a week.
[b] Adjusted for participation in all other types of sports mentioned in the table.

Table 4b. Multinomial regression of physical activity level[a] at 31 years on types of sports at age 14 years in females. Odds ratios[b] (OR) and their 95% confidence intervals (CI).

Participation in sports at age 14 (yes vs. no)	Females at 31 years (N = 4,130)			
	Active vs. Inactive		Very active vs. Inactive	
	OR	CI	OR	CI
Ball games				
Ice hockey	1.60	0.72–3.52	1.46	0.52–4.13
Soccer	0.89	0.49–1.62	0.81	0.35–1.84
Volleyball	1.24	0.91–1.68	0.99	0.65–1.50
Basketball	1.31	0.88–1.95	1.06	0.62–1.83
Other ball games	1.01	0.72–1.43	0.78	0.48–1.26
Endurance sports				
Cross-country skiing	1.16	0.94–1.42	1.24	0.95–1.61
Running	1.34	1.09–1.64	1.44	1.12–1.87
Swimming	0.99	0.77–1.28	0.90	0.64–1.26
Cycling	1.43	1.05–2.00	0.97	0.63–1.51
Walking	1.17	0.83–1.64	1.22	0.78–1.89
Orienteering	1.12	0.35–3.89	3.77	1.24–11.50
Other individual sports				
Skating	1.10	0.87–1.38	0.91	0.67–1.23
Track and field	1.49	1.05–2.12	1.62	1.05–2.50
Gymnastics	1.30	1.01–1.68	1.11	0.80–1.55
Downhill skiing	1.08	0.68–1.70	0.80	0.42–1.51
Riding	1.22	0.82–1.82	1.82	1.15–2.88
Dancing	1.27	0.81–1.99	1.53	0.88–2.63
Combat sports	1.72	0.76–3.89	1.23	0.41–3.71
Strength sports	–	–	–	–
Other small sports	0.45	0.17–1.20	1.16	0.45–3.03

[a] Active = participation in brisk exercise at least two times a week, at least 20 minutes at a time, Very active = participation in brisk exercise at least four times a week, at least 20 minutes at a time, Inactive = participation in brisk exercise less than once a week and in light exercise less than four times a week.
[b] Adjusted for participation in all other types of sports mentioned in the table.

5.2.2 Different adolescent sports and the types of physical activity in adulthood

Participation in a certain type of adolescent sport was associated with participation in a similar type of physical activity in adulthood. In males, participation in different ball games at age 14 was associated with participation in ball games at age 31 (Table 5). For

example, 40% of males who had played soccer at 14 years, participated in some kind of ball games at 31 years, whereas the average prevalence of participation in ball games was 27%. Males' participation in cross-country skiing and running in adolescence was associated with frequent participation in walking, cross-country skiing and running in adulthood. Adolescent orienteering was related to increased adult participation in running in both sexes. In males, adolescent running and orienteering were associated with participation in aerobics or gymnastics at adult age. Participation in track and field at 14 years was related to increased participation in running and ball games at 31 years in both sexes. Males' participation in combat sports at 14 years was associated with frequent participation in running, aerobics or gymnastics, and gym training in adult age. Females' participation in gymnastics at 14 years was associated with frequent participation in aerobics or gymnastics at 31 years (Table 5). Only those adolescent sports that were associated with a high level of physical activity at age 31 were included in Table 5.

Table 5. Participation in different types of leisure-time physical activity at 31 years according to participation in certain types of sports at 14 years.

Types of sports practiced at 14 years (yes vs. no)	Prevalence of participation in different types of activities at 31 years (%)									
	N	Walking	Cycling	Cross-country skiing	Running	Swim-ming	Ball games	Aerobics/ Gymnas-tics	Gym training	Outdoor activities
Males										
Ice hockey	946	47.6	45.3	18.3	17.9	7.1	33.7	4.5	17.0	40.0
Soccer	525	49.9	47.7	18.7	21.7	7.2	40.4	7.2	18.5	39.8
Volleyball	220	52.7	40.5	20.9	25.5	7.3	37.3	6.4	21.4	48.6
Other ball games	278	45.3	43.2	14.4	20.9	5.8	39.9	6.8	21.9	35.5
Cross-country skiing	640	52.0	41.1	28.3	25.8	6.4	23.8	7.0	17.5	41.1
Running	284	55.3	43.0	28.5	27.1	9.5	22.5	9.2	18.3	38.0
Orienteering	35	60.0	48.6	31.4	48.6	2.9	22.9	17.1	17.1	42.9
Track and field	221	52.0	45.2	22.2	28.5	9.5	38.5	8.1	19.0	38.0
Combat sports	66	48.5	53.0	15.2	25.8	6.1	30.3	15.2	28.8	31.8
All	2488	48.6	43.0	18.5	19.3	7.0	26.9	5.7	16.4	41.0
Females										
Running	713	73.4	55.5	18.0	12.8	10.5	10.1	29.9	10.9	44.3
Cycling	234	70.9	57.7	14.5	10.3	9.4	9.8	29.5	8.5	41.9
Orienteering	24	75.0	66.7	20.8	25.0	4.2	8.3	25.0	16.7	37.5
Track and field	182	73.1	57.7	20.9	17.6	12.1	13.7	33.5	15.9	38.5
Gymnastics	351	70.9	54.4	13.1	11.7	9.7	7.7	37.3	13.1	41.0
Riding	131	73.3	55.7	13.7	10.7	11.5	7.6	35.1	8.4	40.5
All	2798	70.1	56.2	15.3	10.6	9.3	8.3	29.2	10.5	41.9

5.2.3 Social determinants of participation in adolescent sports

The percentage of adolescents who were members in a sports club was very high in orienteering, combat sports and track and field (64–86%), and relatively high in different ball games (44–58%) (Table 6). The proportion of adolescents with the highest grades in school sports (nine or ten) was the greatest among participants in track and field, basketball and orienteering (more than 50%). The social background of the family varied between adolescents who participated in different sports. Participants in downhill skiing, dancing, orienteering and riding more commonly came from families with the highest social class (I), and participants in strength sports, walking, cycling and soccer more commonly came from families of low social class (IV). An urban place of residence was related to frequent participation in combat sports, riding, downhill skiing and dancing, and rural residence, in contrast, was related to frequent participation in volleyball, cross-country skiing and running in adolescence.

Table 6. Background characteristics of males and females participating in different sports at age 14.

		Member in a sports club	High grade in sports at school (9–10)	Distribution (%) by social class of the family				Urban place of residence
Sport at 14 years	N	(%)	(%)	I+II	III	IV	farmer	(%)
Ball games								
Ice hockey	1394	44	32	31	36	21	12	40
Soccer	850	50	38	26	38	25	11	47
Volleyball	662	58	44	33	36	22	10	28
Basketball	377	52	53	37	35	19	8	48
Other ball games	682	53	42	41	34	16	9	52
Endurance type of sports								
Cross-country skiing	1998	38	34	27	31	21	20	29
Running	1456	34	34	28	32	22	18	33
Swimming	852	30	24	35	34	21	11	50
Cycling	561	17	5	26	33	25	16	40
Walking	312	14	11	22	32	26	19	37
Orienteering	86	86	52	47	32	14	7	51
Other individual sports								
Skating	1207	24	21	30	36	21	13	38
Track and field	582	64	60	32	35	19	14	36
Gymnastics	566	51	44	36	35	18	10	40
Downhill skiing	297	51	29	64	27	7	1	58
Riding	214	53	25	47	40	8	4	63
Dancing	175	47	39	53	31	12	5	57
Combat sports	140	84	34	39	36	20	6	65
Strength sports	116	36	23	28	32	28	11	37
Other small sports	171	56	34	41	34	16	9	52
All	7794	36	29	30	35	22	13	42

5.3 Physical activity and social status in adolescence as predictors of physical inactivity in adulthood (II)

The proportion of inactive subjects at age 31 years who had participated in sports less often than once a week in adolescence was 41% for males and 30% for females (Table 7), whereas the average proportion of inactive males was 30% and females 24%. Those who participated in sports twice a week or more often at 14 years were less likely to be inactive at 31 years compared to those who participated in sports less often than once a week, independently of many adult social factors (Table 7). Not being a member of a sports club in adolescence was associated with later inactivity in the unadjusted analyses, but not after adjustment for physical activity level in adolescence. A low grade in school sports was associated with inactivity in adulthood among the males, independently of their level of physical activity in adolescence (Table 7).

Having children and having a low level of vocational education were associated with physical inactivity at 31 years in both sexes, independently of the other covariates (Table 7). Entrepreneurs were inactive more often than any other group: 47% of the males and 32% of the females being classified as such compared with 30% of the males and 24% of the females on average. This association persisted in the males, even after adjustment for other social factors in adulthood. On the other hand, the male students were less commonly inactive (17%) than the males on average (30%). Rural residence was associated with inactivity in males in the unadjusted analyses, but not after allowances were made for education, family status and work situation.

The proportion of physically inactive subjects at 14 years was greatest among those with low family social class (IV) (Table 8). Farmers' sons were more commonly inactive than others, but this was not true for the daughters. Low social class (IV) at 14 years, however, was not associated with physical inactivity at age 31 years. Being a farmer's son was associated with adult inactivity, but not after adjustment for the level of physical activity in adolescence (Table 8), while among the farmers’ daughters the association seemed to be the opposite, but not significant. Poor school achievement in adolescence was associated with physical inactivity in adulthood independently of the level of physical activity at 14 years (Table 8).

Table 7. Percentages of physically inactive[a] individuals at age 31 by background characteristics, and multivariate logistic regression analysis of physical inactivity[a] at age 31. Odds ratios (OR) and their 95% confidence intervals (CI).

Explanatory factors	Males, N = 3,069			Females, N = 3,600		
	Inactive subjects	Un-adjusted	Adjusted[b]	Inactive subjects	Un-adjusted	Adjusted[b]
	%	OR	OR (CI)	%	OR	OR (CI)
Participation in sports after school hours at age 14						
Daily	22.1	0.41	0.57 (0.44–0.76)	18.1	0.51	0.53 (0.40–0.70)
Every other day	25.5	0.49	0.67 (0.52–0.87)	19.8	0.57	0.63 (0.48–0.81)
Twice a week	29.8	0.61	0.70 (0.54–0.90)	22.4	0.67	0.69 (0.55–0.86)
Once a week	37.3	0.85	0.88 (0.66–1.17)	25.4	0.79	0.83 (0.67–1.03)
Less than once a week	41.0	1.00	1.00	30.1	1.00	1.00
Membership of a sports club at 14 years						
Yes	24.4	0.64	0.88 (0.73–1.05)	21.8	0.82	1.00 (0.83–1.21)
No	33.4	1.00	1.00	25.5	1.00	1.00
Grade in school sports at age 14 (scale 4–10)						
9–10 high	20.8	0.63	0.69 (0.56–0.86)	21.7	0.86	0.95 (0.78–1.16)
8	29.5	1.00	1.00	24.4	1.00	1.00
≤ 7 low	38.1	1.47	1.29 (1.07–1.56)	27.3	1.16	1.08 (0.89–1.34)

Table 7. Continued.

Explanatory factors	Males, N = 3,069			Females, N = 3,600		
	Inactive subjects	Un-adjusted	Adjusted[b]	Inactive subjects	Un-adjusted	Adjusted[b]
	%	OR	OR (CI)	%	OR	OR (CI)
Children in family at age 31						
No children	26.4	1.00	1.00	18.5	1.00	1.00
One or more	32.4	1.34	1.47 (1.25–1.73)	26.9	1.63	1.69 (1.40–2.04)
Education at age 31						
University degree	17.8	1.00	1.00	20.0	1.00	1.00
High	22.8	1.37	1.23 (0.89–1.70)	21.8	1.12	1.05 (0.81–1.36)
Medium	33.9	2.37	1.96 (1.44–2.65)	27.2	1.50	1.33 (1.02–1.74)
None	42.9	3.47	2.14 (1.41–3.25)	33.0	1.98	1.55 (1.05–2.29)
Work situation at age 31						
Employed	27.9	1.00	1.00	24.0	1.00	1.00
Entrepreneur	46.3	2.23	1.92 (1.51–2.43)	31.5	1.45	1.30 (0.93–1.82)
Full-time student	15.9	0.49	0.50 (0.29–0.87)	23.5	0.97	0.90 (0.62–1.32)
Unemployed	28.0	1.00	0.75 (0.57–0.97)	23.1	0.95	0.81 (0.63–1.04)
Child care leave	–	–	–	23.8	0.98	0.80 (0.64–1.00)
Other	32.9	1.27	1.00 (0.68–1.48)	23.6	0.98	0.80 (0.57–1.13)
Place of residence at age 31						
Urban	25.9	1.00	1.00	24.4	1.00	1.00
Semi-urban	32.4	1.37	1.00 (0.80–1.24)	22.8	0.92	0.87 (0.70–1.08)
Rural	36.2	1.63	1.11 (0.92–1.35)	25.1	1.04	0.93 (0.77–1.12)

[a] Inactive at 31 years = brisk exercise less than once a week and light exercise less than four times a week.
[b] Adjusted for all other explanatory variables in the table.

Table 8. Percentages of physically inactive subjects at 14[a] and 31[b] years by social class and school achievement at 14 years, and logistic regression analysis of physical inactivity[a] at 31 years. Unadjusted and adjusted odds ratios (OR) and their 95 % confidence intervals (CI).

Explanatory factors	Males, N = 3,069				Females, N = 3,600			
	Inactive subjects				Inactive subjects			
	at 14 years	at 31 years	Un-adj.	Adjusted[c]	at 14 years	at 31 years	Un-adj.	Adjusted[c]
	%	%	OR	OR (CI)	%	%	OR	OR (CI)
Social class of family at 14 years (father's occupation)								
I and II, skilled professional	13.5	29.4	1.00	1.00	24.9	24.1	1.00	1.00
III, skilled worker	17.1	28.9	0.97	0.95 (0.79–1.14)	30.4	25.6	1.08	1.06 (0.89–1.27)
IV, unskilled worker	20.4	28.3	0.95	0.88 (0.72–1.08)	35.5	25.0	1.05	1.00 (0.82–1.22)
Farmer	24.2	35.7	1.34	1.18 (0.94–1.49)	28.3	20.5	0.81	0.80 (0.63–1.02)
Average grade at school at 14 years (scale 4–10)								
≥ 9.0 high	9.2	21.4	1.00	1.00	18.5	18.8	1.00	1.00
8.0 – 8.9	13.6	23.2	1.11	1.09 (0.65–1.81)	24.9	22.4	1.25	1.19 (1.01–1.63)
7.0 – 7.9	15.8	28.4	1.46	1.40 (0.85–2.31)	32.0	26.6	1.57	1.47 (1.23–2.01)
≤ 6.9 low	22.2	36.9	2.14	1.96 (1.19–3.24)	47.0	31.4	1.98	1.75 (1.36–2.46)

[a]Inactive at 14 years = participation in sports after school hours less than once a week.
[b]Inactive at 31 years = brisk exercise less than once a week and light exercise less than four times a week.
[c]Adjusted for the frequency of participation in sports after school hours at 14 years.

5.4 Physical activity from adolescence into adulthood and obesity in adulthood (III)

At age 31 the mean BMI was 25.2 kg/m^2 in males and 24.2 kg/m^2 in females, and the mean WC was 88.9 cm in males and 78.8 cm in females. The prevalence of overweight was higher in males than in females at age 31 (41 vs. 22%), but obesity was equally prevalent in both genders (8%). The prevalence of mild abdominal obesity was 18% in both genders, and the prevalence of severe abdominal obesity was 9% in males and 18% in females.

Most subjects, 60% of males and 55% of females, were classified as persistently active, and a small group, 7% of males and 9% of females, were classified as persistently inactive between adolescence and adulthood. More females (21%) than males (10%) had become active and more males (23%) than females (15%) had become inactive during the transition from youth to adulthood. The prevalence of overall and abdominal obesity was highest among those who had been persistently inactive or had become inactive between adolescence and adulthood (Table 9).

In males, becoming inactive between adolescence and adulthood was associated with overall obesity (OR 1.53, CI 0.99–2.37), while being persistently inactive was not associated with overall overweight or obesity (Table 9). In females, becoming inactive and being persistently inactive were associated with overall obesity in unadjusted analyses, but an adjustment for confounding factors made the associations weaker and the CIs wider (OR 1.51, CI 0.94–2.44). This was mainly due to adjustment for the level of education in the case of becoming active, and to adjustment for BMI at 14 years in the case of being persistently inactive.

In males, being persistently inactive was first associated with severe abdominal obesity, but not after adjustment for the level of education and BMI at 14 years (Table 9). Becoming inactive was associated with severe abdominal obesity in unadjusted analyses, and also after adjustment for potential confounders, while the associations disappeared after adjustment for BMI at 31 years. In females, becoming inactive was associated with severe abdominal obesity after adjustment for potential confounders and for BMI at 31 years (OR 1.80, CI 1.13–2.86). Being persistently inactive was first associated with severe abdominal obesity, but the association disappeared after adjustment for BMI at 31 years. Becoming active between adolescence and adulthood was not associated with overall or abdominal obesity in either gender, when being persistently active was the reference group (Table 9).

Table 9. Logistic regression of overall and abdominal obesity at 31 years on the change in the level of physical activity between the ages of 14 and 31. Odds ratios (OR) and 95 % confidence intervals (CI).

Change in the level of physical activity between 14 and 31 years	Obesity at 31 years [a]			Abdominal obesity at 31 years [b]			
	Prevalence of obesity %	Unadjusted OR (CI)	Adjusted* OR (CI)	Prevalence of abdominal obesity %	Unadjusted OR (CI)	Adjusted* OR (CI)	Adjusted** OR (CI)
Males							
Persistently active	7.6	1.00	1.00	7.6	1.00	1.00	1.00
Become active	7.1	1.01 (0.60–1.69)	0.62 (0.30–1.28)	9.4	1.27 (0.80–2.01)	1.10 (0.63–1.91)	1.17 (0.54–2.50)
Become inactive	10.4	1.64 (1.17–2.29)	1.53 (0.99–2.37)	13.1	1.95 (1.43–2.64)	1.85 (1.31–2.63)	1.43 (0.83–2.44)
Persistently inactive	8.6	1.14 (0.65–2.01)	0.66 (0.27–1.59)	12.3	1.82 (1.12–2.95)	1.38 (0.75–2.55)	1.78 (0.76–4.13)
Females							
Persistently active	7.9	1.00	1.00	16.2	1.00	1.00	1.00
Become active	7.6	0.95 (0.66–1.38)	0.70 (0.41–1.18)	16.5	1.01 (0.77–1.32)	0.83 (0.61–1.14)	0.95 (0.59–1.51)
Become inactive	12.0	1.64 (1.16–2.32)	1.51 (0.94–2.44)	23.8	1.68 (1.29–2.19)	1.64 (1.21–2.22)	1.80 (1.13–2.86)
Persistently inactive	15.5	2.24 (1.49–3.38)	1.55 (0.86–2.77)	22.9	1.58 (1.12–2.23)	1.47 (0.99–2.19)	0.92 (0.48–1.76)

[a] Body mass index (BMI) ≥ 30 vs. < 25.0 kg/m^2.
[b] Waist circumference ≥ 102.0 cm vs. < 94.0 cm in males, and ≥ 88.0 cm vs. <80.0 cm in females.
*Adjusted for occupational physical activity, vocational education, alcohol consumption, smoking, BMI at 14 years, maternal BMI, and in females for parity.
** Additionally adjusted for BMI at 31 years.

5.5 Association between occupational physical activity and fitness in young adults (IV)

The mean value of the heart rate after step test was 146 beats/min (SD 17) in males and 149 beats/min (SD 18) in females, and the mean handgrip strength was 501 N (SD 87) in males and 285 N (SD 63) in females (article IV: tables 3 and 4). 399 males (19%) and 705 females (39%) reached the maximum time of four minutes in the trunk extension test.

The percentages of males and females, respectively, in different classes of occupational physical activity were (1) light sedentary work: 29% and 36%, (2) other sedentary work: 11% and 7%, (3) light standing or moving work: 13% and 21%, (4) medium heavy moving work: 20% and 23%, (5) heavy manual work: 20% and 12% and (6) very heavy manual work: 7% and 2%.

Males engaged in heavy or very heavy manual work were more often inactive and less often active during their leisure time, compared with males engaged in light sedentary work (Article IV: Table 2 and Fig. 1). In females the trend was similar, but less pronounced.

Step test. Occupational physical activity was associated with the result of the step test in males ($p< 0.001$) and in females ($p=0.037$) after adjustment for leisure-time physical activity, body height and weight and smoking (Article IV: Table 5). The adjusted results of Figure 6 show a 5% decline in heart rate from lowest to highest occupational activity groups in males, while in females a decline in heart rate is recorded mainly in those doing very heavy work.

Handgrip test. Heavy physical work was associated with greater handgrip strength in males ($p< 0.001$), but not in females ($p=0.065$), although the females who did very heavy work showed a relatively high value (Fig. 8, Article IV: Table 6).

Trunk extension test. Males and females who reached the maximum time of four minutes in the test were treated as censored in the Cox regression analyses. Plots of log/-log hazards suggested no violation of the assumption of proportional hazards. Occupational physical activity was significantly associated with the trunk extension test in males, independently of other factors ($p=0.029$), males doing very heavy manual work having a 27% lower risk of failure than males doing light sedentary work (Fig. 8, Article IV: Table 7). The adjusted analysis revealed no significant association between occupational physical activity and the trunk extension test in females ($p=0.153$) (Article IV: Table 7), but an isolated high value was seen in women doing heavy sedentary work (Fig. 8).

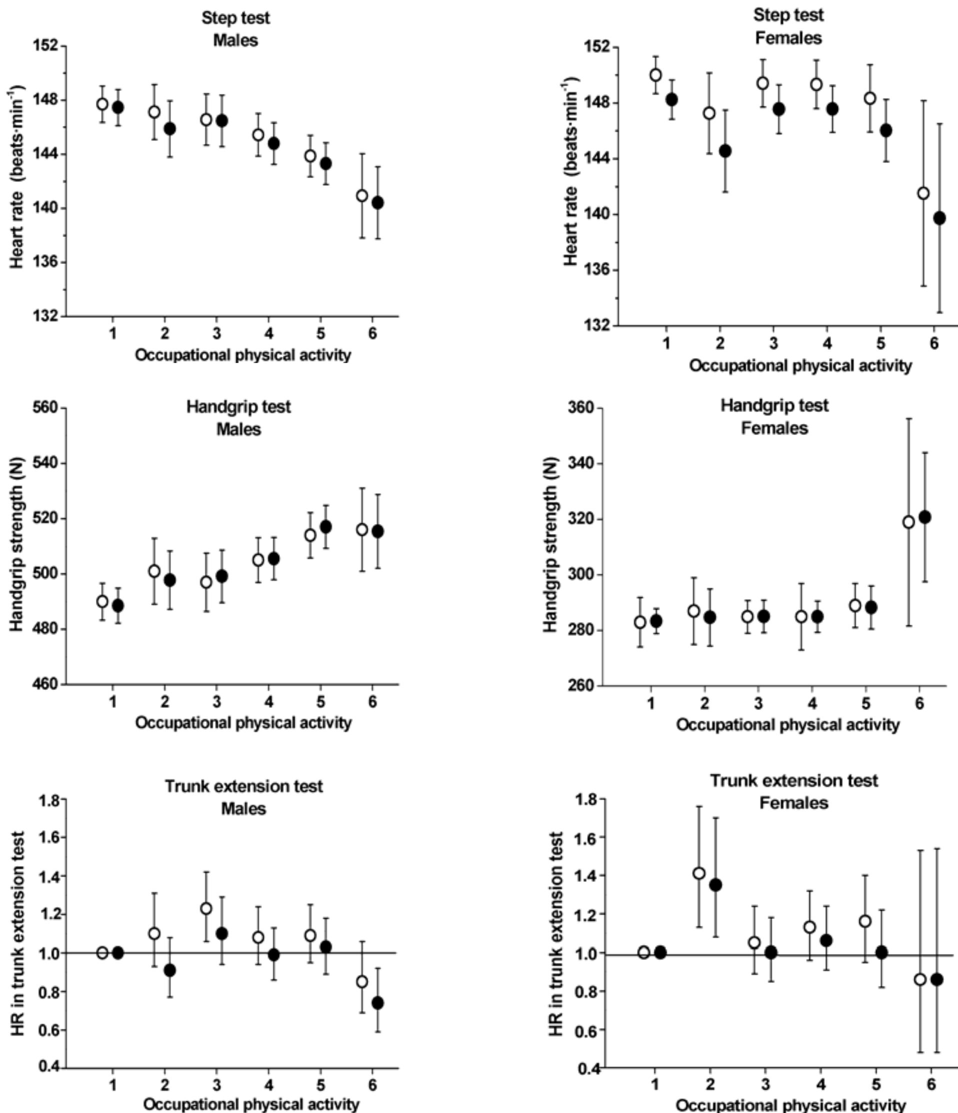

Fig. 8. Results of the step test, handgrip test and trunk extension test according to following levels of occupational physical activity: 1) light sedentary work, 2) other sedentary work, 3) light standing or moving work, 4) medium heavy moving work, 5) heavy manual work and 6) very heavy manual work. Mean values or hazard ratios (HR) and their 95% confidence intervals. Hazard ratios represent the probability of failure at the trunk extension test before maximum time. ○ = crude values from univariate analyses, ● = values adjusted for leisure-time physical activity, height, weight and smoking.

5.6 Cardiorespiratory fitness of young adults (V)

The laboratory sample of 123 males and females showed a 5–6 beats/min lower mean heart rate immediately after the step test than the whole cohort population examined, indicating better cardiorespiratory fitness of the laboratory subsample (Article V: Table 1). Males of the laboratory sample participated in brisk physical activity more frequently than the whole cohort population. There was no major difference in the level of leisure-time physical activity or BMI between those who participated in medical examination and those who participated only in the postal inquiry, but not in medical examination. In the laboratory sample, mean maximal workload was 244 W in males and 163 W in females, and mean maximal heart rate was 191 beats/min in males and 187 beats/min in females (Article V: Table 1).

The adjusted R^2, SEE and regression coefficients for the different $\dot{V}O_{2peak}$ prediction models 1–4 are presented in Table 10. To produce the reference values, Model 4 was selected to calculate $\dot{V}O_{2peak}$ (ml·kg^{-1}·min^{-1}) for those 2,663 males and 2,761 females who participated in medical examination including the step test, because the Model 4 had the highest adjusted R^2 and the lowest SEE (Table 10). The non-exercise Model 3 was used to calculate $\dot{V}O_{2peak}$ values for those 1,410 males and 1,607 females who provided data on their physical activity, body height and weight in postal inquiry but did not participate in the step test in medical examination. On the basis of these models, $\dot{V}O_{2peak}$ values (ml·kg^{-1}·min^{-1}) were calculated for 4,073 males and 4,368 females. The mean, standard deviation and quintiles of the model predicted $\dot{V}O_{2peak}$ reference values are presented in Table 11.

The proportions of persons who participated in brisk physical activity once a month or less, 2–3 times a month, once a week, 2–3 times a week, 4–6 times a week and daily were 22%, 14%, 21%, 29%, 11% and 3% in males, and 19%, 13%, 26%, 30%, 9% and 3% in females, respectively. A linear dose-response relationship was observed between the frequency of participation in brisk physical activity during leisure-time and the level of model predicted $\dot{V}O_{2peak}$ (Fig. 9). Similar dose-response relationship was also observed in overweight and obese persons, although the level of model-predicted $\dot{V}O_{2peak}$ was lower in persons with increased BMI (Fig. 9).

Table 10. Regression models used to predict peak oxygen uptake (ml kg min^{-1}) for the males and females

Variables in the Models 1–4	Males (N= 63)					Females (N=60)				
	adj. R^2	SEE	β	SE	p-value	adj. R^2	SEE	β	SE	p-value
Model 1: HR	0.27	5.48				0.25	5.38			
Constant			77.69	7.00	< 0.001			65.67	6.72	< 0.001
HR			–0.23	0.05	< 0.001			–0.21	0.05	< 0.001
Model 2: HR + BMI	0.36	5.12				0.34	5.07			
Constant			90.00	7.42	< 0.001			70.06	6.51	< 0.001
HR			–0.16	0.05	0.002			–0.16	0.05	0.002
BMI			–0.90	0.27	0.001			–0.53	0.18	0.005
Model 3: BMI + PA	0.47	4.65				0.44	4.61			
Constant			65.35	5.87	< 0.001			49.02	3.75	< 0.001
BMI			–0.98	0.23	< 0.001			–0.72	0.15	< 0.001
PA			1.56	0.31	< 0.001			1.55	0.32	< 0.001
Model 4: HR + BMI + PA	0.51	4.49				0.49	4.42			
Constant			76.02	7.32	< 0.001			61.07	6.10	< 0.001
HR			–0.11	0.05	0.025			–0.11	0.04	0.018
BMI			–0.79	0.24	0.001			–0.56	0.16	0.001
PA			1.35	0.32	< 0.001			1.34	0.32	< 0.001

adj. R^2= R^2 adjusted for the number of variables in the model, SEE = standard error of the estimation model, β = regression coefficient, SE = standard error of the coefficient, HR = heart rate after step test, beats/min, BMI = body mass index, kg/m^2, PA = frequency of brisk physical activity, times/week.

Table 11. Model-predicted reference values of peak oxygen uptake[a] (ml·kg^{-1}·min^{-1}) based on 4,073 males and 4,368 females who participated in the health survey of the Northern Finland birth cohort of 1966 at age 31.

	Males	Females
Mean	43.0	34.3
SD	4.6	4.3
Quintile 1, least fit 20%	≤ 39.5	≤ 31.1
Quintile 2	39.6–42.0	31.2–33.5
Quintile 3	42.1–44.0	33.6–35.3
Quintile 4	44.1–46.6	35.4–37.6
Quintile 5, most fit 20%	≥ 46.7	≥ 37.7

[a] $\dot{V}O_{2peak}$ was predicted by Model 4 (including heart rate after step test, body mass index and frequency of brisk physical activity) for those 2,663 males and 2,761 females who participated in medical examination, and by non-exercise Model 3 (including body mass index and frequency of brisk physical activity) for those 1,410 males and 1,607 females who participated only in the postal inquiry.

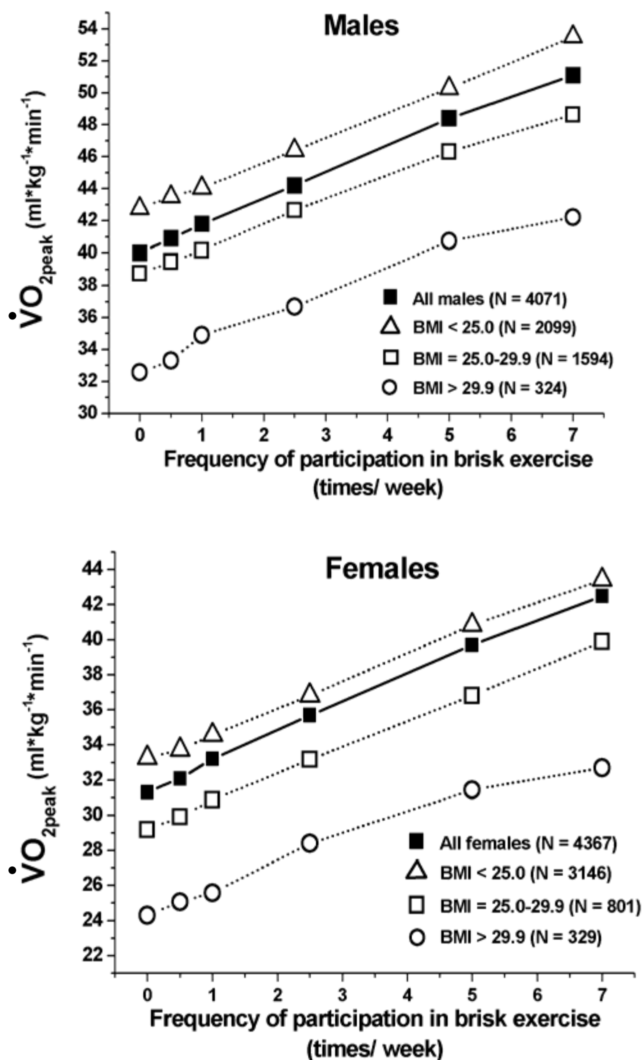

Fig. 9. Model-predicted peak oxygen uptake ($\dot{V}o_{2peak}$) of 4,071 males and 4,367 females at age 31 according to the frequency of participation in brisk exercise during leisure time. Results are from the health survey of the Northern Finland birth cohort of 1966. $\dot{V}o_{2peak}$ is also presented by different level of body mass index (BMI).

6 Discussion

6.1 Participation in adolescent sports and adult physical activity (I)

The present finding about the association between adolescent and adult level of physical activity is in line with the results obtained in previous longitudinal studies (Engstöm 1986, Telama *et al.* 1996, Vanreusel *et al.* 1997). In the present study, participation in sports at least once a week in females and twice a week in males was associated with a high level of physical activity in later life. This level could be interpreted as the minimal dose for adolescent physical activity with respect to enhancement of adult physical activity.

Sallis *et al.* (1996) and Powell *et al.* (1987) have suggested that physical activities that can be performed without a team may carry over to adulthood, but our results do not support this tentative idea. Several individual sports, but also most of the ball games in males, showed a strong carry-over value from adolescence into adulthood. The proportion of males participating in ball games at age 31 was relatively high, 27%, although it may be more difficult for a large number of older friends to get together for such an activity compared to adolescent years. Personality traits may also guide one's selection between individual or team sports. Potentially, those who prefer team sports in adolescence, feel the same in adulthood too.

Adolescent participation in relatively intensive endurance sports, such as skiing, running and orienteering, was associated with a high level of total activity and participation in endurance sports in adulthood. One reason for the high carry-over effect into adulthood may be the ease with which these sports can be performed on one's own time. Participation is not dependent on company or facilities. Another reason may be the self-selection of the most physiologically talented individuals into such endurance sports. Exercising is easy for such individuals both in adolescence and in adulthood. Also Telama *et al.* (1997) suggested that a high intensity of adolescent physical activity, defined as sweating and breath-taking, was one of the best predictors of adult activity. A high level of cardiorespiratory fitness (Barnekow-Bergkvist *et al.* 1998, Glenmark *et al.* 1994, Kemper *et al.* 2001a) and aerobic potential, in terms of a high proportion of oxidative type I muscle fibers (Glenmark *et al.* 1994), have predicted a high level of physical

activity in adulthood. Natural selection into endurance sports or participation in them in adolescence seems to predict a high level of physical activity and participation in endurance sports also at adult age. This conclusion has been supported Kujala *et al.* (2000) who reported in their longitudinal study of top-level athletes that former endurance athletes were physically more active in later life than the other athlete groups and control group.

Participation in organized sports and a high grade in school sports have been reported to be major determinants of continued participation (Telama *et al.* 1997). In the present study, the participants in those adolescent sports which carried over into the adult years were commonly characterized by high grades in school sports and the membership of a sports club. A high grade in school sports may reflect a well developed and wide range of skills, as well as a positive attitude towards sports. Additionally, membership in a sports club may reflect a more organized way of sports participation.

Many sports need some special motor and coordination skills which are evident in early childhood and may direct the child's personal selection of the sport. The more skilled individuals may be more likely to participate in a greater variety and quantity of physical activities on a regular basis. Involvement in ball games and track and field, for instance, may further enhance adolescents' sports skills, and increase the probability that these skills will be used later in life. This underlines the importance of early exposure to high quality and diversified physical activity experiences. The opportunity to participate in a wide range of activities in youth may maximize the probability that one of the activities will suit the needs and skill level of the young person and result in the desire to continue participation into adulthood.

Vanreusel *et al.* (1997) reported that the dropout rate from recreational sport was lower and appeared at later ages compared to a competitive sports career, defined as participation in competitions during each observed year from 13 to 35 years. However, their longitudinal study of 235 males did not provide information about how a recreational style continued after a competitive career in a specific sports In the current study, a continuation of more intensive and organized adolescent sports into adulthood appeared to be more commonplace. An interesting finding in the present study was that participation in walking and skating, and in males also in cycling and strength training, was not associated with a high level of activity in adulthood. Maybe those adolescents who participated in cycling and walking at 14 years, did not participate in any other particular sport, but simply wanted to register some activity in the questionnaire.

Some social determinants of participation in different types of sports in adolescence were also assessed in order to understand better the background of participation in different types of sport. Socioeconomic status of the family appeared be related to the selection between different adolescent sports. Sallis *et al.* (1996) contended that socioeconomic situation is not a major factor in the selection of out-of-school activities and sports by adolescents. However, our results suggest an association between father's occupation and the type of sport. Low social class of the family may weaken parents' ability to transport children to organized sports, and to pay the fees and equipment required for the young person to participate.

Place of residence was also associated with participation in different sports in adolescence. In rural areas, outdoor sports were more popular. In urban areas, adolescents frequently participated in sports demanding special facilities and organized guidance,

such as riding, combat sports and dancing. Compared to their rural counterparts, those who live in an urban environment may have more opportunities to participate in various organized activities and to utilize sports facilities.

6.2 Physical activity and social status in adolescence as predictors of physical inactivity in adulthood (II)

6.2.1 Physical activity in adolescence and physical inactivity in adulthood

Those who participated in sports twice a week or more often at 14 years were less likely to be inactive at 31 years compared with those who participated in sports less often than once a week, independently of many adult social factors. This finding concurs with that of Engström (1986), who stated that early experiences of physical activity have an influence on psychological readiness to participate in physical activities in later life, and that the interaction between psychological readiness and current environmental circumstances explains the participation in physical activity in adulthood. Adult physical activity has also in other longitudinal studies been found to be related to adolescent physical activity (Vanreusel *et al.* 1997, Barnekow-Bergkvist *et al.* 1996, van Mechelen & Kemper 1995, Telama *et al.* 1996), in addition to which our findings also confirm the results of Yang *et al.* (1999), one of the few previous papers to take adult social factors into account.

Being a member of a sports club in adolescence seemed to protect the subjects from later inactivity, as was also mentioned in some earlier Scandinavian reports (Telama *et al.* 1997, Barnekow-Bergkvist *et al.* 1998). We found this association to be stronger among males, suggesting that this kind of socialization into the sports community is especially important for males in terms of later activity. The association disappeared after adjustment for the adolescent level of physical activity, however, due to the correlation between the membership of a sports club and the level of physical activity. The association found here in males between a low grade in school sports and adult inactivity has also been reported earlier (Telama *et al.* 1997, Glenmark *et al.* 1994), and it persisted here even after adjustment for the adolescent level of physical activity. It may be that a high grade in school sports reflects a positive general attitude towards sports and a high level of skills, and would therefore also be associated with an active way of life in adulthood, independently of the adolescent level of physical activity.

6.2.2 Social status in adolescence and physical inactivity in adulthood

The present finding about the association between low social class and physical inactivity at 14 years was also reported in one third of the papers reviewed by Sallis *et al.* (2000). The lack of consistent findings in their review was possibly due to the different measures

used for socio-economic status. Lower income may restrict children's participation in high-cost sports in societies where youth sports do not receive government subsidies. Also, parents with a low educational level may themselves be inactive and thus provide an unfavorable role model for their children.

Low social class of the childhood family was not associated with physical inactivity in adulthood. Social class of the childhood family seems to be a less important predictor of later physical activity level in Finnish society, where differences between the social classes are relatively small. In some earlier studies this association existed in unadjusted analyses (van de Mheen *et al.* 1998, Huurre *et al.* 2003, Wannamethee *et al.* 1996, Blane *et al.* 1996, Kuh & Cooper 1992), but in most cases it disappeared after adjustment for subject's own social class or educational level as an adult (Wannamethee *et al.* 1996, Blane *et al.* 1996, Kuh & Cooper 1992), obviously on account of the close correlation between the childhood and adulthood socio-economic situations.

The father having been a farmer may reflect a rural place of residence rather than a particular socio-economic situation, because the size of the farm was not taken into account in these analyses. Interestingly, farmers' sons were the most inactive, both in adolescence and in adulthood, although the association of adult inactivity with this category disappeared after adjustment for the adolescent level of physical activity. It may be that farmers' sons participate in sufficiently physically demanding work on the farm and do not participate in adolescent sports so often, and that this may form a pathway to adult inactivity.

The present finding that a low average grade at school is associated with physical inactivity in adolescence and in later life confirms earlier findings (Barnekow-Bergkvist *et al.* 1996). High grade average at school was closely associated with a high level of vocational education in later life, which is known to be associated with a high level of physical activity in adulthood (Leino *et al.* 1999, King *et al.* 1992, Yang *et al.* 1999). The subject's own school attainment and education seem to be more important than the childhood family background in determining physical activity as an adult, and higher education seems to be an important pathway to a healthier lifestyle.

In order to promote physical activity in adulthood, it should already be strongly encouraged in youth. Government financial support for youth sports would offer opportunities for all children to participate regardless of their family's socio-economic situation. Compulsory lessons in physical education at school are a notable setting in which to promote physical activity, because it is a way of reaching all adolescents regardless of their social class, interest in physical activity or skills at sports. Physical education and activity programs for young people should be evaluated critically with regard to their contribution to lifetime physical activity, asking whether they give young people positive experiences, enhance the variety of their sports skills and increase their motivation for habitual physical activity regardless of their natural skills.

6.2.3 Associations between social status and physical inactivity in adulthood

Family and work are essential elements in life for young adults. In the present study, having children was associated with physical inactivity in both sexes, although in earlier studies this association has only been found in females (Barnekow-Bergkvist *et al.* 1996, Yang *et al.* 1999). Maybe this is a reflection of the trend that young Finnish males nowadays more often share domestic chores and childcare responsibility with females. It is obvious that taking care of small children may restrain parents' participation in physical activity, an effect which could be alleviated by offering child care services in connection with exercise services, for instance, or by arranging activities for the whole family. Taking care of children may also include physical activity, such as carrying and playing, which may not have been covered by the parents' responses about their leisure-time physical activity.

The amount of leisure time available may partly explain the high prevalence of physical inactivity among entrepreneurs and low prevalence of inactivity among unemployed males. Entrepreneurs here also included farmers, whose low level of leisure-time activity may be partly explained by their heavy manual work. Males engaged in heavy manual were more often inactive during leisure time compared to males engaged in light sedentary work. Our finding that physical inactivity at adult age was common among rural males is similar to that of Yang *et al.* (1999), who speculated that urban people may have better access to sports facilities than their rural counterparts. Adjustment for education erased the relation between rural residence and inactivity in our study, indicating that physical inactivity was more related to a lower level of education than to a rural place of residence.

6.3 Physical activity from adolescence into adulthood and obesity in adulthood (III)

Becoming inactive between adolescence and adulthood was associated with overall obesity in males and females, and with severe abdominal obesity in females. Although genetic factors play an important role in the development of obesity and abdominal obesity (Bouchard 1997), lifelong physical activity seems to have an important independent preventive role, as shown in our analyses adjusted for several potential confounding factors. This finding is encouraging with regard to obesity prevention, because physical inactivity is a risk factor which can be modified. Encouragement to participate in physical activities in youth may be beneficial in the enhancement of adult physical activity and the prevention of obesity.

Our observed association between the high level of continued physical activity and the low level of overall and abdominal obesity can be understood in the light of earlier experimental studies, which have shown that exercise training can reduce adipose tissue (Ross & Janssen 2001). Abdominal fat is suggested to be more responsive to exercise than fat in other parts of the body (Samaras & Campbell 1997). Exercise-induced

alterations in lipolytic activity have been shown to be greater in abdominal than in gluteofemolar adipocytes, and therefore abdominal fat is more readily mobilized during exercise than peripheral depots (Samaras & Campbell 1997). Evidence from randomized controlled trials also suggests that exercise-induced weight loss is associated with reduction in abdominal obesity (Ross & Janssen 2001), and exercise alone, even without weight loss, reduces abdominal fat (Ross *et al.* 2000).

The lack of association between the absolute level of adolescent physical activity and adult obesity measures was consistent with some earlier findings (Lefevre *et al.* 2002, Twisk *et al.* 2002b). Our results are similar to the findings of Hasselstrom *et al.* (2002), who suggested that the change in physical activity from 17 to 25 years was negatively associated with males' waist circumference and fatness at 25 years. In our study the decline in physical activity, becoming inactive, was negatively associated with overall obesity in both genders and severe abdominal obesity in females.

In our study, becoming inactive seems to be even more harmful than being persistently inactive between adolescence and adulthood in terms of development of obesity. One explanation for this may be that it is difficult to adjust the energy intake from food to a decreased level of physical activity, which leads to increase in weight. Similar findings have been observed in follow-up studies of adult population (Williamson *et al.* 1993, Haapanen *et al.* 1997). Williamson *et al.* (1993) showed that a change in the level of physical activity, whether a decrease or an increase, was associated with greater weight gain, compared with those who had been persistently active or inactive. Haapanen *et al.* (1997) reported that the decrease in physical activity was more strongly associated with significant weight gain than being persistently inactive. Abdominal obesity was not evaluated in these two studies, but in the study of Wing *et al.* (1991) the change in physical activity was negatively associated with the change in the waist to hip ratio after adjustment for BMI in middle-aged females. In the present study, the groups who had become active or were persistently active did not differ when we compared the odds ratios for obesity. In our study, an increase in physical activity between adolescence and adulthood was not associated with adult obesity measures when referred to the persistently active group.

The lack of a significant association between being persistently inactive and some obesity measures may be due to the relatively small size of the persistenly inactive group (187 males and 240 females) and adjustment for other unhealthy habits. Physical inactivity may be related to an unhealthy lifestyle and habits, such as smoking and heavy alcohol consumption, as well as an unhealthy diet, which in turn are also known to be associated with obesity (James 1995). The effects of inactivity on obesity may be partly explained by reduced energy expenditure, but they may also be partly transmitted by other unhealthy behavior. In clinical practice, it is not so important to try to separate the independent effects of these habits, but rather to pay attention to the whole life situation and health habits in the counseling aimed at prevention and management of obesity.

Causality between the change in physical activity and obesity cannot be fully asserted in our study, because physical activity patterns may affect weight and fat distribution, but it is also possible that weight or fat distribution influences physical activity (DiPietro 1995). In our analyses we did, however, control for the level of obesity at 14 years.

This study provides rarely reported information about the change in the level of physical activity between adolescence and adulthood as a determinant of adult obesity. Regarding the interpretation of the results, it is worthy to note the way we dichotomized the subjects into active and inactive groups at different ages. Our focus was the classification of the inactive group, and the persons classified as active were not necessarily very active. They participated in sports at least once a week at 14 years, or in brisk exercise at least once a week at 31 years. Therefore, our results demonstrate that the avoidance of physical inactivity, or keeping up at least a moderate level of physical activity, is important in the prevention of overall and abdominal obesity.

The long time period between the ages 14 and 31 may have led to a misclassification of the exposure. Some subjects may have changed their level of physical activity many times during this period. In addition, the frequency of participation in sports at 14 years is only part of habitual physical activity, and therefore it does not represent an accurate measure of adolescent physical activity, but is just a crude estimate of being active or inactive.

Although BMI is correlated with the fat content of the body, some misclassification may be present due to differences in muscle mass. Especially males with a very high content of muscle mass may be misclassified as being overweight, although their fat content is optimal for health. In addition, the level of obesity may influence the reporting of physical activity, because obese persons usually overreport their physical activity (Lichtman *et al.* 1992), which may lead to underestimation of the association between physical activity and obesity.

In conclusion, the results emphasize the independent role of continued physical activity between adolescence and adulthood in the prevention of adult overall and abdominal obesity.

6.4 Association between occupational physical activity and fitness in young adults (IV)

Young males engaged in heavy physical work exhibit higher levels of cardiorespiratory fitness, handgrip strength and trunk muscle endurance than young males doing lighter work; the same applies to cardiorespiratory fitness in young females. The associations were independent of leisure-time physical activity, body weight, height and smoking. Causality cannot be asserted, but a training effect of heavy work is a reasonable assumption. Self-selection of the fittest to physically demanding jobs, and of the least fit or sickly individuals to lighter work, may also partly explain our findings.

The finding of the positive association between heavy physical work and good cardiorespiratory fitness is similar to that of Jonsson & Åstrand (1979), who stated that young men who sweat daily at work possess better aerobic capacity than their non-perspiring counterparts; however, their finding was restricted only to males who were inactive during leisure time. In their study, the difference in heart rate between the heaviest and lightest work-load groups was 10 beats/min in submaximal cycle ergometer work – similar in magnitude to the difference of eight beats/min observed in our study.

Our findings on muscular endurance are in line with those reported by Era *et al.* (1992), who showed greater muscular strength in young male manual laborers than in young white-collar workers. The large sample size, more accurate assessment of occupational physical activity and adequate control of relevant confounding factors may partly explain why significant associations were observed here, but not so clearly elsewhere. We further suggest that a positive association may exist between occupational physical activity and cardiorespiratory fitness in young females, although the effect may be restricted to females doing very heavy physical work.

Although leisure-time physical activity, height, weight and smoking were all strongly related to different measures of physical fitness, their confounding effect was only a minor one, except for the trunk extension test in males and the step test in females. The true relationship between occupational physical activity and heart rate in females was initially hidden by the greater weight of females doing heavy work, which shows the importance of confounders to be considered.

These results, involving young workers engaged in heavy physical work, differ from those involving middle-aged workers, who were found to have lower fitness than workers engaged in lighter work (Nygård *et al.* 1987). Most earlier studies also fail to report any positive effect of heavy work on muscular fitness. An exception is the study by Torgen *et al.* (1999), who found some evidence that heavy work, especially lifting of heavy objects, may have a training effect on the muscular fitness of the upper extremities of middle-aged workers. Two intervention studies have also suggested that increased frequency of stair climbing during the workday may enhance the cardiovascular fitness of subjects with poor physical fitness (Ilmarinen *et al.* 1978, Ilmarinen *et al.* 1979).

However, the high fitness of the young males engaged in heavy physical work in this study raises the issue of an optimal level of occupational physical activity for improving and maintaining physical fitness. In some occupations, the frequency, intensity and duration of exercise at work may be very close to optimal, especially if its rhythm, manner and pauses can be freely modified by the worker.

Our findings also raise the question of why physical work would be advantageous in younger but not in older workers, as reported in the literature (Nygård *et al.* 1987). With advancing age, the beneficial effect of work may be reversed by decreased fitness related to biological aging and an increase in chronic diseases. In addition, the young males engaged in heavy physical work in this study were often relatively inactive during leisure time, and this, too, could render their fitness relatively poor later in life. In females, a heavy physical load during occupational work may exceed a tolerable level at an earlier age than in males because of their lower level of physical capacity. This would offer some grounds for allocating younger and older workers, as well as males and females, to work tasks with different demands on physical capacity.

Our results also emphasize the importance of taking occupational physical activity into account in epidemiological studies evaluating the relationship between leisure-time physical activity and fitness. Occupational physical activity is associated with both leisure-time physical activity and physical fitness, and may therefore counfound the relationship between these two variables.

Self-selection of the fittest to physically demanding jobs, and of the least fit or sickly individuals to lighter work, might partly explain our findings. However, in an earlier study involving middle-aged workers, the poorer fitness of workers in heavy jobs

(Nygård *et al.* 1987) did not reflect this kind of health-based selection (Östlin 1988). One reason for this phenomenon may be that a change of occupation or work may be more difficult in later life than at some earlier stage of the career. The cross-sectional setting of the present study does not enable us to assert causality between occupational physical activity and fitness; this remains to be assessed in subsequent follow-up studies. In addition, there is a need to determine the critical age beyond which the beneficial effect of occupational activity becomes deteriorating, and whether it could be shifted by appropriate leisure-time activity.

Occupational physical activity is said to be too one-sided and static, typically having an overloading rather than a training effect on the cardiorespiratory system (Ilmarinen 1989). This may be because in industry the rhythm of movements is often determined by machines rather than by the individual, and other adverse circumstances, such as high or low environmental temperature, an awkward posture or heavy loading of small muscle groups, may be present. During heavy work, the frequency and intensity of exercise may be adequate, but its excessive duration provides insufficient recovery time between workdays, particularly in persons with poor physical fitness.

6.5 Cardiorespiratory fitness of young adults (V)

6.5.1 Measurement of cardiorespiratory fitness

The traditional Åstrand-Ryhming step test (Åstrand & Ryhming 1954) was chosen for this study as an objective exercise test because stepping is a familiar exercise mode to most people, and the method is inexpensive, portable and requires little calibration. The shortening of the original test from five minutes to four minutes was done to save the total time of 100 hours in the testing of 6,000 subjects. In our study, a relatively high mean heart rate after the stepping and a small heart rate difference between the third and the fourth minutes indicated that this step test was long enough, and the intensity was high enough for most of the subjects to result in a steady state at the suggested heart rate level of 125–170 beats/min (Åstrand & Ryhming 1954).

Model 4 was the most accurate of the four models tested and was therefore used to calculate $\dot{V}O_{2peak}$ for those who participated in medical examination. The non-exercise Model 3 was used to calculate $\dot{V}O_{2peak}$ for those who did not participate in step test in medical examination but provided data on their physical activity and body dimensions by postal inquiry. Model 3 seemed to be as accurate as the objective Model 2 in predicting $\dot{V}O_{2peak}$. Non-exercise models have been reported to be as accurate as submaximal exercise testing (Jackson *et al.* 1990) and seem to be a reasonable alternative when objective exercise testing is not possible, but an estimation of $\dot{V}O_{2peak}$ is needed. In epidemiological studies of this kind, non-exercise models provide a method for replacing missing data for those who did not participate in the exercise test, but filled out the questionnaire with data about their physical activity level and anthropometrics.

Model 2 was formed by adding BMI into Model 1, which increased the accuracy of the estimation. Model 2 is suggested to be used when there is a need to calculate $\dot{V}O_{2peak}$ objectively for the whole cohort population, for instance when an independent effect of both physical activity and cardiorespiratory fitness on certain outcome is evaluated.

$\dot{V}O_{2max}$ was also calculated by the traditional Åstrand nomogram (Åstrand 1960, Åstrand & Ryhming 1954) based on body weight and heart rate after four minutes' stepping, with a correction factor of 0.935 for age (Åstrand 1960). The Åstrand nomogram overestimated the $\dot{V}O_{2max}$ notably, 5 $ml \cdot kg^{-1} \cdot min^{-1}$ in males and 10 $ml \cdot kg^{-1} \cdot min^{-1}$ in females. Therefore the development of more accurate prediction models for the present study population was necessary.

6.5.2 Reference values of cardiorespiratory fitness

Reference values for cardiorespiratory fitness have usually been formed on the basis of relatively small (Shvartz & Reibold 1990) and, most probably, selected samples. Subjects who agree to participate in a maximal exercise test may be selected by their relatively high level of physical activity and fitness. In such cases, the reference values may be too high when compared with actual fitness of the population. In the present study, the subjects in the laboratory sample which performed the maximal exercise test had slightly higher levels of fitness and physical activity than the whole cohort population. By projecting the model-predicted values to a highly representative population of 4,073 males and 4,368 females, we assumed to have more representative reference values compared with the slightly selected laboratory sample.

The present mean values of $\dot{V}O_{2peak}$ for 31-year-old males and females were very similar (± 1 $ml \cdot kg^{-1} \cdot min^{-1}$) compared with the norm values presented by Shvartz & Reibold (1990) which are generally used in Finland. A low level of cardiorespiratory fitness is associated with an increased risk of cardiovascular diseases and mortality (Blair *et al.* 1989, Laukkanen *et al.* 2001, Talbot *et al.* 2002). Especially the least fit 20% of males and the least fit 40% of females had a higher mortality risk than more fit males and females in the follow-up study of about 10,000 males and 3,000 females (Blair *et al.* 1989). The present reference values were also very similar to the 20th percentiles of $\dot{V}O_{2max}$ provided by Institute of Aerobics Research in USA for males and females aged 20–29 years and 30–39 years (Franklin *et al.* 2000), with the exception that the limit for the least fit 20% was at about 2–3 $ml \cdot kg^{-1} \cdot min^{-1}$ higher in our data, which suggests that the present population of Finnish males and females includes fewer persons with a very low fitness level.

6.5.3 Participation in brisk exercise and cardiorespiratory fitness

Our result showed a linear dose-response relationship between the frequency of participation in brisk exercise and cardiorespiratory fitness. A similar dose-response relationship was also observed among overweight and obese males and females, although

the level of $\dot{V}O_{2peak}$ related to body weight was naturally lower in persons with increased BMI. At age 31, very low levels of $\dot{V}O_{2peak}$ were associated with a combination of infrequent participation in brisk exercise and increased BMI. On the other hand, obese persons may have a relatively high level of cardiorespiratory fitness if they are physically active. Persons with BMI equal to or greater than 30.0 had generally $\dot{V}O_{2peak}$ very close to the average, if they participated in brisk exercise four times a week or more.

Regular participation in brisk exercise is important in terms of maintaining and enhancing cardiorespiratory fitness. Gathering a large total amount of both light and brisk physical activity is valuable in terms of weight management, and therefore indirectly enhances cardiorespiratory fitness as well. Regular physical activity, a high level of cardiorespiratory fitness and maintaining normal weight are all important in terms of overall health.

These reference values can be used in fitness testing and physical activity counseling. Figure 9 demonstrates how the levels of physical activity and obesity are both strongly associated with cardiorespiratory fitness. By comparing the fitness test results to these reference values one can deepen the interpretation of the results and evaluate the level of physical activity generally needed to achieve the wanted level of fitness.

6.6 Methodological considerations

The major strengths of this prospective study are the large and unselected population sample, the opportunity to control for potential confounding factors, a long follow-up time and a high participation rate. Extensive data based on the general population offered a unique opportunity to study the association between a wide range of adolescent sports and adult physical activity. The measurement at 31 years can be used as baseline measurement in later follow-ups, in which the level of physical activity and fitness at 31 years will be related to incidence of diseases in later life.

Reliance on self-reported measures of physical activity is a limitation in surveys of this kind. Social desirability bias can lead to over-reporting of physical activity (Sallis & Saelens 2000), and therefore the number of inactive individuals may actually be greater than that reported. Such an obviously non-differential bias is, however, unlikely to affect the association between physical inactivity and the explanatory factors. Our questions about physical activity status in adolescence should be interpreted as indicators of engagement and participation in physical activity. We did not measure the total amount of physical activity in adolescence, but only participation in sports, which is not always the predominant amount of physical activity during adolescent years. Questionnaire methods do not generally provide accurate data on individual energy expenditure, but they are considered useful for grouping people into categories on the basis of their physical activity (Montoye *et al.* 1996).

Selective losses to follow-ups may be an important source of bias in this kind of longitudinal studies. The compliance with the study may be higher in the healthiest part of the population. In the present study the response rate at 14 years was extremely high and enabled the characterization of those who did not participate in the follow-up at 31 years. Those who did not participate at all in the follow-up at 31 years did not essentially

differ from those who participated at 31 years with regard to key variables, such as physical activity and body mass index at age 14, although they came slightly more often from families with a low social class and had slightly more often low grade average at school at 14 years. Those who participated in the medical examination at 31 years were not physically more active or less obese compared to those who only answered the postal inquiry at 31 years. The population that participated in the follow-up at age 31 seems to be representative of the whole Northern Finland birth cohort of 1966 by their level of physical activity and BMI.

The highest level of evidence is generally thought to be achieved from randomized controlled trials. However, some phenomena cannot be evaluated in trials of this kind. For instance, it would not be ethically acceptable to form a study group of children who would remain physically inactive until adulthood and to compare them with a physically active group. The present study includes cross-sectional and prospective observational research. The causality between the variables cannot be fully asserted based on these kinds of study settings. Therefore, the results should be interpreted with a certain amount of caution, also keeping the possibility of resiprocal effect and natural selection in mind.

The results can most likely be generalized to represent Finnish adults aged about 31 years, as well as other Western developed countries with similar geographical and sociopolitical situations. Some results, for instance the prevalence of different types of sports are typical for the area of northern Finland. However, the society and also the types of sports among adolescents have changed considerably since 1980, and further information is required to evaluate the patterns and the social determinants of adolescent physical activity today.

7 Summary of the findings and conclusions

The main findings of the study were:

1. Adolescent participation in sports after school hours twice a week or more was associated with a high level of physical activity at age 31. Adolescent participation in rather intensive endurance sports and in some sports that demand or develop diversified skills at sports seemed to be most beneficial with respect to the enhancement of adult physical activity, although the differences between various sports were only modest. (I)
2. Infrequent participation in adolescent sports, and especially in males, not being a member in a sport club and a low grade in school sports at 14 years, were associated with physical inactivity at 31 years. (II)
3. Low social class of the childhood family was associated with physical inactivity in adolescence but not with inactivity at 31 years. Poor scholastic achievements were associated with physical inactivity at age 14, and additionally, with physical inactivity at age 31, independent of adolescent physical activity. (II)
4. Becoming inactive between adolescence and adulthood was associated with overall obesity at age 31 in males and females, and with severe abdominal obesity in females. Being persistently inactive between adolescence and adulthood was not significantly associated with overall obesity or abdominal obesity at age 31 in either gender after adjustment for confounding factors (III).
5. A high level of occupational physical activity was associated with high levels of cardiorespiratory fitness, handgrip strength and trunk muscle endurance in males aged 31 years. The same applied to cardiorespiratory fitness in females. A high level of occupational physical activity was associated with a low level of leisure-time physical activity. (IV)

Reference values of cardiorespiratory fitness were produced for young adults aged 31 years with the mean $\dot{V}O_{2peak}$ of 43 $ml \cdot kg^{-1} \cdot min^{-1}$ in males and 34 $ml \cdot kg^{-1} \cdot min^{-1}$ in females. A linear dose-response relationship was observed between the frequency of participation in brisk exercise and model-predicted $\dot{V}O_2$peak. Very low levels of $\dot{V}O_2$peak were associated with a combination of infrequent participation in brisk exercise and increased BMI. (V)

Regular physical activity, a high level of cardiorespiratory fitness and the maintenance of normal weight are known to contribute strongly to several positive health outcomes. It is also known that physical activity is an important means of maintaining adequate cardiorespiratory fitness and normal body weight. The present results emphasize the role of brisk exercise in the maintenance of a high level of cardiorespiratory fitness among both normal weight and obese individuals, and the role of continued physical activity from youth to adulthood in the prevention of adult obesity.

Measurement of health-related fitness is an important part of health monitoring. Regular monitoring of fitness seems to be especially justified in young workers engaged in heavy physical work, since earlier studies have suggested a negative effect of heavy work on fitness with advancing age. Fitness tests may assist in identifying the need for health-enhancing or fitness-improving physical activities. The reference values of cardiorespiratory fitness produced in the present study can be used in the interpretation of fitness test results and in physical activity counseling.

Maintaining high levels of physical activity across the lifespan is an important challenge for public health promotion. For young adults, the interventions conducted at workplaces and physical activity guidance provided by occupational health service may be the most natural settings to promote physical activity. Physical activity promotion in youth is especially important, because a high level of physical activity in adolescence seems to improve the likelihood of being physically active in adulthood as well. Physical education lessons at school are a notable setting to promote physical activity, because it is a way of reaching all adolescents regardless of their social class, interest in physical activity or skills at sports. Special encouragement is suggested for those adolescents with a low level of scholastic perfomance. Public financial support for different youth sports is important in offering equal opportunities for all children to participate regardless of their family's socio-economic situation. Frequent participation in youth sports, positive experiences and a wide range of sports skills acquired at an early age may be the best preparation for lifelong physical activity.

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Appendices

Appendix 1

Table 1. Summary of the longitudinal studies on physical activity in youth and from youth to adulthood. Age at baseline less than 25 years, follow-up time at least 2 years. FA = physical activity, LTFA=leisure-time physical activity, ↓=decrease, ↑=increase, y = years.

Authors and publication year	Subjects, follow-up time, design, year, country and name of the study	Measurement of physical activity and other essential variables	Main results about the stability, tracking correlations, change and early age predictors of physical activity
Aarnio *et al.* 2002a	• 2311 males, 2717 females, twins born in 1975-1977 • **16 y→18 y** • 3 y follow-up, in 1991→95 • Finland	• **PA:** frequency of LTFA annually by questionnaire • **Other:** health-related behavior, social relationships and health status	• **Predictors of PA:** 20% of males and 13% of females were persistent exercisers, and 7% of males and 5% of females were persistently inactive at all surveys. Smoking, irregular breakfast eating, attending vocational school and poor self-perceived health at 16 y were associated with being persistently inactive from 16 to 18 y.
Aarnio *et al.* 2002b	• 1338 males, 1596 females, twins born in 1975-77 • **16 y→18 y** • 3 y follow-up • in 1991→1995 • Finland	• **PA:** frequency of LTFA annually by questionnaire, and participation in different sports, in organised sports and in competitions at 17 y • **Other:** perception of own physical fitness	• **Stability of PA:** Moderate tracking of PA (0.56/0.44, in males/females). 47%/ 6% of those who participated in FA daily at 16 y did so also at 18 y. 44%/34% of them who were inactive at 16 y were also inactive at 18 y. The proportion of persistent exercisers was highest among those who participated in cross-country skiing, gym-training and ball-games in both sexes, and jogging in males.
Aaron *et al.* 2002	• 410 males, 372 females • **12-15 y→ 16-19 y** • 4 y follow-up • in 1990→1993 • USA	• **PA:** total LTPA (h/wk) and participation in different activities during past year, annually by questionnaire	• **Stability of PA:** Probability of maintaining participation in a specific activity was low to moderate 2-71%, probability of not participating in a specific activity was high 70-100%. • **Change in PA:** Total LTPA (h/wk) ↓ 43% in males and 26% in females, this was primary due to a ↓ in the number of activities 7→3.
Andersen *et al.* 1993	• 88 males, 115 females • **15-19 y→ 23-27 y** • 8 y follow-up • in 1983→1991 • Denmark	• **PA:** time of sports activity (h/wk) by questionnaire • **Other:** several coronary heart disease risk factors.	• **Stability of PA:** Low tracking in males (0.31), no tracking in females (0.20, ns). Inactivity tracks in males, 53% of males but only 8% of females were persistently inactive. • **Change in PA:** PA time ↓ in males 1.7 h/wk ($p < 0.05$) and in females 1.2 h/wk (ns), the number of persons having PA more than 4 h/wk ↓ in males 43%→36% and in females 39%→26%.
Andersen 1994	• 117 males, 142 females • **16 y→18 y** • 2 y follow-up • Denmark	• **PA:** PA time (h/wk), participation in organized and unorganized sports, and other FA, by questionnaire. • **Other:** fitness	• **Change in PA:** No ↓ in FA time in either gender, but fewer girls participated in leisure-time sports at the 2nd test (49% → 33%, $p < 0.001$). Change in fitness level was not related to change in PA.
Anderssen *et al.* 1996	• 2328 males, 2787 females • **18-30 y→25-37 y** • 7 y follow-up •since 1985-86 • USA	• **PA:** score in exercise units, a sum of moderate and vigorous intensity scores, by questionnaire	• **Stability of PA:** Moderate tracking, correlation 0.57 for the entire sample, varying between 0.57 (white males) and 0.42 (black females) • **Change in PA:** Mean PA ↓ 30%, in black males 38%, black females 30%, white males 52%, white females 81%. FA ↓ sharply during the early years of adulthood.

Table 1. Continued.

Barnekow-Bergkvist *et al.* 1996	• 194 males, 179 females • **15-18 y→33-36 y (mean 16→34 y)** • 18 y follow-up • in 1974→1992 • Sweden	• **PA:** participation in sports, number of sports, membership of sports clubs, attitudes to different sports, marks at physical education at 16 y. LTPA (times/wk and h/wk) at 34 y. • **Other:** sociodemographic characteristics at 34 y	• **Change in PA:** vigorous PA ↓, light PA stayed constant. About 40% of males and females changed their activity pattern (active vs inactive), and more females than males became active in adulthood. • **Predictors of PA**: At 16 y, participation in sports, membership in a sports club, and being satisfied with sports performance (in both sexes), high marks in PE and positive attitude to aerobic training (only in males) were associated with a ↓ risk for being inactive at 34 y. In multivariate analyses participation in sports in males and membership in sports club in females remained significant.
Barnekow-Bergkvist *et al.* 1998	• 154 males, 121 females • **mean 16 y→34 y** • 18 y follow-up • in 1974→1992 • Sweden	• **PA:** See Barnekow-Bergkvist et al. 1996. • **Fitness:** fitness tests at 16 and 34 y • **Other:** sociodemograpic characteristics	• **Predictors of PA:** PA, 9-min run, and mother working (in males), and membership of sports club, two hand lift performance, father manual worker (in females) at 16 y were associated with a high level of LTPA at 34 y (MET-hours/wk).
Barnekow-Bergkvist *et al.* 2001	• 157 males, 121 females • **15-18 y→33-36 y** • 18 y follow-up • in 1974→1992 • Sweden	• **PA:** See Barnekow-Bergkvist et al. 1996. • **Fitness:** fitness tests at 16 and 34 y • **Other:** cardiovascular risk factors at 34 y	• **Predictors of PA:** Leisure sports activity along with high performance in 9-min run in males and in 2-hand lift test in females at 16 y were associated with frequent participation in LTPA at 34 y (≥ once a week) in multivariate analyses.
Beunen *et al.* 2001	• 109 males • **13 y→40 y** • 27 y follow-up • Leuven, Belgium	• **PA:** work, leisure time and sport indeces (WI, LTI, SI) by Baecke questionnaire • **Fitness:** sit and reach, leg lifts, bent arm hang, heart rate at rest, step test, stick balance, plate tapping, vertical jump, arm pull, shuttle run 50 m	• **Predictors of PA:** Fitness levels at 13, 15, and 18 y were significantly associated with only SI at 40 y. When upper and lower adult PA quintiles were contrasted, adolescent fitness measures were different for adult WI, LTI and SI. However, some adolescent fitness measures (arm pull and bent arm hang) were inversely related to adult PA.
Blane *et al.* 1996	• 5645 males • aged 35-64 y • cross sectional setting • in 1970-1973 • Scotland	• **PA:** physical exercise outside work (h/wk), including also light PA. • **Other:** occupational class retrospectively in childhood, and in adulthood	• **Predictors of PA:** Father's social class was not significantly associated with PA level in adulthood, when own social class in adulthood was included into regression model simultaneously. However, the trend of association seemed to be similar for both variables in univariate comparisons.
Campbell *et al.* 2001	• 77 males, 76 females • **8-18 y →~20-30 y (mean 13→25)** • 12 y follow-up • 1980→1992 • Canada, Quebec	• **PA:** daily energy expenditure (DEE, kJ), time spent in moderate to vigorous PA (MVPA) and physical inactivity (IA) by 3-day activity record • **Other:** Aerobic fitness, parental data from baseline	• **Change in PA:** DEE ↑, MVPA ↓ in males 8.0→5.1, in females 6.8→2.4, IA stable. • **Stability of PA:** Low tracking correlations for DEE 0.07/ 0.22, for MVPA 0.14/ 0.22 and for IA 0.25/0.06 (males/females). • **Predictors of PA:** Parental PA and fitness at baseline did not add any predictive value of PA at 25 y, with the exception of paternal DEE, which accounted for 8% of the variance in males
Dennison *et al.* 1988	• 453 males • a cohort with earlier fitness data • **10-18 y → 24 y** • in about 1972→1986 • USA	• **PA:** current time spent in moderate, hard and very hard PA at work and leisure-time, and PA history by questionnaire at 24 y • **Fitness:** Youth Fitness tests at 10-18 y.	• **Predictors of PA:** Active adults had better fitness in youth than inactive adults, 548.6 m run was the best predictor. Proportion of inactive adults was higher among those who as a child scored in the lowest quintile of the 548.6 m run, compared to those who scored higher. Parental and spousal encouragement of exercise as child and participation in organized sports after school predicted a high level of adult PA.

Table 1. Continued.

Dishman *et al.* 1988	• 265 males who came to participate in an exercise program in 1972-1977 • **youth → 50 y** • USA	• **PA:** current weekly caloric expenditure, based on self-reported PA. Participation in school sports was interviewed retrospectively.	• **Predictors of PA:** No significant differences in supervised and free-living PA between former athletes and nonathletes (p>0.05), althought former athletes were slightly more active in adulthood.
Dovey *et al.* 1988	• 400 males, 375 females, one-year birth cohort • **15 y→18 y** • 3 y follow-up • New Zealand	• **PA:** PA time included PA at school, in competitions, at leisure time undertaken for exercise or recreation, by Minnesota Leisure Time Physical Activity questionnaire.	• **Change in PA:** PA time ↓ 37%, 11.7→7.8 h/wk in males and 7.5→4.3 h/wk in females. Number of activities ↓ 7→3 in males and 6→3 in females. Participation rate of almost all different activities ↓. • **Predictors of PA:** very good self-assessed health, playing sport in a school team and judging own fitness better than peers at 15 y predicted a high level of PA at 18 y
Eaton *et al.* 1989	• 7018 children • **birth→7 y** • USA	• **PA:** motor activity level (AL) observed by two persons 5 times between birth and age 7 y • **Other:** birth order	• **Predictors of PA:** AL ↓ linearly across birth position in 8-month-old, 3-y-old and 4-y-old children. Early borns were more active than later borns. Possible explanatory mechanisms includes social processes in the family and parity-related perinatal factors.
Engström 1980	• 2144 males and females, 22% drop out • **15 y→25 y** • 10 y follow-up • in 1968→1978 • Sweden	• **PA:** frequency and intensity of PA, sports club membership, by postal inquiry	• **Change in PA:** PA changed 15→20→25 y 4.8→2.6→2.9 h/wk in males and 3.3→1.8→2.2 h/wk in females. First 50% ↓ 15 y→20 y and then slight ↑ 20 y→25 y. Percentages of members in sports clubs15 y→25 y ↓ in males 45%→35%, but was constant 18% in females.
Engström 1986	• 1675 males and females, 8th grade pupils • 15 y → 30 y • 15 y follow-up • in 1968→1983 • Sweden	• **PA:** 6-level PA grouping based on frequency and intensity of PA, by postal inquiry • **Other:** psychological readiness (1-6), present life situation and environment, earlier experiences of PA	• **Change in PA:** % of regularly active persons was constant, vigorous PA ↓ • **Predictors of PA:** Early experiences of PA were related to psychological readiness for PA to participate in keep-fit activities in later life. High psychological readiness is not a sufficient prerequisite alone, but interaction between psychological readiness and current environmental circumstances largely explains PA behaviour.
Fogelholm *et al.* 1994	• 1274 males, former top-level athletes, 788 controls • young adults → 36-94 y • in1920-1965→ 1985 • Finland	• PA: LTPA index (MET h/day or MJ/d), based on intensity, duration and montly frequency of PA, in 1985 by questionnaire.	• Predictors of PA: Being a top-level athlete predicted a higher PA 20 y later compared to controls. MET scores (MJ/day) were: endurance athletes 1.5, mixed athletes (endurance and weight training) 1.3, power athletes 1.2 and controls 0.8.
Fortier *et al.* 2001	• 951 males, 958 females • 11-69 y → ~18-77 y • 7 y follow-up • in 1981→1988 • Canada	• PA: daily time of activity (TA) min/d and activity energy expenditure (AEE) kJ/d and kJ/kg/d, by Minnesota LTPA questionnare • Other: muscular fitness	• Stability of PA: low tracking ranged from –0.08 to 0.39 for AEE, from -0.10 to 0.33 for TA, significant tracking only in adulthood • Change in PA: for youth aged 11-16 y AEE (kJ/d) ↑, TA ↑ and AEE (kJ/min/d) ↓, which may be due light intensity PA, for adults aged 30 y and older PA ↑

Table 1. Continued.

Glenmark *et al.* 1994	• 62 males, 43 females, sample physically more active than the average population • 16 y → 27 y • 11 y follow-up • in 1974-1985 • Sweden	• PA: PA index based on frequency and duration of LTPA, membership in a sports club, attitude to PA, by questionnaire. • Fitness: Vo_{2max} by submaximal testing, 9-min run, muscular fitness tests • Other: muscle biopsy	• Change in PA: PA index ↓ and PA time ↓ in males but not in females. Attitude to endurance activities changed to a more positive direction in females and to less positive in males. • Predictors of PA: The aerobic potential (Vo_{2max}, and % of type I muscle fiber), running performance, strength performance, PA and marks in physical education at 16 y explained 47% of the PA level at 27 y in males and 82% in females.
Hirvensalo *et al.* 2000	• 663 males and females • **65-84 y → ~73-92 y** • 8 y follow-up • in 1988→1996 • Finland	• **PA:** PA level during 8 y follow-up prospectively and past PA retrospectively by questionnaires	• **Predictors of PA:** Participation in competitive sport earlier in life, as early as at 10-19 y, and in females participation in recreational sports at 40–64 y predicted a high level during follow-up period.
Huurre *et al.* 2003	• 2143 males and females • **16 y → 22 y** • in 1983→1989 • Finland	• **PA:** open question on leisure activities: yes or no physical activity • **Other**: parental socioeconomic status: non-manual or manual, own educational level at age 22	• **Predictors of PA:** LTPA was less common among 16-year-old males and females of manual class origin. After controlling for the person's own socioeconomic status, the effect of parental socioeconomic status diminished but remained significant in males up to 22 years.
Janz *et al.* 2000	• 61 males 62 females • **7-12 y → ~11-16 y** • 4 y follow-up • Muscatine, USA	• **PA:** vigorous PA by 3-day sweat recall and sedentary behavior by TV/video game recall and interview, every 3 months • **Other:** aerobic fitness, body composition	• **Stability of PA:** Moderate tracking, correlation 11 y→15 y 0.52-0.65. Sedentarism tracks well in males, 75% of males, only 21 % of females who were in the most sedentary tertile at baseline remained so 4 y later. Sedentary males at 11 y were 2.2 times more likely to be sedentary at 15 y. • **Change in PA:** Vigorous PA ↑ in males, unchanged in females. Sedentary behavior ↓ during first year, then unchanged.
Kelder *et al.* 1994	• 2376 males and females • **6th→ 12th grade** • 6 y follow-up • in 1983→~1989 • USA	• **PA:** 4 PA categories (h/wk), and tertiles of PA score frequency and intensity PA, by self-report • **Other:** other health habits	• **Stability of PA:** a clear pattern of tracking was observed during the follow-up, the mean PA value of the baseline categories did maintain their relative rank during the follow-up compared with other categories
Kemper *et al.* 1997	• 93 males, 107 females • **13 y→22 y** • 9 y follow-up • in 1977→1986 • The Netherlands	• **PA:** interview, total weekly PA based on the frequency, intensity and duration of PA during the previous 3 months • **Other:** skeletal age, body fat %, fitness	• **Predictors of PA**: late maturers had a slightly higher activity pattern at 17-22 y than early maturers (males $p< 0.05$, females ns), which may be due to earlier change to the passive lifestyle of adults • Later maturers had lower body fat % and better aerobic power than early maturers between 12-22 y.
Kemper *et al.* 2001a	• 164 males, 201 females • **13 y→33 y** • 20 y follow-up • in 1977→1997 • The Netherlands	• **PA:** metabolic and mechanical PA, MET/wk, METPA and MECHPA • **Other**: 12-min run (m) and maximal running test at treadmill (Vo_{2max}), and 7 tests of muscular and motor fitness	• **Stability of PA:** lower tracking correlations 0.35 (METPA) and 0.29 (MECHPA). Higher tracking of heavy (0.43) than light (0.26) METPA. • **Predictors of PA:** Good cardiorespiratory fitness at 13 y predicted a high level of PA at 33 y, but only in females. Other fitness tests at 13 y did not predict PA at 33 y.

Table 1. Continued.

Kemper *et al.* 2001b	• 83 males, 98 females • **13 y→27 y** • 15 y follow-up • in 1977→1992 • The Netherlands	• **PA:** MET/wk based on interviewed frequency, intensity and duration of PA during previous 3 months • **Other:** aerobic fitness (Vo_{2max})	• **Change in PA:** PA ↓ in males 5000→ 3400 MET/wk and in females 3800→3300 MET/wk. Fitness level did not affect the change in PA. The most fit tertile at 27 y, was more active than the least fit tertile along the whole period, and the difference in PA did not change along the period.
Kimm *et al.* 2000	• 2379 females • **9-10 y→18-19 y** • 9 y follow-up • in 1985→1994 • USA	• **PA:** 3-days Caltrac monitoring, 3-days activity diary (AD) and a habitual patterns questionnaire (HAQ)	• **Change in PA:** steep ↓ in PA. AD scores ↓ 35% (447 → 292 MET-min/day), HAQ scores ↓ 83% (29→5 MET-times/wk), similar ↓ in Caltrac monitoring
Kuh & Cooper 1992	• 2144 males and females • birth cohort of 1946 • **13 y→36 y** • 31 y follow-up • in 1959→1982 • England, Scotland, Wales	• **PA:** at 36 y by Minnesota LTPA inquiry • **Other:** ability in sports and extraversion at 13 y; energy level at 15 y; serious illness, parental social class and education in childhood	• **Predictors of PA:** The most active persons at 36 y were above average at school sports, were more often extrovert or extremely energetic, had fewer health problems in childhood, had parents with higher education, and, in females, higher paternal social class in childhood.
Kujala *et al.* 2000	• 1235 males, former top-level athletes and their 743 controls • **young adulthood** → ~ **58 y** • in 1920-1965→ 1985 • Finland	• **PA:** LTPA (METh/d) calculated from intensity, duration and monthly frequency of PA, by questionnaire in 1985. PA history: being a top-level athlete in 1920-1965 or not (controls)	• **Predictors of PA:** All athlete groups participated more often in vigorous PA in 1985 than the controls (endurance 37%, power speed 28%, others athletes 38%, controls 12%). MET index was 38 for endurance, 32 for power speed, 29 for other athletes and 15 for controls. Former endurance athletes were more active than former power speed athletes. Natural selection to sports or PA at a younger age predicts PA in later life.
Lefevre *et al.* 2000	• 130 males • **18 y→40 y** • 22 y follow-up • in 1974→1996 • Belgium	• **PA:** participation in sports (h/wk), adult work index, active leisure time index and total activity index (MET) • **Other:** body composition and fitness etc.	• **Stability of PA:** moderate tracking, correlations for sports participation were 18→30 y 0.37, 30→35 y 0.50, 35→40 y 0.44, for active leisure-time index 30→35 y 0.34, 35→40 y 0.30, and for work index 30→35 y 0.54, 35→40 y 0.58
Macera *et al.* 1995	• 1192 males, 2031 females • aged ≥ 18 y, mean 46 y • 4 y follow-up • 1987→1991 • USA	• **PA:** type and frequency of LTPA during the past month. Inactive: participation in large muscle LTPA < 3 times/ wk.	• **Changes and predictors of PA:** Among those who were inactive in 1987, 14-24% adopted PA 4 y later. The predictors for adopting LTPA among those who were initially inactive were: 12 y or more education in females and having a physician discuss PA during a routine visit in both sexes.
Pietilä *et al.* 1995	• 1489 males • areal birthcohort 1966 • **14 y → 24 y** • 10 y follow-up • in 1980→1990 • Finland	• **PA:** self-reported participation frequency in physical exercise • **Other**: Parent's characteristic, smoking and drinking behavior.	• **Continuity of PA:** 71% of those who participated in physical exercise at least once a week at 14 y did so also at 24 y • **Predictors of PA:** Frequent participation in sports at 14 y, high social class at 14 y, mother's high education were associated with frequent participation in exercise at 24 y.

Table 1. Continued.

Raitakari *et al.* 1994	• 961 males, females • 12-18 y→ 18-24 y • 6 y follow-up • in 1980→1986 • Finland	• **PA:** PA index calculated from intensity, duration and monthly frequency of participation from questionnaires. • **Other**: cardiovascular disease risk	• **Stability:** moderate tracking, correlations for PAI (males/ females): 12→15 y 0.35/ 0.33, 12→18 y 0.18/ 0.17, 15→18 y 0.45/ 0.37, 15→21 y 0.27/ 0.27, 8→21 y 0.54/ 0.39, 18→24 y 0.43/ 0.37. About 57% of those classified as inactive remained inactive after a 6-y follow-up and 44% of those classified as active remained active.
Taylor et al. 1999	• 105 males • aged 32-60 y, mean 45 y • retrospective setting • USA	• **PA:** questionnaire about experiences, participation in sports, and psychosocial factors in youth, and daily energy expenditure in adulthood	• **Predictors of PA:** Being forced to exercise during childhood was negatively, and being couraged to exercise positively associated with adult PA. Self-rated skill in PA during teenage years was associated with adult PA. Type of sports (team, individual, both, or none) in childhood was not associated with adult PA.
Telama *et al.* 1996	• 581 males, 739 females, participated in 1992 • **9-18 y → 21-30 y** • 12 y follow-up • in 1980→1992 • Finland	• **PA:** PA index (PAI) based on LTPA and sport, intensity, frequency of PA and sports club training and competitions. Small changes in 1992 inquiry.	• **Stability of PA**: tracking correlations of PAI within a 3-year interval were significant but rather low: 0.50-0.80 in males and 0.40-0.61 in females. Among different PA variables the frequency of participation in sports club training had the highest correlations 0.40-0.78 in males and 0.28-0.64 in females.
Telama *et al.* 1997	• 1398 males and females • **9-18 y → 21-30 y** • 12 y follow-up • in 1980→1992 • Finland	• **PA:** see Telama et al. 1996.	• **Stability of PA:** tracking correlations of PAI were 0.18-0.47 (9 y) and 0.00-0.27 (12 y). • **Change in PA**: general PA ↓, sport club PA ↓, high intensity PA ↑ • **Predictors of PA:** Frequent participation in sports, participation in competitive sports and a high grade in physical education ↑ the probability of a high PA level in later life.
Telama & Yang 2000	• 748 males, 939 females • **9-18 y → 18-27 y**, • 9 y follow-up • 1980→1989 • Finland	• **PA:** see Telama et al. 1996.	• **Change in PA:** Frequency of PA ↓ and sports participation ↓ after 12 y, intensity of PA ↑. Steeper ↓ in males. The steepest ↓ between 12-15 y in males and 15-18 y in females. Males were divided into two groups with age: totally sedentary and fitness-oriented activity.
van Mechelen & Kemper 1995	• 84 males, 98 males • **13 y→27 y** • 14 y follow-up • in 1977→1991 • The Netherlands	• **PA:** weekly energy expenditure MET/wk and total PA time/wk were calculated based on PA interview	• **Stability of PA:** low or moderate tracking, correlations for weekly energy expenditure for organised sports (males/ females), 13-16→21 y 0.40/0.32, 13-16→27 y 0.17/ 0.14, 21→27 y 0.22/0.34. Tracking for weekly energy expenditure similar but slightly lower.
Vanreusel *et al.* 1997	• 236 males • **13 y→35 y** • 22 y follow-up • in 1969→1992 • Leuven, Belgium	• **PA:** time (h/wk) spent on sports participation during past year by questionnaire, 4 PA groups: inactive (< 1h/wk), moderately active (1-3 h/wk), active (3-6 h/wk), very active (>6 h/wk)	• **Stability of PA:** Tracking correlations of sports participation at age 13→18 y were 0.33-0.62, and at age 13→35 y 0.09-0.31. Dropout rate for recreational sport participation style was lower than for competitive sport involvement. • **Changes in PA:** Changes in PA were common between 13 and 18 y. • **Predictors of PA:** Inactive males at 17 y were likely to become inactive adults at 30 y. Very active males at 17 y did not have a better chance of being active at 30 y than moderately active males at 17 y.
Yang *et al.* 1999	• 616 males, 779 females • 9-18 y → 21-30 y • 12 y follow-ups • in 1980→1992 • Finland	• **PA:** sum index of physical activity (PAI) • **Other:** education, place of residence, employment status, occupation, marital status at adult age,	• **Predictors of PA:** Adult PA appeared to be more influenced by PA in youth than by the current social and environmental factors. The social and health-related factors such as occupation, employment status and smoking also predicted PA in some age-gender groups.

Appendix 2

Table 1. Summary of longitudinal studies on the association between physical activity and obesity from youth to adulthood. Follow-up time at least 2 years. BMI=body mass index, WC=waist circumference, WHR= waist to hip ratio, BF= body fat, SSF=sum of skinfolds, PA=physical activity, CVD =cardiovascular disease, y= years, ↓=decrease, ↑=increase

Authors and publication year	Subjects, follow-up time, design, year and country	Measurements	Main results and comments
Andersen *et al.* 1993	• 88 males, 115 females • **15-19 y→ 23-27 y** • 8 y follow-up • in 1983-1991 • Denmark	• **Obesity:** BMI, BF% from 4 skinfolds • **PA:** PA time h/w of sports activity by questionnaire • **Other:** CVD disease risk factors.	• Change in PA correlated with change in BF% in males (r=-0.35, p<0.01) but not in females (r=-0.16, ns), and not with change in BMI.
Barnekow-Bergkvist *et al.* 2001	• 157 males, 121 females • **15-18 y→33-36 y** • 18 y follow-up • in 1974-1992 • Sweden	• **Obesity:** BMI at 16 and 34 y, WHR at 34 y • **PA:** Participation in leisure sports at 16 y yes vs no. • **Other:** CVD risk factors at 34 y	• Participation in sports at 16 y was not associated with high BMI (≥27) or WHR (≥0.95 in males and ≥ 0.85 in females) at 34 y.
Hasselstrom *et al.* 2002	• 133 males, 172 females • **15-19 y→23-27 y** • 8 y follow-up • in 1983-1991 • Denmark	• **Obesity:** WC, BF% from 4 skinfolds at 25 yrs • **PA:** h/wk of different sports activities by questionnaire • **Other:** cardiorespiratory and muscular fitness, CVD risk factors	• Level of PA at 17 y was positively associated with WC (r=0.28) and BF% (r=0.19) at 25 y in males • Change in PA (17→25 y) was negatively associated with WC (r=-0.31) and BF% (r=-0.23) at 25 y in males, but not in females
Kemper *et al.* 1999	• **13 y→32 y** • in about 1977→1996 • The Netherlands	• **Obesity:** BMI, sum of 4 skinfolds • **PA:** (N=200) 13-27 y, weighted energy output • **Other:** dietary intake	• PA between 13-27 y was inversely associated with fat mass, if fat mass was estimated from SSF but not if estimated from BMI
Lefevre *et al.* 2002	• 166 males • **13-18 y→ 30, 35, 40 y** • in 1969-1996 • Leuven, Belgium	• **Obesity**: BMI, WC, WHR and BF% from 4 skinfolds at 40 y • **PA:** adolescent participation in sports, adult energy expenditure in METs, work and active leisure time indeces • **Other:** CVD risk factors	• No relationship between adolescent sports participation and BMI, BF%, WC or WHR at 40 y.

Table 1. Continued.

Raitakari *et al.* 1994	• 961 males and females • **12-18 y→ 18-24 y** • 6 y follow-up • in1980-1986 • Finland	• **Obesity:** BMI and subscapular skinfold (SS) • **PA:** PA index based on intensity, duration and frequency of PA, by questionnaires. • **Other:** CVD risk factors	• SS was lower in persistently active males (n=44) (9.9 vs 12.1 mm, p=0.012) and females (n=23) (10.5 vs. 14.2 mm, p=0.005) compared to those who were persistently sedentary (44 males, 55 females). No difference in BMI.
Twisk *et al.* 1997	• 98 females, 83 males • **13 y→29 y** • 16 y follow-up • The Netherlands • AGAHLS	• **Obesity:** BF% by sum of 4 skinfolds, WHR • **PA**: Daily PA (MET's/wk) by interview based on total time and intensity of all daily PA • **Other:** CVD risk factors	• Daily PA was negatively associated with BF% (-0.20, p< 0.01), and positively related to WHR (r=0.26, pa< 0.01) in females, during the entire follow-up period.
Twisk *et al.* 2002b	• 132 males, 145 females • **13-16 y→ 32 y** • in 1977-1997 • The Netherlands	• **Obesity:** WHR, WC, and sum of 4 skinfolds (SS) at 32 y and • **PA:** the amount of total PA (min/ week and METs/ week), heavy and vigorous PA, and only vigorous PA during previous 3 months, by interview • **Other**: CVD risk factors, aerobic fitness	• PA between 13-16 years were not related to SS at 32 y. Some weak associations between adolescent PA and adult abdominal obesity: total PA at 13-16 y was positively related to WC at 32 y (r=0.13, p< 0.05) and heavy and vigorous PA at 13-16 y was negatively associated with WHR at 32 y in females (r=-0.24, p< 0.05).
van Lenthe *et al.* 1998	• 84 males, 98 females • 13 y → 27y • in 1977-1991 • The Netherlands	• **Obesity**: WC, subcapular skinfold (SS) • **PA**: weighted activity score based on leisure-time PA, exercise, and school- or work-related PA, by interview • **Other:** micronutrient intake, smoking, alcohol intake	• Mean PA from 13 to 27 y was not associated with WC at 27 y (adjusted fot total body fat). Mean PA from 13 to 27 y was associated with SST at 27 y in males, but explaining only 2.3 % of its variance.

Appendix 3

Table 1. Summary of studies on the association between occupational physical activity and physical fitness. PA = physical activity, OPA=occuaptional physical activity, LTPA=leisure-time physical activity, M=males, F=females, ↓=decrease, ↑=increase, y = years.

Authors and publication year	Subjects, follow-up time, design, year, country and name of the study	Measurements of physical activity and fitness	Main results and comments
Andersen *et al.* 1993	• 88 males, 115 females • randomized sample • 15-19→ 23-27 yrs • 8 yrs follow-up in 1983-91 • Denmark	• **Fitness:** Vo_{2max} (ml/kg/min), maximal test • **OPA:** 5 occupational categories based on work situation and level of education • **Other:** LTPA, several coronary heart disease risk factors.	• Blue collar workers and the unemployed had the largest ↓ in Vo_{2max} 19% with age, whereas the other groups ↓ only 4%
Era *et al.* 1992	• 388 males • 3 age groups: 31-35 y (n=131), 51-55 y and 71-75 • cross-sectional study • Finland	• **Fitness:** isometric muscle strength of several muscles • **OPA:** occupation • **Other:** LTPA, self-rated health	• At 31-35 yrs: manual workers tended to have higher strength values in all muscle groups than white collar workers • At middle or older age group manual workers had poorer performance compared to white collar workers.
Ilmarinen *et al.* 1991	• 32 males and 35 females • aged 51 years • 4 yrs follow-up • Finland	• **Fitness:** Vo_{2max} (ml/kg/min) predicted by submaximal cycle ergometer test • **OPA:** 3 work content groups (physical, mental and mixed) • **Other:** LTPA	• Work content was not associated with the level of Vo_{2max} in either gender. • Fitness ↑ 8% in males and ↓ 6% in females. The changes were greatest in the mental group. In males, ↑ in fitness was associated with ↑ in LTPA.
Jonsson *et al.* 1979	• 1050 males and females aged 18-65 y, including 120 males and 90 females aged 26-35 y • cross-sectional study • Sweden	• **Aerobic fitness:** heart rate at cycle ergometer loads 50 W and 100 W • **OPA:** Self-reported workload, get sweaty everyday at work or not • **Other:** LTPA	• In young males aged ≤35 y, who were inactive at leisure time, sweating at work was associated with good aerobic fitness
Lefevre *et al.* 2000	• 130 males • 30→40 y • 10 y follow-up • Belgium	• **Fitness:** Vo_{2peak} (ml/kg/min) during maximal test, hand grip strength, sit-up test • **OPA:** high (n=37) and low (n=37) OPA groups formed based on work index (MET)	• No difference in Vo_{2peak} between high and low OPA groups • Hand grip strength corrected for body weight was better in high OPA group (6 kg higher at 35 y, and 8 kg at 40 y) • No interaction between OPA and age on fitness.
Nygård *et al.* 1987	• 69 males and 60 females • aged 52 y (mean) • cross-sectional study • Finland	• **Muscular fitness:** Isometric strength (trunk flexion and extension, hand grip strength), back mobility, sit-up test • **OPA:** physical, mental and mixed groups based on AET job analyses	• Physical group in females, and physical or mixed groups in males had systematically but non-significantly the lowest mean values in almost all tests. • Significant differences between the OPA groups: the physical group had the lowest values in females' right hand grip test and in males' sit-up test.

Table 1. Continued.

Nygård *et al.* 1988a	• 69 males and 60 females • aged 52 y (mean) • cross-sectional study • Finland	• **Fitness:** see Nygård et al. 1987 • **OPA:** AET job analyses, low or high muscular load at work (static or dynamic, short or long duration)	• Muscular strength and endurance was systematically lower among those with high muscular load compared to those with low load at work
Nygård *et al.* 1988b	• 39 males, 44 females • aged 55 y (mean) • 3½ y follow-up • Finland	• **Fitness and OPA:** see Nygård et al. 1987	• The greatest ↓ in muscular fitness (trunk flexion and extension, hand grip strength) in physical or mixed groups in males and in mental group in females.
Rantanen *et al.* 1993	• 92 females, 51 trained in sports and 41 untrained • aged 66-85 y • Finland	• **Muscular fitness:** isometric strenth of hand grip, arm flexion, leg extension, trunk flexion and extension and sit-up tes • **OPA:** history of heavy manual employment by interview	• History of heavy manual work was not systematically associated with muscular fitness, except for one positive correlation (trunk extension test among untrained females)
Torgen *et al.* 1999	• 232 males, 252 females • 41-58 y • retrospective recall • in 1970-1993 • Sweden	• **Fitness:** muscular fitness (maximal isometric strength and dynamic endurance) and aerobic power (submaximal ergometer test) • **OPA:** Physical work load score (PWL), current and past OPA by questionnaire (period, job title, main tasks, working hours)	• Long-lasting high OPA was associated with low trunk flexion strength, squatting endurance and aerobic power • Low isometric hand grip strength and low weight lifting endurance was seldom seen among those with high OPA, which reflects possible training or maintaining effect on upper extremities
Tuxworth *et al.* 1986	• 1394 males from a food factory • aged 35-60 years • cross-sectional study • England	• **Fitness:** Vo_{2max} predicted by submaximal cycle ergometer test • **OPA:** activity at work by interview	• OPA was not associated with fitness.
Sobolski *et al.* 1988	• 2565 Belgian and Slovakian males • healthy workers • aged 40-55 y • cross-sectional study	• **Fitness:** workload at heart rate 150 beats/min (PWC_{150}) in submaximal bicycle exercise test • **OPA:** occupational energy expenditure kJ/h based on postures and type of work	• OPA was associated with fitness in Belgian (low level correlation $r = 0.06$, $p<0.05$), but not in Slovakian workers.

Appendix 4

Original questions (translated from Finnish)

a) Postal inquiry at 14 years, in 1980

Weight _____ kg (nttv001)

Height _____ cm (nttv004)

How often do you participate in sports after school hours? (nttv019)

1. daily
2. every other day
3. twice a week
4. once a week
5. every other week
6. once a month
7. generally not at all

Which are the main types of sports you are engaged in? (nttv020)

Are you a member in some sports club? (nttv021) 1. yes/ 2. no

The grade in sports in school report of spring 1980 _____(nttv023)

The average of all subjects in school report of spring 1980 _____ (nttv033)

Mother's current occupation _____________________________ (nttv040)

Father's current occupation _____________________________ (nttv044)

b) Postal inquiry at 31 years, in 1997-1998

Marital status (zp01)

1. married since year 19__
2. cohabit without marriage since year 19__
3. unmarried
4. divorced or separated since 19__
5. widow since year 19 __

How many children of your own do you have? (zp02) (include dead children, mark 0 if no children) ____ children

What is your vocational education? (zp07)

1. no vocational education
2. occupational course
3. occupational school
4. vocational college
5. vocational high school
6. university or polytechnic
7. other education, what? _______
8. education unfinished, what? _____

Your weight _____ kg (zp1001)

Your height ____ cm (zp1011)

How often do participate in physical activity/ exercise during your leisure-time?

a) Light physical activity (no sweating or breathlessness) (zp1301)

1. once a month or less often
2. 2-3 times a month
3. once a week
4. 2-3 times a week
5. 4-6 times a week
6. daily

b) Brisk physical activity (at least some sweating and breathlessness) (zp1302)

1. once a month or less often (0)
2. 2-3 times a month (0.5)
3. once a week (1)
4. 2-3 times a week (2.5)
5. 4-6 times a week (5)
6. daily (7)

The frequencies times/week used in the calculations in study V are presented in parenthesis.

How long do you participate in physical activity/exercise at a time?

a) Light physical activity (no sweating or breathlessness) (zp1401)

1. not at all
2. less than 20 minutes
3. 20-39 minutes
4. 40-59 minutes
5. 1-1.5 hours
6. more than 1.5 hours

b) Brisk physical activity (at least some sweating and breathlessness) (zp1402)

1. not at all
2. less than 20 minutes
3. 20-39 minutes
4. 40-59 minutes
5. 1-1.5 hours
6. more than 1.5 hours

Which of the following alternatives best represents your current work situation? (zp15)

1. permanent full-time job
2. temporary full-time job
3. part-time job
4. self-employed
5. entrepreneur
6. full-time student
7. unemployed
8. subsidized employment or education
9. laid off or shortened working time
10. on maternity or childcare leave
11. retired
12. out of working life for other reason, why?_____

Have you ever smoked? (zp79) 1. no, 2. yes, I began at ___ years.

Do you smoke at present? (zp82)

1. 7 days a week
2. 5-6 days a week
3. 2-4 days a week
4. once a week
5. sporadically
6. not at all.

c) Computer assisted questionnaire (pen micro) which was filled up in the medical examination at 31 years, in 1997-1998

What is the physical work load of your current work? (zk05) Choose one of the alternatives 1-7.

1. not at work
2. light sedentary work: sedentary work, only light manual tasks
3. other sedentary work: sedentary work with heavy manual tasks
4. light standing or moving work: standing work without heavy work movements, or moving work without carrying heavy loads
5. medium heavy moving work: moving work with a lot of bending and carrying (no heavy loads), or with walking a lot of stairs, or with moving rather long distances quite fast
6. heavy manual work: standing work with constant carrying of light loads, or lifting and carrying of heavy loads with some sitting and standing in between
7. very heavy manual work: constant or almost constant heavy work movements for long periods without break

How often do you participate in the following physical activities? (zk2401-zk2420). Choose the alternative that best represents the situation during the previous year in the season that was suitable for that activity. The alternatives: walking/ cycling/ cross-country skiing/ swimming/ running/ gym-training/ down-hill skiing/ aerobics/ gymnastics/ badminton, volley ball, tennis, squash/ indoor bandy, ice hockey, soccer, bandy, basket ball/ golf/ shooting/ motor sports (ralley)/ dancing/ driving cross-country vehicle (snowmobile, buggy, cross-country motorcycle)/ gardening/ hiking/ hunting, fishing/ berry picking.

1. not at all
2. once a month ore less
3. 2-3 times a month
4. once a week
5. 2-3 times a week
6. 4 times a week or more often.

Appendix 5

Table 1. Distibution (%) of certain variables at 14 years in different study samples.

	Samples who participated in different parts of the study			
	Postal inquiry at 14 years	Postal inquiry at 14 years but not at 31 years	Postal inquiry at 31 years	Medical examination[a] at 31 years
	N=11010	N=2652	N=8643	N=5958
Frequency of participation in sports at 14 years	N=10712	N=2574	N=8138	N=5620
daily	18	18	17	18
every other day	20	21	20	20
twice a week	22	20	22	23
once a week	16	15	16	17
less than once a week	25	26	24	24
Body mass index at 14 years, males	N=5066	N=1421	N=3644	N=2517
underweight, < 15th percentile	15	15	15	14
normal weight, 15th-85th percentile	70	68	70	71
overweight, 85th-95th percentile	10	10	10	10
obese, >95th percentile	6	7	5	5
Body mass index at 14 years, females	N=5046	N=987	N=4060	N=2783
underweight, < 15th percentile	15	14	15	15
normal weight, 15th-85th percentile	70	72	70	70
overweight, 85th-95th percentile	10	10	10	10
obese, >95th percentile	5	4	5	5
Social class of the family at 14 years	N=10913	N=2654	N=8254	N=5958
I and II skilled professionals	29	27	30	29
III skilled workers	35	37	35	35
IV unskilled workers	24	27	22	22
farmers	12	8	13	15
Grade average at school at 14 years	N=9952	N=2161	N=7791	N=5515
≥ 9.0 (high)	7	5	7	6
8.0–8.9	33	28	34	33
7.0–7.9	37	37	37	38
≤ 6.9 (low)	24	30	22	22

[a] all those whose body weight and height were measured in medical examination at 31 years

Table 2. Distibution (%) of certain variables at 31 years in different study samples.

	Samples who participated in different parts of the study			
	Postal inquiry at 31 years	Postal inquiry but no medical examination at 31 years	Medical examination at 31 years	Maximal exercise test at 31 years
	N=8643	N=2685	N=5958	N=123
Frequency of brisk PA at 31 years	N=8513	N=2630	N=5883	N=120
4 times a week or more	13	14	13	23
2-3 times a week	30	31	29	29
once a week	23	22	24	21
2-3 times a month	14	13	14	8
once a month or less	21	20	21	20
Vocational education	N=8489	N=2617	N=5958	N=120
university	11	15	10	15
high education	34	32	34	40
medium education	48	45	48	38
no vocational education	7	8	7	8
Work situation at 31 years	N=8497	N=2616	N=5881	N=121
employed	61	62	60	72
entrepreneurs	8	6	9	5
full-time students	4	5	4	-
unemployed	13	12	14	19
on chilcare or maternity leave	9	10	8	2
others (e.g. long-term sick leave, house-wife)	6	6	6	3
Self-reported body mass index at 31 years, kg/m^2	N=8358	N=2603	N= 5755	N=117
underweight, < 18.5	9	9	9	10
normal weight, 18.5-24.9	54	55	54	55
overweight, 25.0-29.9	29	28	29	31
obese, ≥ 30.0	8	9	8	4
Measured body mass index at 31 years, kg/m^2	-	-	N=5958	N=122
underweight, < 18.5	-	-	9	7
normal weight, 18.5-24.9	-	-	52	56
overweight, 25.0-29.9	-	-	31	35
obese, ≥ 30.0	-	-	9	2

[a] all those whose body weight and height were measured in medical examination at 31 years

Table 3. Mean value ± standard deviation of certain variables measured at 31 years in different study samples.

	Samples who participated in different parts of the study		
	Postal inquiry at 31 years,	Medical examination at 31 years	Maximal exercise test at 31 years
	N=8643	N=5958	N=123
Self-reported body mass index, kg/m^2	24.4 ± 4.0 (N=8368)	24.4 ± 3.9 (N=5761)	24.0 ± 3.6 (N=117)
Measured body mass index, kg/m^2	–	24.7 ± 4.2 (N=5958)	24.1 ± 3.4 (N= 122)
Heart rate after step test, beats/min	–	148 ± 17 (N=5487)	142 ±17 (N=119)

[a] all those whose body weight and height were measured in medical examination at 31 years