LEISURE-TIME PHYSICAL ACTIVITY, BODY MASS INDEX, AND WAIST CIRCUMFERENCE: A LONGITUDINAL TWIN STUDY FROM ADOLESCENCE TO ADULTHOOD

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ABSTRACT

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The aim of this study was to investigate the effects of persistence and changes in the frequency of leisure- time physical activity on body mass index and waist circumference from adolescence to adulthood. Also, this study investigates the effect of the intensity of physical activity on body mass index (BMI) and waist circumference in adulthood.

Participants in the study, members of the Finn-Twin 16 study cohort (N=6084), answered study questionnaires between 1991 and 1995 at age 16 and later at age 17, 18.5, and 24, about the frequency and intensity of their leisure-time physical activity, body height, and weight. Participants also measured their waist circumference at a mean age of 24. One question with seven alternative responses probed the stability of participants' leisure-time physical activity outside school. Another question with four alternative responses probed the intensity of that leisure-time physical activity.

This study concludes that a high total frequency and intensity of leisure-time physical activity results in smaller BMI growth from adolescence to adulthood and in a smaller waist circumference at a mean age of 24. Physically inactive boys had larger BMI increases than boys participating very frequently in physical activity, while physically inactive girls had larger BMI increases than girls participating in high intensity physical activity.
This study also concludes that at a mean age of 24, the waist circumference of boys and girls who participate in vigorous physical activity is smaller than the waist circumference of those who participate in very light, light, or moderate physical activity.

On the basis of earlier studies and on the results of this study, we can conclude that the intensity of physical activity and a high level of physical activity frequency may play an important role in reducing the growth of a person's BMI from adolescence to adulthood and in reducing waist circumference growth in adulthood. Reducing the growth of BMI and waist circumference is known to lower the risk of metabolic syndrome and cardiovascular diseases.

Key words: physical activity, twins, body mass index, waist circumference, adolescents, longitudinal study

TIIVISTELMÄ

VAPAA-AJAN LIIKUNTA, KEHON PAINOINDEKSI JA VYÖTÄRÖN YMPÄRYSMITTA-PITKITTÄINEN KAKSOSTUTKIMUS NUORUUSIÄSTÄ AIKUISIKÄÄN

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Tämän tutkimuksen tarkoituksena oli selvittää pitkittäisen kaksostutkimuksen avulla vapaa-ajan liikuntafrekvenssin ja sen muutosten yhteyttä kehon painoindeksiin ja vyötärön ympärysmittaan nuoruusikäisillä ja nuorilla aikuisilla. Tämä tutkimus selvittää myös liikuntaintensiteetin vaikutusta kehon painoindeksiin ja vyötärön ympärysmittaan aikuisiässä.

Tutkimusaineisto koostui Finn-Twin-16-kaksostutkimus aineistosta (N=6084) rajattuna niihin tutkimukseen osallistuneisiin henkilöihin, jotka olivat vastanneet tutkimuksen kyselylomakkeessa esitettyihin kysymyksiin vuosien 1991- 1995 välisenä aikana ollessaan 16 vuoden ikäisiä ja myöhemmin 17, 18.5 ja 24 vuoden iässä koskien koulun ulkopuolisen vapaa-ajan liikunnan frekvenssiä, intensiteettiä, kehon pituutta ja painoa ja vyötärön ympärysmittaa. Vapaa-ajan liikunnan frekvenssiä oli tutkimuksessa arvioitu seitsemänportaisella asteikolla ja intensiteettiä neljäportaisella asteikolla. Kehon pituutta ja painoa ja vyötärön ympärysmittaa tutkittavat olivat arvioineet kotona tehtävillä ohjeistetuilla mittauksilla.

Tutkimuksen johtopäätöksenä oli, että vapaa-ajan liikunnan kokonaismäärällä ja suurella liikunnan intensiteetillä on vaikutusta painoindeksiin ja vyötärön ympärysmittaan. Määrällisesti runsasta liikuntaa harrastavilla pojilla ja intensiteetiltään raskasta liikuntaa harrastavilla tytöillä painoindeksin nousun todettiin olevan pienempää kuin liikunnallisesti passiivisilla henkilöillä. Tutkimuksessa todettiin myös vyötärön ympärysmitan olevan 24 vuoden iässä pienempi intensiteetiltään rasittavaa liikuntaa harrastavilla tytöillä ja pojilla verrattuna erittäin kevyttä, kevyttä tai keskiraskasta liikuntaa harrastaviin.

Aikaisempien tutkimusten ja tämän tutkimuksen tulosten perusteella voimme todeta, että liikunnan intensiteetillä ja suurella liikunnan kokonaismäärällä on merkittävä rooli painoindeksin kasvun vähentämisessä nuoruusiän ja aikuisiän välisenä aikana sekä vyötärön ympärysmitan kasvun vähentämisessä aikuisiässä. Tiedetään, että painoindeksin ja vyötärön ympärysmitan kasvun väheneminen alentaa riskiä sairastua metaboliseen oireyhtymään ja sydän- ja verisuonisairauksiin.

Asiasanat: liikunta, kaksoset, kehon painoindeksi, vyötärön ympärysmitta, nuoruusikäiset, pitkittäistutkimus

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1 INTRODUCTION

Sedentary lifestyle is one of the established predictors of obesity, and earlier studies demonstrate that obesity, particularly abdominal obesity and abdominal fat distribution, is a risk factor for developing diabetes or coronary heart disease (Wagner et al. 2001, Mustelin et al. 2009). Obesity is increasingly prevalent among children and adolescents in Finland and in other industrialised countries: a worrying trend, since prevalent childhood obesity is known to increase the risk of obesity in adulthood (Childhood Obesity 2005).

Twin studies can be used to assess the importance of the genetic or inheritable component relative to the environmental component when regarding different domains of behaviour. Twin studies may also be employed to investigate disease susceptibility (see Ha et al. 2007). A population-based twin study investigating the heritability of obesity and physical activity established that physical activity can modify the heritability of Body Mass Index (BMI) and waist circumference. Significantly, a link was discovered in sedentary subjects between inherited factors and body weight and adiposity. Another significant finding was that the genetic component affects physically active individuals less than it does physically inactive individuals. We may expect therefore that physical activity prevents weight gain and waist circumference growth in individuals genetically prone to obesity (see Mustelin et al. 2009).

During the transition from adolescence to adulthood a person’s physical activity decreases and physical activity habits change (Mechelen et al. 2000). In a longitudinal study, Tammelin et al. (2004) found a link between changes in physical activity and adulthood obesity. Most importantly, they found that persistent inactivity and becoming inactive from adolescence to adulthood predict abdominal and overall obesity in adults at age 31, and concluded that continued physical activity from adolescence to adulthood plays an independent role in preventing overall obesity and abdominal obesity in adults.

Several studies have examined the role of physical activity and the effects of physical activity on weight gain and waist circumference growth (see Tammelin et al. 2004, Kettaneh et.al. 2005, Kimm et al. 2005). However, knowledge is scarce on the frequency and intensity of physical activity that prevents weight gain and waist circumference growth in adults.

This study explores the relationship between leisure-time physical activity and BMI in subjects at age 16 and 24, and the physical activity and waist circumference of twin individuals at age 24 in a longitudinal study. It examines changes in BMI between subjects at 16 and 24 years of age and 18.5 and 24 years of age, and compares the BMI and waist circumference of physically active and inactive individuals. Specifically, it questions whether a physically active, adolescent group engaging in physical activity at a certain intensity experiences a smaller body BMI and a smaller waist circumference in adulthood.

1

2 REVIEW OF THE LITERATURE

2.1 Fundamentals of twin studies

Twin studies stand in principle on the simple fact that monozygotic (MZ) twins have identical genomes and that dizygotic (DZ) twins share half their segregating DNA (Petronis 2006). According to Hasselbalch et al. (2008), genetic variation divides into additive and non-additive variations; the additive consists of the sum of allelic effects on the phenotype relevant loci, while the non-additive includes the interaction of the alleles in the same locus and between loci.

The term environmental variation refers to both variations derived from environmental factors shared by twins and to variations derived from factors not shared by twins. It is assumed that shared environmental variations—and all relating environmental factors—have the same effect on monozygotic and dizygotic twin pairs. Environmental factors that make twin siblings similar include childhood experiences and the socio-economic status of the parents. An 'un-shared' environment covers environmental factors and experiences that make siblings dissimilar, as well as possible measurement errors.

Poulsen et al. (2007) argue that twin studies are important for medical research, research that can be instrumental in estimating the importance of genetic versus non-genetic components in human disease etiology. They discovered that the similarity of monozygotic and dizygotic twin pairs can be proved through concordance rates and interclass correlation coefficients. Consistent evidence exists that phenotypes, whose similarity is greater in monozygotic than in dizygotic twin pairs, have a genetic etiological component.

Mustelin et al. (2008) show that, independent of genetic factors, obesity links to poor fitness, low insulin sensitivity, and the reduced expression of genes involved in mitochondrial oxidative metabolism in skeletal muscles. Their conclusion is based on a study of a group of genetically identical MZ twin pairs discordant or concordant for BMI.

2.2 Twin research designs

Numerous designs in twin research methodology have been reported; in this study I focus on a few of these designs only. The classic twin-study method means monozygotic and dizygotic twins are reared together. This study compares the resemblance between monozygotic twin pairs to the resemblance between dizygotic twin pairs—a twin method that assumes equal environmental influences for both types of twins. As all inheritance is common and shared, differences between monozygotic twin pairs are explained by environmental effects. Differences between dizygotic twin pairs are explained by both genetic and environmental influences because dizygotic twins share half of their genes (Segal 1990).

A co-twin control-study provides different training programs or 'treatments' for each member of monozygotic twins; training outcomes are assessed later. Alternatively, a treatment may be available to one twin only or the same treatment may be available to both twins but at different periods of time, so as to allow for the examination of interactions between training and maturation (Segal 1990).

Longitudinal twin studies offer valuable opportunities to examine genetic influences on behavioural consistency at selected periods during the course of an individual's development. Twin studies also enable an examination of the timing and expression of physical and behavioural characteristics. The efficiency of these studies improves when using both twins and their singleton siblings (Segal 1990).

2.3 The assessment of anthropometry

Use of an anthropometric measure to assess the anthropometry of children and adolescents is complicated by the development and constant growth of those children and adolescents (Daniels 2009). Anthropometry is a commonly-used and inexpensive though possibly inaccurate method of assessing body fatness. The measurements most frequently used are height and weight combined as weight / height (m^2). A variety of measurements such as skin fold and circumference have been employed when assessing fat distribution or body fatness (Freedman & Sherry 2009).

2.3.1 Body weight and body mass index (BMI)

Mokdad et al. (2003) have established that both overweight and obesity are associated significantly with diabetes, high blood pressure, high cholesterol levels, asthma, arthritis, and with fair or poor health status. According to Must and Anderson (2006), BMI is also the most commonly-used measure to assess overweight or obesity in adults. BMI does not however distinguish between overweight excess from fat mass and overweight excess from lean mass.

Table 2 presents BMI classifications for adults (WHO 2006).

Table 2. BMI classifications for adults (WHO 2006).

BMI classification
< 18.5 less than optimal weight
18.5-24.9 optimal weight
25.0-29.9 overweight
≥ 30 obese
30.0-34.99 obese class I
35.0-39.9 obese class II
≥40 obese class III

Several direct measurements exist for assessing body fatness; one of those measurements is dual-energy radiograph absorptiometry (DEZA). Another measurement, the 4-compartment model, estimates mineral, total body water, bone density, and body weight and is used as a reference method for assessing body fatness (see Freedman & Sherry 2009).

Daniels (2009) contends that evaluations of overweight and obesity in children and adolescents in clinical settings support the use of BMI (weight/height (m^2) percentiles. BMI is useful when assessing the presence of increased body fat because BMI levels correlate with both body fat and with cardiovascular risk factors. BMI has led to clinicians using selected cut points when making decisions about the treatment and prevention of overweight.
Table 3 presents BMI categorisations according to percentiles for children and adolescents.

Table 3. BMI Categorisations according to percentiles for children and adolescents (Daniels 2009).

BMI Percentile	Category
< 5 th	Underweight
5th-84th	Healthy weight
85th-94th	Overweight
≥95th	Obesity

Freedman and Sherry (2009) have established that the accuracy of BMI as an indicator of adiposity varies according to degree of body fatness and that BMI is a reliable indicator of adiposity among overweight children. They demonstrated that differences in BMI among relatively thin children can result from differences in fat-free mass such as muscles, bones, water, minerals, and proteins. Also, BMI's limitations in characterising adiposity are known to differ according to ethnicity and gender. Asians, considered obese at lower BMI thresholds than other ethnic groups, may be at particular risk for co-morbidities. Differences in amounts of fat and muscle mass also exist between genders during growth and maturation: boys usually have more muscle mass while girls have more fat mass (Daniels 2009).

Hjelmborg et al. (2008) state that BMI level at its baseline is genetically influenced and that genetic influence on the rate of change in BMI is moderate to high in adult males and females. The proportion of variance in levels of BMI due to additive genetic effects was 80 % and the proportion of variance for rate of change was 60 %.

Daniels (2009) contends that BMI has several benefits as a screening test. Using BMI is relatively cheap, easy to use in practice, and non-invasive; BMI presents little or no harm and does not require expensive equipment, or that trained personnel do more than measure height and weight. BMI also has solid test characteristics—such as sensitivity and specificity—for minimising false-positive and false-negative results. On the other hand, BMI also possesses limitations in its ability to assess adiposity. A weight-for-height measure, BMI does not distinguish between fat mass and lean body mass: individuals with increased muscle mass may have an increased BMI, and individuals with decreased lean body mass and an increased adiposity may be misclassified by a BMI assessment.

2.3.2 Waist circumference

Waist circumference measurements can be used when assessing the health risks of obesity to determine the BMI of patients mildly or significantly obese. Korhonen et al. (2008) argue that waist measurements are somewhat unreliable, citing that waist circumferences measured by participants in their study were greater than waist circumferences when measured by a professional. Measures varied by up to 20 cm or even more and the mean difference between the two measures—participant and professional—was -3.76 ± 6.59 cm for women and -2.41 ± 4.49 cm for men ($p<0.001$).

Table 4 estimates morbidity risk according to waist circumference classifications (Fogelholm 2006a).

Table 4. Morbidity risk estimations according to classifications of waist circumference (Fogelholm 2006a).

Waist circumference, cm	No risk	Moderate risk	High risk
men	< 90	90 - 100	> 100
women	< 80	80 - 90	> 90

Visceral fat occurs with increased waist circumference and is also called abdominal obesity (Adulthood Obesity 2007). Misra and Vikram (2003) and Eckel et al. (2005) establish that obesity, particularly abdominal obesity, presents a risk factor for metabolic disturbances of fat adipose tissue. Adipose tissue, visceral adipose tissue in particular, may expose the body to free fatty acids and tumour necrosis factor alpha (TNF- α), which impairs insulin action in skeletal muscles.

Excessive adipose tissue is linked to decreased production of the adipose-specific molecule adiponectin, impairing insulin sensitivity in skeletal muscles (Alberti et al. 2006). In the metabolic disturbance of fat adipose tissue, an increased flow of free fatty acids occurs that levers in blood circulation and increases production of very low density lipoprotein and a high amount of triglycerides (VLDL) (Eckel et al. 2005). Misra and Vikram (2003) discovered other significantly disturbing factors in the metabolism of fat adipose tissue, including decreased amounts of high density lipoprotein (HDL) and increased amounts of triglycerides in circulation. These disturbances alter the consistency of triglyceride particles, making those particles smaller and thicker and decreasing the amount of HDL in circulation.

2.4 Physical activity

Physical activity may be defined as a bodily movement produced by skeletal muscles, resulting in a substantial increase in energy expenditure over energy expenditure at rest. A person’s total daily energy expenditure is modified by factors such as physical activity at leisure time, exercise, sport, occupational work, and chores. Leisure-time physical activity can be defined as activity undertaken in an individual’s discretionary time, leading to an increase in total daily energy expenditure, which includes resting and activity energy expenditure, the thermic effect of food, and for children, the energy required for growth and maturation (Bouchard et al. 1994).

According to the American College of Sports medicine (2009, 2-17), physical activity may be defined via the following measures: percentages of maximal oxygen consumption (VO_{2max}), oxygen consumption reserve (VO_2R), heart rate reserve (HRR), maximal heart rate (HR_{max})

and metabolic equivalents (METs). METs may be used as a convenient way to describe the intensity of the variety of physical activities (ACSM 2009, 2-17). METs can be expressed as in kcal x min or kg x min; 1 MET is equal to 3.5 ml of oxygen consumption per kilogram per minute (Ainsworth et al. 1994).

Table 1 presents classifications of physical activity intensity.

Table 1. Classifications of physical activity intensity (ACSM 2009, 2-17).

	Relative intensity		**Absolute intensity ranges across fitness levels (METs)**			
Intensity	VO_2R(%) HRR (%)	Max HR (%)	12MET VO_{2max}	10 MET VO_{2max}	8 MET VO_{2max}	6 MET VO_{2max}
Very light	< 20	< 50	< 3.2	< 2.8	< 2.4	< 2.0
Light	20-39	50-63	3.2-5.3	2.8-4.5	2.4-3.7	2.0-3.0
Moderate	40-59	64-76	5.4-7.5	4.6-6.3	3.8-5.1	3.1-4.0
Hard (vigorous)	60-84	77-93	7.6-10.2	6.4-8.6	5.2-6.9	4.1-5.2
Very hard	≥85	≥94	≥10.3	≥8.7	≥7.0	≥5.3
Maximal	100	100	12	10	8	6

2.4.1 Assessing physical activity through objective techniques

Physical activity occurs in four dimensions, namely frequency—sessions per time—and intensity, the rate of energy expenditure adjusted for body size, time, and type. Measuring physical activity is known to be challenging, particularly measuring physical activity in children and adolescents (Must & Tybor 2005). Nonetheless, obtaining an accurate measurement of physical activity is crucial to determining a person’s level of physical activity. Accurate measurements help us to better understand the dose-response relationship between health and physical activity for physical activity guidelines. Accurate measurements also help us to determine useful programs for improving physical activity (Sirard & Pate 2001). Sirard and Pate (2001) state the primary standards for assessing the physical activity of children and adolescents as direct observation, doubly-labelled water, and indirect calorimetry. Doubly-labelled water is considered a criterion measure for energy expenditure in field evaluations that assess total energy expenditure.

Direct observation is used to assess different patterns of physical activity and energy expenditure directly or after reviewing film or videotapes. This technique can be used for either short or long periods of time and in different settings, but is time-consuming, intrusive, and may cause alterations in typical behaviour (Ainsworth et al.1994).

Double-labelled water assesses total caloric expenditure. It estimates carbon dioxide production using isotope dilution over a minimum of three days. This technique can be used readily in normal daily life, having a low reactivity and to within a three-to-four percentage accuracy in measuring calorimeter values in adults. It has several limitations, however; for example, isotopes are expensive and difficult to obtain. Double-labelled water unfortunately cannot be used as a technique for large studies (Sirard & Pate 2001).

Indirect calorimetry is used to measure energy expenditure from O_2 consumption and CO_2 production. Its use in measuring physical activity is overly problematic, as it requires non-portable gas analysis equipments. For this reason, this technique is also impractical for measuring usual or weekly physical activity (Sirard & Pate 2001).

Several objective techniques exist, including heart rate monitors, pedometers and accelerometers, to estimate physical activity, and to estimate energy expenditure. Heart rate measurements are based on maximal oxygen consumption (VO_{2max}) and on the similarity between VO_{2max} and heart rate, a similarity that suggests that a litre of oxygen consumed is approximately equivalent to five kilocalories of energy expenditure. Heart-rate monitoring can be carried out using a heart-rate belt around the chest, while a watch around the wrist records heart rates beat-by-beat during rest and exercise from thirty minutes to twenty-four hours per day (see Ainsworth et al.1994).

Sirard and Pate (2001) state that this method of heart-rate monitoring is unobtrusive and cost-effective for small and moderately sized studies, and requires minimal effort from participant and experimenter. Its limitations are in the need to calibrate individual heart rate to VO_2 max so as to avoid the effects of psychological and environmental stressors. Must and Tybor (2005) show that factors such as psychological state and the temperature of the surrounding environment influence the heart-rate of the individual being monitored.

Sirard and Pate (2001) describe pedometers as relatively simple electronic devices for estimating and counting the number of steps taken over a period of time. Pedometers are inexpensive, re-useable, non-reactive, and objective for population-based assessments of physical activity. Pedometers cannot assess the intensity of the performed pattern or physical activity, however. Other limitations of pedometers include their restriction to measuring walking type activities and their weak to moderate correlation with accelerometry (Must & Tybor 2005).

Accelerometers capture movements in three dimensions and measure accelerations produced by body movements; they use piezoelectric transducers and micro processors that convert recorded accelerations into a digital signal referred to as counts (Sirard & Pate 2001). The main purpose of accelerometers is to detect patterns of physical activity and total activity and to estimate energy expenditure, if height, weight, age, and gender are supplied. This method is an objective, re-useable, and non-reactive tool for assessing physical activity. Its limitations are that it is expensive and that it requires a subject to remember to put it on each day, which limits its use to longitudinal settings. Accelerometers also have a limited ability to assess cycling, locomotion on a gradient, or activities with limited torso movement (Must & Tybor 2005).

2.4.2 Assessing physical activity through subjective techniques

According to Sirard and Pate (2001), four classifications of survey method for estimating physical activity levels exist: self-administered questionnaires, interviewer–administered questionnaires, diaries, and proxy report questionnaires. Subjective methods rely on responses from participants and make physical activities difficult to recall, categorise, and quantify.

Responding to self-administered questionnaires, participants assessed their physical activity by answering questions on the forms of physical activity; for example, by recalling the intensity and duration of activity from periods of one week to one year. The method is very inexpensive for estimating the physical activity levels of large numbers of individuals. Limitations to the method include recall errors, its subjectivity, deliberate misrepresentation, social desirability, and other biases in activity reporting. A wide range (r= -0.10 to 0.88) of correlation of coefficients exist between this method and direct observation, heart rate, or motion detection; therefore should be used cautiously with adolescents and the pediatric population (Sirard & Pate 2001).

Ainsworth et al. (1994) discovered that usual or actual physical activity can be assessed by interviewer-administered questionnaires over a period of one to four weeks. This method provides information about specific types of physical activity, allowing for the quantification of physical activity during the period assessed. Compared to other subjective techniques, this method is easy to complete.

The limitations of interviewer-administered questionnaires are that physical activity recalled from a previous week or month does not accurately represent a person's true yearly activity. Moreover, the presence of an interviewer will cause additional bias. According to Sirard and Pate (2001), the range of correlation of coefficients between this method and heart rate varies considerably (r= 0.10-0.89).

A physical activity diary is a tool for assessing activity levels over a period of one day to one year from sleeping to light to heavy everyday activities to various intensity exercises. While considered one of the most accurate subjective techniques for adults, the accuracy of adolescent diary reports should be viewed with caution, as recalling the intensity of physical activity accurately may present difficulties. Examples of activities of light to moderate intensity include walking, general household activities, and gardening (Sirard & Pate 2001).

A proxy report consists of a teacher's or parent's assessment of an adolescent's physical activity over a period of one to five days. It limitations are that questions about physical activity assess subjective behaviour rather than objective facts, and that proxy reports produce a lower level of agreement between the criterion measure and the proxy respondent (Sirard & Pate 2001).

2.4.3 Trends in leisure-time physical activity among adolescents

Rates of participation in unorganised leisure-time physical activity dropped in Finland during 1977 to 1985, then increased until 2007. 61 % of Finnish boys participated in unorganised leisure-time activities at least twice a week in 1977; the corresponding figures for 1985 and 2007 are 47 % and 64 %. Percentages of very active participation in sport by young people have also increased from 1977 to 2007: a trend common to both genders (Laakso et al. 2008). Laakso et al. (2008) contend that boys and girls—particularly girls—are increasingly participating in organised youth sport. A rising level of competition in international elite sport is the most obvious reason for this growth, competition that in turn causes federations and clubs to increase efforts to recruit more adolescents. Globalisation of sport has also enabled an increase in the number of sport events and disciplines and in the introduction of sports to young people in many countries. Nonetheless, the rate of drop-outs from participation in sport has remained almost static.

Habitual physical activity decreases during adolescence and with changes in leisure time. Previous studies have established that moderate physical activity level is linked to changes in adiposity. Adolescent girls and boys with decreased physical activity had a higher body mass index, a larger waist circumference, and a greater sum of skin-fold thickness during the two year follow-up. On the other hand, fat mass percentages decreased in boys (Kettaneh et al. 2005). Types of physical activity also change with growth and development: free play or other unsustained activities give way to such activities as team sports, sports clubs, individual activities, and school-based education (Must & Tybor 2005).

A study entitled Norwegian Longitudinal Health Behaviour established that the frequency of leisure-time physical activity varies considerably between adolescents and when maintained into adulthood, and differs across activity types and activity domains. The authors of the study also discovered that time spent in most leisure time activity types dropped significantly between the ages of 13 and 33, a drop greater in males than females. These findings suggest that adolescent males who are inactive early seem likely to continue inactive later into adulthood. The findings also indicate that participation in several physical activities simultaneously during adolescence is moderately related to later activity levels in adulthood (Kjonniksen et al. 2008).

2.4.4 The effects of aerobic physical activity and resistance training

Physical activity can be defined according to two main modes, aerobic and resistance exercise. Aerobic exercise, rhythmic exercise involving large muscle groups, results in the improvement and maintenance of cardiovascular fitness through—for instance—walking, cycling, aqua-aerobics, dancing, jogging, and aerobics. Aerobic exercise divides into moderate or vigorous physical activity on the basis of the intensity of the activity. A moderately intense aerobic exercise involves 40 % to 59 % of a person’s maximal oxygen uptake reserve (VO_2R), while a vigorously intense aerobic exercise involves 60 % to 84 % of person’s maximal oxygen uptake reserve (ACSM 2009, 152-182).

According to ACSM (2009, 2-17), regular aerobic exercise improves cardiovascular and respiratory functions by increasing the maximal oxygen uptake resulting from central and peripheral adaptations. Aerobic exercise decreases minute ventilation and myocardial oxygen cost at a given absolute sub-maximal intensity. It causes heart rate and blood pressure to drop at a given sub-maximal intensity, increases capillary density in skeletal muscles, and increases the exercise threshold for the accumulation of lactate in the blood. In addition, the effects of aerobic exercise include an exercise threshold for the onset of disease signs or symptoms. Other health benefits of aerobic exercise are reduced resting systolic, diastolic blood pressure, increased serum high-density lipoprotein cholesterol, and decreased serum triglycerides. Positive effects include reduced total and intra-abdominal body fat, reduced insulin needs, blood platelet adhesiveness and aggregation, and improved glucose tolerance.

Resistance training exercises consist of weight lifting, free weight lifting, machines with stacked weights or pneumatic resistance, and rubber bands. Resistance training can improve all components of muscular fitness including power, endurance, and strength. It should include compound or multi-joint exercise, meaning that an exercise affects more than one muscle group and strengthens both agonist and antagonist muscle groups. Recommendations state that multi-joint exercise should focus on the major muscle groups of chest, shoulder, lower and upper back, abdomen, hips, and legs (ACSM 2009, 152-182).

Regular resistance training can increase muscular strength by increasing the activation of the nervous system in skeletal muscles; it can also increase muscle mass by adding to the structural thickness of connecting tissue. Regular resistance training can also improve the maximal aerobic force, muscle endurance, and velocity of force profit in both young and older people (Suni 2006). According to Verney et al. (2006), three months of resistance training can improve muscle mass by increasing the cross-sectional area of muscle. A three-month training program increased maximal isometric and isokinetic torque. Combined lower-limb endurance training and upper-limb resistance training significantly lowered percentages of total body fat mass and abdominal fat mass. The training program also had positive effects on the concentration of cholesterol values, on the amount of triglycerides in circulation, and in decreasing LDL cholesterol.

2.4.5 The effects of physical activity on body weight and BMI

ACSM (2009, 225-271) states that a body weight reduction of five to ten percent may have a positive impact on an individual's health, and that the benefits of that reduction are easy to maintain through aerobic physical activity and by maintaining weight loss. Generally, the recommendation for aerobic physical activity is to increase aerobic exercise progressively from 200 to 300 minutes a week or energy expenditure by more than 2000 kilocalories a week so as to attain lasting weight control.

Aerobic physical activity improves body weight control in normal and overweight individuals, increases total energy expenditure, and eases the body's regulation of its energy balance by decreasing short-time appetite and increasing food control. Aerobic activity also affects body composition positively by decreasing body fat mass and visceral fat adipose tissue and by increasing body fat-free mass or muscle mass. Increased body muscle mass in turn causes the ability of skeletal muscle to use insulin to grow and the use of fatty acids for energy to increase (Mustajoki et al. 2003).

Kvaavik et al. (2003) established that BMI tracks significantly from adolescence to adulthood. They also showed that BMI as an adolescent, the BMI of the subject's father, and leisure-time physical activities as an adult are strong predictors of a subject's adult BMI. Moreover, Hallal et al. (2006) found that higher physical activity levels in adolescence may cause improved health benefits as an adult, namely positive effects in adult physical activity levels—as opposed to sedentary behaviour, which results in poor physical fitness.

Kimm et al. (2005) suggested that a decline in activity at 10 MET times per week (equivalent to two to five brisk walks per week) is associated with a 0.14 and 0.09 kg/m^2 gain in BMI. The study was a cohort of 1152 black and 1135 white girls from USA followed over ten years. Differences existed between groups deriving from races and activity level. BMI gains for inactive girls remained significantly greater than gains for active girls of both races during the time measured ($0.0001 \leq p \leq 0.02$). Black girls were significantly heavier and had a higher body fat mass than white girls throughout adolescence. Each 10 MET-per-week habitual activity questionnaire decline was associated with a greater gain in BMI by 0.05 kg/m^2 for black girls than for white girls.

Ortega et al. (2007) showed that children and adolescents with a low or a middle level of total physical activity were more likely to be overweight (p= 0.019 and p=0.006) than those with a high level of total physical activity. Subjects with a low level of vigorous physical activity were four times likelier to be overweight (p=0.001) than those with a high level of vigorous physical activity.

2.4.6 The effects of physical activity on waist circumference

Habitual physical activity can prevent the accumulation of visceral and ectopic fat after controlling for genetic liability and childhood environment (Leskinen et al. 2009). Reichert et al. (2009) found a significant decline in visceral adipose tissue (-42.0±9.3 cm3, measured by DEXA) in the subcutaneous abdominal adipose tissue (-69.7±55.9 cm3, measured by MRI) and body fat percentage (-3.57±0.80 %) of individuals after eight months of moderate physical training and dietary change. Aerobic physical activity may also reduce a person's subcutaneous fat mass, total body fat mass, and waist circumference, even if no changes in weight occur (Ross et al. 2004).

Aerobic physical activity changes the amount of lipoproteins in circulation by stimulating the degradation of triglyceride particles into fatty acids and glycerol. Triglyceride particles move via the impression of exercise to muscle cells, where they are used as an energy source. Physical activity also stimulates the metabolism of lipoproteins so that the amount of triglycerides and LDL cholesterol decreases while HDL cholesterol increases. Carrying out these changes requires high amounts of physical activity, about five hours a week (Kraus et al. 2002). You and Nicklas (2008) established that aerobic physical activity raises the amount of anti-inflammatory adiponectin protein in circulation; adiponectin protein plays a significant role in controlling the decomposition of fatty acids and in regulating the amount of glucose in circulation.

Changes in waist circumference may be the most accurate predictor of changes in abdominal fat adipose tissue. Consistent evidence exists that physical activity three times a week at a moderate intensity decreases the visceral fat and waist circumference of normal and overweight persons. Also, the intensity of the physical activity is important in terms of changes in waist circumference; vigorous physical activity is the most effective way of decreasing waist circumference (see Koh-Banerjee et al. 2003). Tremblay et al. (1990) showed in the Canada Fitness Survey that the subcutaneous fat and waist-to-hip-ratio of subjects who engaged regularly in vigorous physical activities were generally lower than for those not performing these activities.

2.4.7 Physical activity guidelines for healthy adolescents and adults

Tammelin et al. (2007) suggest that approximately fifty percent of Finnish adolescents are sufficiently active according to current recommendations for physical activity. Sedentary behaviours such as television viewing or sitting in front of a computer often replace time spent on physically active pursuits.

Recommendations state that adolescents should pursue aerobic physical activity at a moderate or vigorous intensity at least 60 minutes or more a day, and should include in that exercise vigorous physical activity at least three days a week. Adolescents should also pursue muscle and bone-strengthening exercises at least three days a week as a part of their daily physical activity. It is important to encourage adolescents to engage in these activities, which are enjoyable, offer variety, and are appropriate for their age (The US. Department of Health & Human Service 2008).

Adults should engage in moderately intense physical activity at least two hours a week or vigorous physical activity for at least one hour and fifteen minutes a week. Aerobic physical activity should be performed in episodes of at least ten minutes a time and that activity should be spread throughout the entire week. Adults should increase their aerobic physical activity to five hours a week at a moderate intensity or to 150 minutes vigorous physical activity a week to attain more or extensive health benefits. Muscle-strengthening activities performed at a moderate or high intensity—and involving all muscle groups—two or more times a week offer additional health benefits to adults (The US. Department of Health & Human Service 2008).

According to Finnish recommendations for physical activity, adults should pursue aerobic physical activity at least two to five times a week at a moderate intensity and at 20 to 60 minutes per time. Adults should also do muscle-strengthening exercises one to three times a week for 20 to 60 minutes per time, and every adult should pursue everyday physical activities five to seven days a week for at least thirty minutes per day. Adolescents and children should perform aerobic physical activity at a moderate or vigorous intensity for at least 60 minutes a day (Fogelholm & Oja 2006b). Hakkarainen et al. (2009) contend that adolescents should also do muscle-strengthening exercises at least three days a week and that a variety of physical activity is important for an adolescent's physical growth and development.

3 THE PURPOSE OF THE STUDY

This study aims to investigate the effects of persistence and change on the frequency of a person's leisure-time physical activity on BMI and waist circumference from adolescence to adulthood. Also, it investigates the effects of the intensity of that physical activity on BMI and waist circumference in adulthood. The first aim is to compare the BMI and changes in BMI of physically active and physically inactive twin individuals from age 16 to 24. The second aim is to compare the waist circumference of physically active and inactive twin individuals at age 24. The third aim is to investigate whether a certain intensity and frequency of physical activity at age 16 links to a smaller BMI at age 24.

The study will compare the BMI of participants at age 16 and 24, and the waist circumference of participants at age 24 between different physical activity frequency and intensity groups.

The research questions of this study are as follows.

1. Do the BMI and waist circumference of different physical-activity frequency groups differ in the period from adolescence to adulthood?
2. Do the BMI and the waist circumference of different physical-activity intensity groups and of persistently active and inactive groups differ in adulthood?

The hypotheses of this study are as follows.

1. A high level of leisure-time physical activity frequency and intensity has a positive association with low BMI from adolescence to adulthood.
2. A high level of leisure-time physical activity frequency and intensity has a positive association with low waist circumference in adults and persistent physical activity has a positive association with low waist circumference in adults.

4 STUDY MATERIAL AND METHODS

4.1 Subjects and background information

The study sample is part of Finn Twin 16 (N=6084), a population-based study of five birth cohorts of Finnish twins born between the years 1975 and 1979. The birth cohorts were identified through the Central Population Registry of Finland.

Assessments were collected through mailed questionnaires administered sequentially from 1991 to 1995 within two months of the twins' sixteenth birthdays. The baseline questionnaire included a survey asking participants to record their sex, age, and zygosity, and to self-administer measurements of height and weight. The questionnaire also included a tape measure for measuring waist circumference and a survey of participant health habits covering frequency of meals, eating patterns, use of alcohol, tobacco, and cannabis, religiosity, sexual history, mental health, various health indicators, and frequency and intensity of physical activity. All twins were sent follow-up questionnaires at age 17 and 18.5 and at a mean age of 24 (see Mustelin et al.2009).

The study sample for analysis includes responses from 5778 twin individuals—all data available—at age 16, from 5445 twin individuals—all data available—at age 17, from 5427 twin individuals—data not available from 9 subjects—at age 18.5, and from 5238 twin individuals—data not available from 320 subjects—at age 24. The twin individuals contacted were asked to respond to questions about the frequency and the intensity of their physical activity at a mean age of 16, 17, 18.5, and 24.

The data includes information about waist circumference at age 24 and about height and weight at the ages of 16, 17, 18.5, and 24. At each point in time the study sample was divided in three activity classes. Those who answered—at age 16, 17, 18.5, and 24—that their frequency of physical activity was four to five times a week or more formed the physically active group (yes/no). Those exercising once or twice or three times a week formed the occasionally active group. Those exercising less than once or twice a month formed the physically inactive group. The number of twin individuals who were physically active was 1763 at age 16, 1783 at age 17, 1622 at age 18.5, and 1515 at age 24. The number of twin individuals who were occasionally active was 2723 at age 16, 2612 at age 17, 2639 at age 18.5, and 2348 at age 24. The number of twin individuals who were physically inactive was 1269 at age 16, 1041 at age 17, 1157 at age 18.5, and 1055 at age 24.

The study sample employs the new variable name body mass index (BMI) (weight/height (m^2) at a mean age of 16, 17, 18.5 and 24. The data includes information about the BMI of 5593 subjects at age 16—data not available from 185 subjects, 5316 subjects at age 17—data not available from 129 subjects, 5354 subjects at age 18.5—data not available from 73 subjects, 5209 subjects at age 24—data not available from 29 subjects, and about the waist circumference of 4906 subjects—data not available from 332 subjects—at age 24.

A new variable name, persistence of physical activity, was created to describe the stability of the frequency of physical activity from age 18.5 to 24. Those who were physically active at both ages formed the persistently active group. Those who were occasionally active at both ages formed the occasionally active group. Those who were physically inactive at both ages formed the persistently inactive group. In addition, certain individuals changed from one frequency group to another group. These groups were formed as follows: from physically inactive to occasionally active, from occasionally active to physically inactive, from physically active to physically inactive, from physically active to occasionally active, from physically inactive to physically active, and from occasionally active to physically active.

A new variable name, BMI change, was created to describe changes in BMI between age 16 and 24 and between age 18.5 and 24.

4.2 Measurements

4.2.1 Physical activity

Two questions were employed to measure physical activity. The first question asked participants to report the frequency of their stable leisure time physical activity outside school and had seven alternative responses, namely ‘not at all,’ ‘less than once a month,’ ‘1 to 2 times a month,’ ‘about once a week,’ ‘2 to 3 times a week,’ ‘4 to 5 times a week,’ and ‘about every day.’ The second question concerned the intensity of physical activity and had five alternative responses: ‘profuse sweating and breathlessness,’ ‘moderate sweating and breathlessness,’ ‘little sweating and breathlessness,’ ‘no sweating and breathlessness,’ and ‘no leisure-time physical activity’ (cross-reference Aarnio 2002).

Three activity groups were formed on the basis of the first question; Table 5 presents these groups.

Table 5. The number of subjects in different physical activity groups in different age categories.

Physical activity frequency class	N=at age 16	N= at age 17	N= at age 18,5	N= at age 24
Physically inactive (class 1-3)	1269	1041	1157	1055
Occasionally active (class 4-5)	2723	2612	2639	2348
Physically active (class 6-7)	1763	1783	1622	1515
Total N	5755	5445	5418	4918
boys=1	1=2781	1=2548	1=2530	1=2415
girls=2	2=2997	2=2897	2=2897	2=2823
Data unavailable	23		9	320
Total N	5778	5445	5427	5238

Participants were asked about the intensity of physical activity twice, once at age 16 and once at 24. Table 6 presents the question as it appeared in the questionnaire and the frequency of the intensity of physical activity among the participants.

Table 6. The intensity of physical activity of boys and girls at age 16 and 24.

The intensity of physical activity at age 16	N= at age 16	The intensity of physical activity at age 24(Is your leisure time physical activity as strenuous as?)	N= at age 24
1= profuse sweating and breathlessness a lot	1378	1= like walking as very light physical activity	1149
2= moderate sweating and breathlessness	2377	2=walking and jogging as light physical activity	1272
3= little sweating and breathlessness	1454	3=light jogging as moderate physical activity	1454
4= no sweating and breathlessness	204	4=heavy jogging as vigorous physical activity	1296
5= no leisure time physical activity	327		
Total N	5740	Total N	5171
Data unavailable	22	Data unavailable	67
Total N	5762	Total N	5238

Based on the second question, four physical activity intensity groups were formed. A new variable, physical activity intensity 24, was created to cover data at age 24, with the following four alternative responses: number 1=a very light physical activity such as walking; number 2=a light physical activity such as walking and jogging; number 3=a moderate physical activity such as light jogging; and number 4=a vigorous physical activity such as heavy jogging.

4.2.2 Physiological characteristics

Participants self-administered height and weight measurements for all questionnaires to the closest centimetre and the closest kilogram respectively. BMI was computed as weight (kg) / height (m^2) (cross-reference Aarnio 2002). Waist circumference measurements were self-administered using a tape measure supplied with the questionnaire at a mean age of 24. The comparability of the self-administered and measured data was ascertained in 566 twins; the intra-class correlation for BMI was 0.94 and for waist circumference 0.73 (Pietiläinen et al.2008).

4.3 Statistical analyses

Analyses of the study data were computed using SPSS 17.0 for Windows. To begin with, all the variables as defined were tested by variance analysis—a one-way anova test—to examine associations between BMI and frequency of physical activity in both sexes at age 16 and 24. The one-way anova test also examined associations between waist circumference and different physical activity intensity and frequency groups at age 24.

An independent-sample t-test examined differences in the BMI of boys and girls at age 16 and 24, and examined differences in the waist circumference of boys and girls at age 24. A one-way anova test was used to compare changes in BMI from age 16 to 24 and 18.5 to 24 between physically active and inactive groups, to discover if those changes were statistically significant. A one-way anova test was used to examine the associations between BMI or waist circumference and the stability of the frequency of physical activity from the ages of 18.5 to 24. A two-way anova test was used to examine if a certain intensity and frequency of physical activity leads to a smaller BMI and waist circumference at age 24. Due to the skewness of the distributions, the p-values were computed using log-transformed BMI values and waist circumference values.

5 RESULTS

5.1 Associations between BMI and frequency of physical activity

5.1.1 Distribution of the frequency of physical activity

The percentage of physically active boys was higher than the percentage of physically active girls at age 16 and 24, while a higher percentage of girls were occasionally active than boys were physically active at age 16 and 24. 10.8 % of boys at age 16 pursued leisure-time physical activity less than once or twice a month; 11.2 % of girls were at the same activity level. For both sexes, the proportions of participants in these categories differed by less than 1.5 percentage points at age 24 when considered as group-based data.

Figures 1 and 2 present the percentages of girls and boys at different physical activity levels at age 16 and 24 (appendix 2).

5.1.2 Associations between BMI and physical activity level at age 16 and 24 in physically active and inactive groups

The lowest BMI (20.2) at age 16 was among physically inactive boys and among occasionally active girls (20.9). The highest BMI at age 16 was among occasionally active boys (20.5) and among physically inactive girls (22.0). No significant differences in BMI existed between the physically active and inactive groups of boys or girls at age 16. BMI was lower among boys than girls and the difference was statistically significant (p=0.017).

Appendix Table 1 presents BMI results and comparisons between different activity frequency groups among the boys studied. Appendix Table 2 presents the corresponding results and comparisons among the girls studied (see appendix 3).

The lowest BMI at age 24 was among occasionally active boys and physically active girls. Among girls at age 24, the BMI was lower than among boys: this difference was statistically significant ($p<0.001$). No significant differences ($p<0.05$) in BMI were observed between physically active and inactive groups of boys or girls at age 24. A near-significant difference in BMI was observed between physically active and occasionally active groups among boys.

Appendix Table 3 presents BMI results and comparisons between different activity frequency groups among boys at age 24; appendix Table 4 presents BMI results and comparisons for the girls.

5.1.3 Associations in the change of BMI between physically active and inactive groups from age 16 to 24 and 18.5 to 24

The results show that BMI increased in all groups from age 16 to 24.Comparing changes in BMI between different physical activity frequency groups from age 16 to 24, the highest change was among physically inactive boys (the change in mean BMI was +3.8) and the lowest change among physically inactive girls (the change in mean BMI was +0.3). At age 24, the change in BMI was lower among physically active girls than among physically inactive girls. No significant differences ($p< 0.05$) in BMI changes existed between physically active and inactive groups of boys or girls from age 16 to 24.

From the ages of 18.5 to 24, the BMI of all activity groups increased. Comparing changes in BMI between different physical activity frequency groups from age 18.5 to 24, the highest change was among physically inactive boys (the change in mean BMI was +2.8) and the lowest change among physically inactive girls (the change in mean BMI was + 0.3). A significant difference ($p=0.025$) in BMI changes was observed between physically inactive and active boys from age 18.5 to 24. No significant differences in BMI changes were observed between physically active and inactive girls.

5.2 Associations between waist circumference and frequency of physical activity

Physically active girls and boys at age 24 had the lowest waist circumference. Also, waist circumference was lower in all girls than in all boys: a statistically significant difference ($p<0.001$). No significant differences ($p< 0.05$) in waist circumference were evident between physically active and inactive groups of girls or boys. Table 7 presents the results of the waist circumference measurements and comparisons between different physical activity frequency groups among the boys; Table 8 presents the corresponding results among the girls.

Table 7. The waist circumference (means and 95% CL) of boys at age 24, and comparisons between different groups of physical activity frequency .

		Boys			
Physical activity frequency group	Number of boys (N)	The waist circumference (cm)	(95 % CL)	Comparisons between different activity frequency groups[1]	p[2]
Physically inactive	451	86.2	85.1-87.2	Occasionally active	0.679
				Physically active	0.114
Occasionally active	907	85.3	84.7-85.9	Physically inactive	0.679
				Physically active	0.336
Physically active	735	84.6	84.0-85.2	Physically inactive	0.114
				Occasionally active	0.679
Total	2093	85.2			

[1] =one-way anova test (p-values from ln of waist circumference)
[2]= Post- Hoc-tests (Tamhane)

Table 8. The waist circumference (means and 95% CL) of girls at age 24, and comparisons between different groups of physical activity frequency.

	Girls				
Physical activity frequency group	Number of girls (N)	The waist circumference (cm)	(95 % CL)	Comparisons between different activity frequency groups[1]	p[2]
Physically inactive	535	75.5	74.6-76.4	Occasionally active	0.308
				Physically active	0.154
Occasionally active	1282	75.0	74.4-75.5	Physically inactive	0.308
				Physically active	0.532
Physically active	694	74.7	74.0-75.3	Physically inactive	0.154
				Occasionally active	0.532
Total	2511	75.0			

[1]=one-way anova test (p-values from ln of waist circumference)
[2]=Post-Hoc tests (LSD)

5.3 Associations between waist circumference and intensity of physical activity

5.3.1 Distribution of physical activity intensity

A higher percentage of boys than girls at age 16 and 24 engaged in categories of physical activity intensity that involved profuse sweating and breathlessness. A higher percentage of girls at age 16 and 24 engaged in moderately intense physical activity. 13.4 % of girls at age 16 pursued physical activity that caused little sweating and breathlessness. At age 24, 14.3 % of girls and 7.9% of boys pursued very light physical activity.

Figures 3 and 4 (appendix 5/1, 2) present the percentages of participants at different intensity levels of physical activity at age 16 and 24.

5.3.2 Associations between the waist circumference and the physical activity intensity at age 24

Girls and boys who engaged in vigorous physical activity had the lowest waist circumference, while those pursuing very light physical activity had the highest waist circumference. Waist circumference was lower among all girls than all boys across the physical activity intensity groups; this difference was statistically significant ($p<0.001$). Also, significant differences in waist circumference ($p< 0.0001$) existed between boys in different intensity groups, with the exception of between boys in moderate and vigorous intensity groups, very light and light intensity groups, and light and moderate intensity groups. Among the girls, significant differences in waist circumference existed between all the intensity groups except between the moderate and vigorous intensity groups.

Table 9 presents boys' waist circumference measurements and comparisons between different physical activity intensity groups. Table 10 presents corresponding measurements and comparisons for the girls studied.

Table 9. The waist circumference (means and 95 % CL) of boys at age 24, and comparisons between different groups of physical activity intensity.

		Boys			
Physical activity intensity group	Number of boys (N)	The waist circumference (cm)	(95 % CL)	Comparisons between different intensity groups[1]	p[2]
1= very light physical activity	388	88.0	86.9-89.2	2 3 4	0.376 <0.001* <0.001*
2= light physical activity	385	86.5	85.5-87.5	1 3 4	0.376 0.097 <0.001*
3= moderate physical activity	653	84.9	84.2-85.5	1 2 4	<0.001* 0.097 0.206
4= vigorous physical activity	807	83.9	83.4-84.4	1 2 3	<0.001* <0.001* 0.206
Total	2233	85.4			

[1] one-way anova test (p-values from ln of waist circumference)
[2] Post- Hoc tests (Tamhane) *p< 0.05

Table 10. The waist circumference (means and 95 % CL) of girls at age 24, and comparisons between different groups of physical activity intensity.

	Girls				
Physical activity intensity Group	Number of girls (N)	The waist circumference (cm)	(95 % CL)	Comparisons between different intensity groups[1]	p[2]
1= very light physical activity	686	77.4	76.6-78.3	2	0.005*
				3	<0.001*
				4	<0.001*
2= light physical activity	813	75.5	74.8-76.1	1	0.005*
				3	<0.001*
				4	<0.001*
3= moderate physical activity	704	73.5	72.9-74.1	1	<0.001*
				2	<0.001*
				4	0.835
4= vigorous physical activity	413	73.0	72.2-73.7	1	<0.001*
				2	<0.001*
				3	0.835
Total	2616	75.1			

[1]one-way anova test (p-values from ln of waist circumference)
[2] Post- Hoc tests (Tamhane)
*p< 0.05

Figure 5 (appendix 6) presents waist circumference measurements and the standard deviations in different physical activity intensity groups among girls and boys. The lowest waist circumference was that of boys (83.7 cm) and girls (71.9 cm) who were physically inactive and who participated in vigorous physical activity, as compared to other intensity and frequency groups. No significant (p=0.635) interaction was noted between physical activity and intensity or frequency among boys or girls (p=0.498) (see appendix 7, appendix Table 5, appendix Table 6).

5.3.3 Associations between BMI and physical activity intensity at age 24

Boys pursuing moderate physical activity had the lowest male BMI, and boys pursuing light physical activity had the highest male BMI. All the girls had a lower BMI than all the boys: the difference was statistically significant (p<0.001). No significant differences in the BMI of boys existed between any other intensity groups. Among the girls, the lowest BMI belonged to girls who participated in vigorous physical activity and the highest to those who participated in very light physical activity. Significant differences p<0.05) in BMI existed between girls in different intensity groups, except between the moderate and vigorous intensity groups.

Table 11 presents the BMI of boys in different groups of physical activity intensity and comparisons between those groups; Table 12 presents the corresponding data for the girls studied.

Table 11. The BMI (means and 95 % CL) of boys at age 24, and comparisons between different groups of physical activity intensity.

		Boys			
Physical activity intensity group	Number of boys (N)	BMI	(95 % CL)	Comparisons between different intensity groups[1]	p[2]
1= very light physical activity	404	24.3	23.9-24.7	2 3 4	0.995 0.179 0.594
2= light physical activity	400	24.1	23.7-24.3	1 3 4	0.995 0.434 0.926
3= moderate physical activity	700	23.7	23.5-23.9	1 2 4	0.179 0.434 0.819
4= vigorous physical activity	855	23.8	23.6-24.0	1 2 3	0.594 0.926 0.819
Total	2359	23.9			

[1]one-way anova test (p-values from ln of BMI)
[2] Post- Hoc-tests (Tamhane)

Table 12. The BMI (means and 95% CL) of girls at age 24, and comparisons between groups of physical activity intensity.

	Girls				
Physical activity intensity Group	Number of girls	BMI	(95 % CL)	Comparisons between different intensity groups[1]	p[2]
1= very light physical activity	734	23.0	22.7-23.3	2 3 4	0.005* <0.001* <0.001*
2= light physical activity	864	22.3	22.1-22.5	1 3 4	0.005* 0.015* 0.001*
3= moderate physical activity	750	21.8	21.6-22.0	1 2 4	<0.001* 0.015* 0.522
4= vigorous physical activity	438	21.6	21.3-21.8	1 2 3	<0.001* <0.001* 0.522
Total	2786	22.2			

[1] one-way anova test (p-values from ln of BMI)
[2] Post- Hoc-tests (Tamhane)
*p< 0.05

Figure 6 (appendix 8) presents the BMI results and standard deviations in different physical activity intensity groups of the girls and boys studied.

An interesting finding was that boys who were occasionally active and in a moderate intensity group had the lowest BMI (23.4) at age 24 compared to boys in other intensity and frequency groups. No significant interaction existed between the physical activity intensity and frequency of the boys (p=0.235) or girls (p=0.661). Girls (N=37) who were physically inactive and in the vigorous intensity group had the lowest BMI (21.2) at age 24 when compared to other intensity and frequency groups.

Table 13 presents comparisons in BMI between different groups of physical activity intensity and frequency among boys; Table 14 presents the corresponding comparisons for girls.

Table 13. Comparisons in the BMI (means) of boys at age 24 between different physical activity intensity and frequency groups.

Boys			
Physical activity intensity group	N	Frequency groups	BMI[3]
1= very light physical activity	154	physically inactive	24.0
	140	occasionally active	24.5
	69	physically active	23.8
Total	363		
2= light physical activity	101	physically inactive	24.0
	182	occasionally active	23.9
	90	physically active	23.9
Total	373		
3= moderate physical activity	109	physically inactive	23.8
	332	occasionally active	23.4
	210	physically active	24.0
Total	651		
4= vigorous physical activity	88	physically inactive	23.8
	306	occasionally active	23.5
	396	physically active	24.1
Total	790		

N= number of subjects
[3]2-way anova test

Table 14. Comparisons in the BMI (means) of girls at age 24 between different physical activity intensity and frequency groups.

Girls			
Physical activity intensity group	N	Frequency groups	BMI[3]
1= very light physical activity	219	physically inactive	23.2
	339	occasionally active	23.0
	131	physically active	22.9
Total	689		
2= light physical activity	182	physically inactive	21.9
	424	occasionally active	22.4
	214	physically active	22.4
Total	820		
3= moderate physical activity	120	physically inactive	21.8
	392	occasionally active	21.7
	213	physically active	22.0
	725		
Total			
4= vigorous physical activity	37	physically inactive	21.2
	204	occasionally active	21.5
	181	physically active	21.6
Total	422		

N=number of subjects
[3]2-way anova test

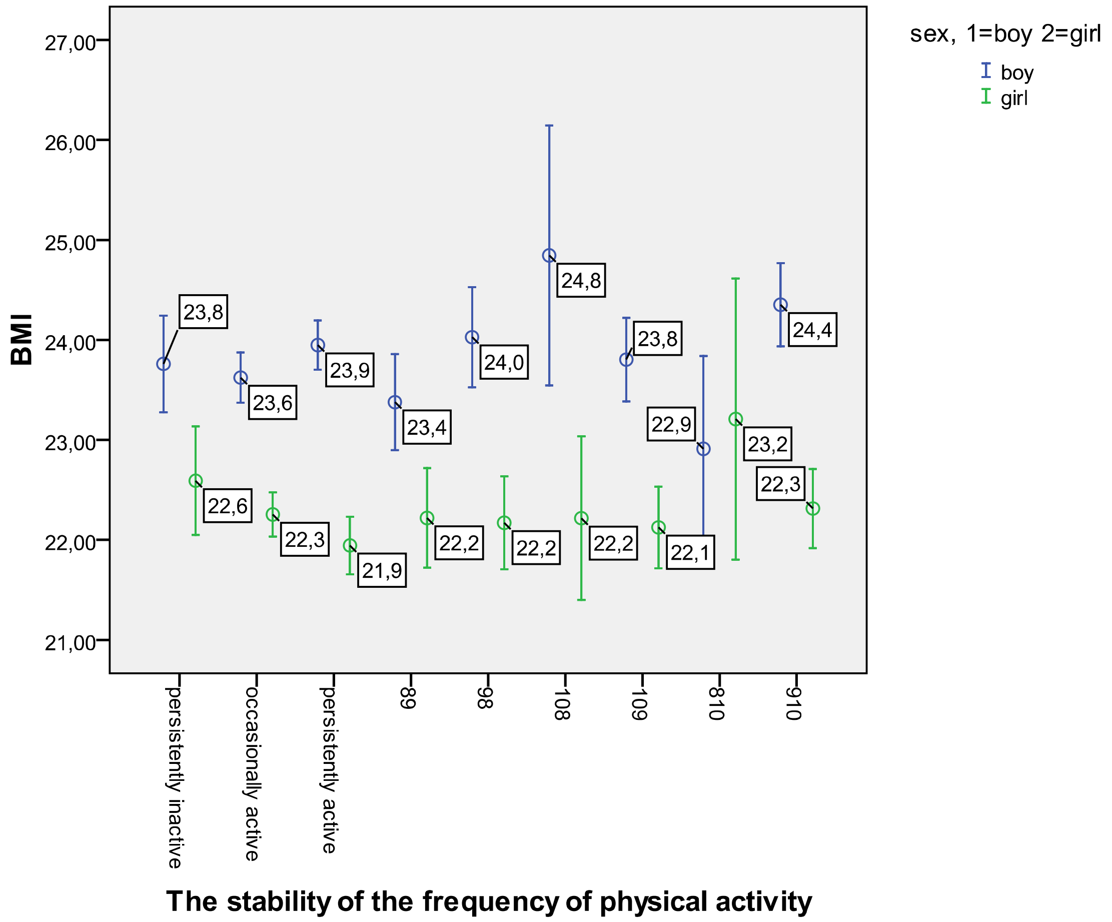
5.3.4 Associations between the stability of the frequency of physical activity, BMI, and waist circumference of boys and girls from age 18.5 to 24

Table 15 and Figures 1 and 2 present the BMI, waist circumference, and the stability of the frequency of physical activity of boys and girls from age 18.5 to 24.

Table 15. Comparisons in the BMI (means) and the waist circumference (means) of different physical activity frequency groups and the distribution of the stability of physical activity frequency from age 18.5 to 24 among girls and boys.

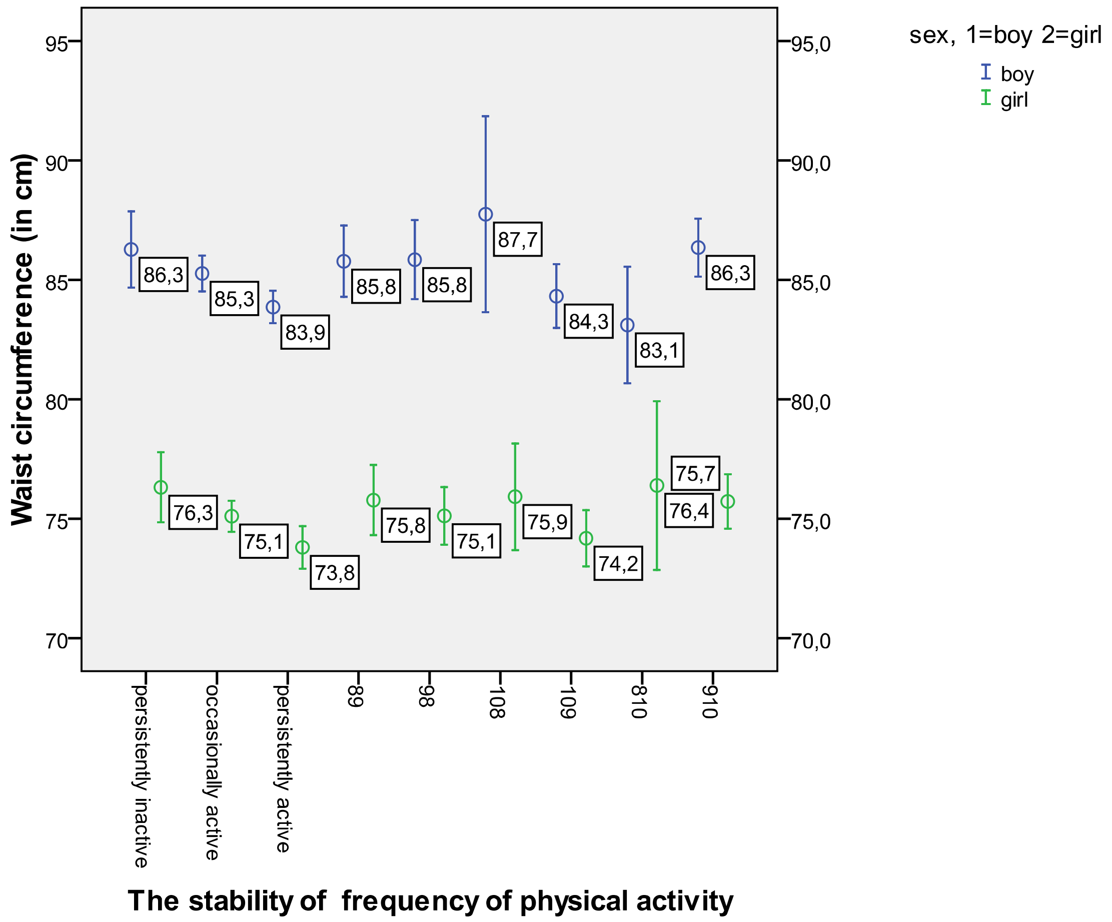
	Boys				**Girls**			
Persistence of physical activity frequency from age 18.5 to 24	**N**	**N %**	**BMI[1]**	**WC[1]**	**N**	**N %**	**BMI[1]**	**WC[1]**
Persistently inactive	290	9.8	23.8	86.3	266	8.5	22.6	76.3
Occasionally active	643	21.8	23.6	85.3	924	29.5	22.3	75.1
Persistently active	536	18.1	23.9	83.9	423	13.5	21.9	73.8
Physically inactive at age 18.5, becoming occasionally active at age 24	230	7.8	23.4	85.8	245	7.8	22.2	75.8
Occasionally active at age 18.5, becoming physically inactive	196	6.6	24.0	85.8	285	9.1	22.2	75.1
Physically active at age 18.5, becoming physically inactive at age 24	57	1.9	24.8	87.7	77	2.5	22.2	75.9
Physically active at age 18.5, becoming occasionally active at age 24	216	7.3	23.8	84.3	310	9.9	22.1	74.2
Physically inactive at age 18.5, becoming physically active at age 24	65	2.2	22.9	83.1	50	1.6	23.2	76.4
Occasionally active at age 18.5, becoming physically active at age 24	273	9.2	24.4	86.3	312	10.0	22.3	75.7
Total	2506	84.8			2892	92.5		
Data not available	450	15.2			236	7.5		
Total	2956	100			3128	100		

[1]One-Way anova-test
N= number of subjects
WC =waist circumference



89= from physically inactive to occasionally active
98= from occasionally active to physically inactive
108= from physically active to physically inactive
109= from physically active to occasionally active
810= from physically inactive to physically active
910= from occasionally active to physically active

Figure 1. The BMI (means and 95 % CL) of boys and girls from age 18.5 to 24, in comparison to stability of physical activity frequency groups.



89= from physically inactive to occasionally active
98= from occasionally active to physically inactive
108= from physically active to physically inactive
109= from physically active to occasionally active
810= from physically inactive to physically active
910= from occasionally active to physically active

Figure 2. The waist circumference (means and 95 % CL) of boys and girls from age 18.5 to 24, in comparison to stability of physical activity frequency groups.

Boys who were physically inactive at age 18.5 and who became physically active at age 24 had the lowest male BMI (22.9), while boys who were physically active at age 18.5 and who became physically inactive at age 24 had the highest male BMI (24.8). The BMI of boys who became physically inactive to occasionally active differed significantly (p=0.036) from the BMI of boys who became occasionally active to physically active. Persistently active girls at age 18.5 and 24 had the lowest female BMI (21.9); the highest female BMI (23.2) was of those physically inactive at age 18.5 who became physically active at age 24. No significant differences in BMI were noted among girls or boys in relation to the stability of the frequency of physical activity.

The lowest male waist circumference, 83.1 cm, was among boys physically inactive at age 18.5 and who became physically active at age 24. The highest male waist circumference (87.7 cm) was among boys who were physically active at age 18.5 and who became physically inactive at age 24. A significant difference (p=0.031) in waist circumference existed between persistently active boys and boys who became occasionally active to physically active. No significant differences in waist circumference were noted among boys in relation to the stability of physical activity frequency.

Persistently active girls at age 18.5 and 24 had the lowest female waist circumference (73.8 cm). The highest female waist circumference (76.4 cm) was among girls who were physically inactive at age 18.5 and who became physically active at age 24. No significant differences in waist circumference were noted among girls in relation to the stability of physical activity frequency.

6 DISCUSSION AND CONCLUSIONS

6.1 Main results

This study demonstrates that BMI increases from adolescence to adulthood in all groups and both sexes. In adulthood, all the girls studied had smaller waist circumference than the boys studied. All the girls also had a lower BMI in adulthood than boys, except girls who were physically inactive at 18.5 years of age and who became physically active at age 24. These results indicate that changes in BMI are linked to frequent physical activity in boys from age 18.5 to 24.

Among girls, BMI and waist circumference are associated with differences in the intensity of physical activity at age 24, except between moderate and vigorous intensity groups. Waist circumference is not associated with the frequency of physical activity among boys or girls at age 24. Among boys, an association exists between waist circumference and physical activity intensity, except between moderate and vigorous intensity groups and between very light and light intensity groups and light and moderate intensity groups. The results of this study indicate that the BMI of girls and boys from age 18.5 to 24 is not associated with the stability of the frequency of physical activity.

6.1.1 Associations between BMI and the frequency of physical activity among boys and girls at age 16 and 24

Percentages of physically active and inactive boys and girls were quite similar at ages 16 and 24, substantial number of individuals changed from one activity group to another from age 16 to 17 and from 17 to 18.5. Earlier studies have reported similar results. In a Finnish 8-year follow-up study, competitive sports practice at age 10 to 19 was associated (odds rations was 1.86 in men, 2.31 in women) with level of physical activity in adulthood (Hirvensalo et al. 2000). In a Canadian 12-year follow-up study, childhood physical activity level was found to be positively associated (r=0.20) with total physical activity level in adults (Trudeau et al. 2004). Several studies (Kettaneh et al. 2005, Nelson et al. 2005, Kjonniksen et al. 2008) have shown that leisure-time physical activity seems to decrease from adolescence to adulthood.

BMI was not linked in this study to the frequency of physical activity of boys or girls at age 16 and 24. One possible reason for this lack of association might be changes from one physical activity frequency group to another from adolescence to adulthood. Moreover, additional factors such as age and stage of maturation influenced BMI during adolescence. Daniels et al. (1997) showed in a cross-sectional study of 192 healthy subjects (100 boys and 92 girls, 103 white, and 89 black) aged 7 to 17 that BMI correlated positively with age and with the stage of maturation.

Parsons et al. (2006) report similar results, stating that the frequency of physical activity from age 11 to 45 does not influence subsequent BMI or changes in BMI; however, females aged 16 who were more active gained BMI slower than other females; specifically, 0.007kg/ m^2 /year per activity category over a period of 16 to 45 years. Most active males gained BMI faster than other males; specifically, 0.005 kg/ m^2/year per activity category. Kettaneh et al. (2005) found that a moderate physical activity level was associated with changes in adiposity. During a two-year follow-up study, adolescent girls and boys who decreased their physical activity level had a higher BMI than others. According to Lahti- Koski et al. (2002), BMI is associated with a moderate or high level of leisure-time physical activity among men and women.

6.1.2 Associations between changes in BMI and in the frequency of physical activity

The largest changes in BMI from 16 to 24 years of age were in the BMI of physically inactive boys; the BMI of physically active boys changed less. Girls displayed different results: physically inactive girls had the least changes in BMI, which did not decrease with more frequent physical activity. Changes in BMI from age 16 to 24 were not linked to frequency of physical activity among boys or girls.

When comparing changes in BMI from age 18.5 to 24, the highest change was among physically inactive boys and the lowest change among physically active boys. Changes in BMI were associated with a high level of physical activity frequency among boys from age 18.5 to 24. Earlier studies have demonstrated that aerobic physical activity improves body weight control in both normal-weight and overweight individuals. Aerobic physical activity increases total energy expenditure and has positive effects on body composition by decreasing the amount of body fat mass and visceral adipose tissue and by increasing body fat free mass (Mustajoki et al. 2003). Similar results have been reported in a cohort study conducted over one year of the early adolescence of 5120 boys and 6767 girls from the USA. Boys who spent increased time in aerobics or dance experienced a significant decline in BMI (-0.34 kg /m^2) relative to boys who did not (Berkey et al. 2003).

Among girls, changes in BMI from age 18.5 to 24 were not associated with frequency of physical activity. Kimm et al. (2005) have reported opposite results among girls in an earlier study. A cohort of 1152 black and 1135 white girls from the USA whose physical activity was followed from age 9 or 10 to 18 or 19, the BMI differences between active and inactive girls were significant ($p<0.001$). For black girls, BMI differences were 2.98 kg/m^2 and for white girls 2.10 kg/m^2. In a cohort study over one year of early adolescence, girls who increased their involvement in aerobics or dance experienced a decline in BMI (-0.197 kg/m^2), while girls who did not take part in those activities did not (Berkey et al. 2003).

6.1.3 Associations between waist circumference and the frequency and intensity of physical activity

The percentage of physically active boys and girls was nearly equal at age 24; 15.7 % and 15.1 % respectively. However, the percentage of physically inactive girls, 11.7 %, was higher than the percentage of physically inactive boys, 9.8 %. Waist circumference was not associated in this study with frequency of physical activity among boys or girls. The lowest waist circumferences were among physically active girls and boys, and the highest among physically inactive girls and boys. According to Ross et al. (2004), waist circumference is associated with the frequency of physical activity. They also discovered that aerobic physical activity may also reduce an individual's subcutaneous fat mass, total body fat mass, and waist circumference, even without changes in weight. Koh-Banerjee et al. (2003) demonstrated that moderately intense physical activity three times a week decreases the visceral fat and waist circumference of normal and overweight persons.

Several studies report an association between waist circumference and frequency of physical activity. Tammelin et al. (2004) contend that persistent male inactivity from age 14 to 31 is associated with mild abdominal obesity at age 31, and that becoming persistently inactive is linked to severe abdominal obesity in females at age 31. A study of Swedish young male twins from 1998 to 2002 showed a significant difference (2.5 cm, $p < 0.001$) in attained waist circumference between sedentary and physically active individuals (Karnehed et al. 2005). Ortega et al. (2008) studied Swedish children (N=557) and early age adolescent (N=518) girls and boys, reporting that the boys were more physically active and had higher levels of cardiovascular fitness than the girls. In individuals with a low cardiovascular fitness level, Ortega et al. found that total physical activity was negatively associated with waist circumference. Also, in individuals with a high cardiovascular fitness level, total and moderate and vigorous physical activity were positively associated with waist circumference (p-values ranged from 0.025 to <0.001).

The findings of this study indicate that the intensity of physical activity of boys and girls at age 16 does not predict waist circumference at age 24. Moreover, the percentage of boys and girls pursuing moderate physical activity declined from age 16 to 24—and more so among girls than among boys—but the percentage of girls in the moderate physical-activity group, 14.5%, was a little higher at 24 than the percentage of boys, 13.6 %. Contrastingly, the percentage of girls who participated in vigorous physical activity at age 16 and 24 was smaller than the corresponding percentage of boys. Also, the percentage of boys belonging to the vigorous physical activity group increased from age 16 to 24, while the proportion of girls decreased (boys 16.6%, girls 8.5 % at 24).

The findings show that the waist circumference of girls differs significantly between groups of physical activity intensity, except between moderate or vigorous intensity groups. Among boys, differences in waist circumference are also associated with intensity of physical activity, except between moderate and vigorous intensity groups, between very light and light intensity groups, and between light and moderate intensity groups. Earlier studies have shown that the intensity of a physical activity is important in bringing about changes to waist circumference and that vigorous physical activity is the most effective way of decreasing waist circumference (Koh-Banerjee et al. 2003). Tremblay et al. (1990) demonstrated that the subcutaneous fat and waist-to-hip-ratio of individuals pursuing regular vigorous physical activity is generally lower than in those not doing so.

Similar results were reported among girls in an earlier study. Kettaneh et al. (2005) carried out a population-based-study of 222 French boys and 214 French girls aged 8 to18; they found that girls who decreased their relative level of moderate physical activity had higher waist circumference in the follow-up stages. Among boys, opposite results were reported in an earlier study (Kettaneh et al. 2005). The waist circumferences of boys did not differ significantly according to changes of physical activity level in the follow-up stage.

6.1.4 Associations between BMI and intensity of physical activity at age 24

This study finds that BMI is not associated with the intensity of physical activity among boys. Possible reasons for these findings may include additional factors that influence BMI during the period from adolescence to adulthood; for example, differences between genders during growth and maturation concerning quantities of muscle mass and fat mass. Boys usually have more muscle mass and girls more fat mass (Daniels 2009). Among girls, differences in BMI were associated with the intensity of physical activity, but no significant BMI differences existed between moderately and vigorously intense groups.

Several studies have established the role of physical activity intensity and its association with BMI among boys and girls among boys and girls. Stevens et al. (2007) contend that BMI is linked to moderately and vigorously intense physical activity among adolescent girls and to highly intense physical activity among adolescent girls and boys (McMurray et al. 2000). In a study of African American and white adolescent boys and girls aged from 10 to 16, 1240 females and 1149 males participated in as a little as one high-intensity physical activity three to five days a week. As a result, males decreased their ethnically and socio-economically adjusted relative risk of being overweight (RR=0.646, CI: 0.427 to 0.977). For females, the ethnically and socio-economically-adjusted relative risk of being overweight was not altered significantly by physical activity (McMurray et al. 2000).

A longitudinal study of sixth- grade (N=1576) and eighth-grade (N=1285) girls from the USA reported similar results. Girls who were moderately to vigorously physically active 31.8 minutes per day had a BMI 1.04 units lower than girls moderately to physically active 13.7 minutes per day (Stevens et al. 2007).

6.1.5 Associations between the stability of the frequency of physical activity, BMI, and waist circumference from age 18.5 to 24

This study found that at age 24, BMI was 1.2 units higher among persistently inactive boys than among persistently inactive girls. One reason for this might be that boys usually have a higher muscle mass than girls (Daniels 2009). BMI among boys was linked to a moderate and high level of physical activity frequency. No association existed between BMI and the stability of the frequency of physical activity among boys or girls. One possible explanation for this result might be the smaller proportion of persistently active boys and girls in comparison to occasionally active boys and girls; the effect of the stability of frequency of physical activity on BMI was therefore not visible in the results. Nonetheless, contradictory results have been reported. Consistent evidence exists—based on a longitudinal study of five birth cohorts (1975-1979) of Finnish twins—that physical inactivity in adolescence predicts risk of obesity (OR 3.9, 95 % CL 1.4-10.9) and abdominal obesity (OR 4.8, 95 % CL 1.9-12.0) at age 25, after adjusting for baseline and current BMI (Pietiläinen et al. 2008).

Waist circumference measurements were 10 cm higher among persistently inactive boys than among persistently inactive girls at age 24, a statistically significant difference ($p<0.001$). The waist circumference of boys was associated with a moderate and high level of physical activity frequency. Waist circumference was not associated with the stability of the frequency of physical activity among girls or boys. Different results have been reported in an earlier, longitudinal study whose major finding was that persistent inactivity and becoming inactive in the period from adolescence into adulthood was associated with abdominal and overall obesity in adults at age 31 (Tammelin et al. 2004).

6.2 Methodological issues

The major strengths of this study are its longevity, its high number of participants, and the high response rates of its participants. The study material consisted of data from individuals representing a standard population of Finnish adolescents and young adults, individuals from 16 to 24 years of age. Both boys and girls were represented fairly in the study population. Subjects completed responses to the questionnaire four times, once at 16, 17, 18.5, and 24 years of age, covering a nine-year period from late adolescence to early adulthood.

This study does not analyze early adolescence; another limitation is that while the subjects were twins, they were considered as individual adolescents in the data analysis stage and not as pairs of twins. Pair-wise analyses were not used, another limitation, and there was a lack of adjustment in results by age 24. It means that study population consisted of individuals, whose age was under 24 or over 24.

Other limitations included the accuracy of the self-administered questionnaires, including the accuracy of the reported frequency and intensity of physical activity. Measuring physical activity accurately is known to be challenging, particularly measuring the physical activity of children and adolescents (Must & Tybor 2005). This study assessed leisure-time physical through self-administered questionnaires that measured the frequency of physical activity by asking the participant to report time spent per week in leisure-time physical activities, from a choice of seven alternative responses. Intensity of physical activity was measured through questions about breathing intensity and about sweating during physical activity, questions with four alternative responses. Some recall bias cannot be avoided: individuals may have exaggerated the amounts of physical activity reported in the questionnaires. Previous studies have shown that the reliability and validity of self-administered questionnaires can vary substantially. For example, the WHO Health Behavior in Schoolchildren Survey questionnaire indicated substantial overall reliability (frequency r=0.73 and duration r=0.71). A statistically significant correlation was found between VO_{2peak} and questions concerning both frequency (r=0.39) and duration (r=0.33) (Rangul et al. 2008).

Chinapaw et al. (2009) reported in a test-retest reliability study of the Activity Questionnaire for adults and adolescents that the test-retest reliability in adolescents was fair to moderate (intraclass correlations ranking from 0.30 to 0.59). Correlations between the AquAA and accelerometer were not significant. In this study, the use of a self-administered questionnaire as a measurement-tool was the most cost-efficient way to study physical activity epidemiologically with a large number of subjects.

Moreover, body composition measurements of height and weight and waist circumference were self-administered for all the questionnaires. BMI was computed as weight (kg) / height (m^2) and waist circumference was measured using a tape measure supplied with the questionnaire at a mean age of 24 (cross-reference Aarnio 2002). A limitation of this study was the lack of control for measuring height, weight, and waist circumference. Some measurement biases cannot be avoided with self-administered measurements: it is possible that individuals make errors when assessing and measuring their own height, weight, and waist circumference.

6.3 Conclusions

Leisure-time physical activity and aerobic exercise are known to have dwindled in western industrialised countries with mechanisation, industrialisation, and with the development of technology.

On the basis of earlier studies and on the results of this study, we can conclude that the intensity of physical activity and a high level of physical activity frequency may play an important role in reducing the growth of a person's BMI from adolescence to adulthood and in reducing waist circumference growth in adulthood. A high level of physical activity frequency among boys and a high level of physical activity intensity among boys and girls reduce the growth of BMI from adolescence to adulthood and reduce growth in waist circumference at the mean age of 24. Reducing the growth of BMI and waist circumference is known to lower the risk of metabolic syndrome and cardiovascular diseases. A similar result has been reported lately. Ortega (2008) found in a study of 557 Swedish children and 518 adolescents that individuals with a low level of physical activity are more likely to be overweight and more likely to have a high waist circumference, compared to those with a high level of vigorous physical activity.

This study results relate to the Finnish population and might be generalised to apply to the standard population of Finnish adolescents and young adults. Further research is needed to investigate if certain types of sports activity during adolescence may predict a smaller growth of BMI and waist circumference in adults.

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APPENDIX 1/ 1-9

ORIGINAL QUESTIONS AT AGE 16 (TRANSLATED FROM FINNISH)

1 SEX

1 girl

2 boy

2 DATE OF BIRTH____________/___________20

3 CURRENT HEIGHT___________ cm

4 CURRENT WEIGHT__________ kg

5 WHAT KIND OF FAMILY DO YOU HAVE?

1 mother and father

2 mother and stepfather

3 father and stepmother

4 only mother

5 only father

6 someone else , who?

6 IS YOUR TWIN THE SAME SEX AS YOU?

1 no ---→ go to question 11

2 yes

SMOKING

20 HAVE YOU EVER SMOKED (OR TRIED SMOKING)?

1 no -> go to question 24

2 yes

APPENDIX 1/ 2

21 HOW MANY CIGARETTES HAVE YOU SMOKED ALTOGETHER UP TO NOW?

1 none

2 only one

3 about 2-50

4 over 50

22 WHICH OF THE FOLLOWING BEST DESCRIBES YOUR CURRENT SMOKING HABITS?

1 I smoke once or more daily

2 I smoke once or more a week, but not every day

3 I smoke less often than once a week

4 I am trying to or have quit smoking

5 I have never smoked

23 HAVE YOUR PARENTS REMARKED ABOUT YOUR SMOKING LATELY?

FATHER	MOTHER
1 often	1 often
2 sometimes	2 sometimes
3 not at all	3 not at all
4 I have no father	4 I have no mother

PHYSICAL ACTIVITY

39 HOW DO YOU PERCEIVE YOUR PRESENT PHYSICAL FITNESS? IS IT

1 very good

2 rather good

3 satisfactory

4 rather poor

5 very poor

APPENDIX 1/ 3

40 WHICH OF THE FOLLOWING ALTERNATIVES BEST DESCRIBES YOUR PRESENT SPORTS/ FITNESS ACTIVITIES? I USULLY DO SPORTS OR EXERCISE SO THAT:

1 I breathe hard and sweat profusely

2 I breathe rather hard and sweat somewhat

3 I breathe and sweat a little

4 I don't sweat and breathe at all

5 I don't do sports or exercise during my free time

41 HOW OFTEN DO YOU EXERCISE OR DO SPORTS DURING YOUR FREE TIME?

(SCHOOL PHYSICAL ACTIVITIES DON'T COUNT HERE)

1 not at all

2 less than once a month

3 1-2 times a month

4 about once a week

5 2-3 times a week

6 4-5 times a week

7 about every day

APPENDIX 1/ 4

ORIGINAL QUESTIONS AT AGE 17 (TRANSLATED FROM FINNISH)

HEIGHT AND WEIGHT

7 CURRENT HEIGHT__________ cm

8 CURRENT WEIGHT_________ kg 10 WHICH OF THE FOLLOWING BEST DESCRIBES YOUR CURRENT SMOKING HABITS?

1 I smoke daily at least 10 cigarettes

2 I smoke daily, not more than 9 cigarettes a day, anyway

3 I smoke once a week or more; not every day, anyway

4 I smoke less than once a week

5 I am on strike or have quit smoking

6 I have never smoked

EXERCISE

16 HOW DO YOU PERCEIVE YOUR PRESENT PHYSICAL FITNESS? IS IT

1 very good

2 rather good

3 satisfactory

4 rather poor

5 very poor

17 HOW OFTEN DO YOU EXERCISE OR DO SPORTS DURING YOUR FREE TIME?

(SCHOOL PHYSICAL ACTIVITIES DON`T COUNT HERE)

1 not at all

2 less than once a month

3 1-2 times a month

4 about once a week

5 2-3 times a week

APPENDIX 1/5

6 4-5 times a week

7 about every day

18 WHAT TYPE OF SPORTS DO YOU DO? (SCHOOL PHYSICAL ACTIVITIES DON`T COUNT HERE)

1 I don't exercise at all-> move to question 20

2 cycling	8 aerobics	14 baseball
3 jogging	9 other gymnastics	15 basketball
4 swimming	10 tennis	16 rinkball
5 skiing	11 football	17 ice hockey
6 downhill skiing	12 volleyball	18 skating
7 bodybuilding	13 badminton	19 weightlifting

20 anything else; what? ______________________________

19 Do you participate in sports competitions nowadays or do you play in a team?

1 no

2 yes, what kind of sport or sports:

____

APPENDIX 1/6

ORIGINAL QUESTIONS AT AGE 18 (TRANSLATED FROM FINNISH)

HEIGHT AND WEIGHT

9 CURRENT HEIGHT__________ cm

10 CURRENT WEIGHT_________ kg

13WHICH OF THE FOLLOWING BEST DESCRIBES YOUR CURRENT SMOKING HABITS?

1 I smoke at least 10 cigarettes daily

2 I smoke daily; not more than 9 cigarettes a day, anyway

3 I smoke once a week or more; not every day, anyway

4 I smoke less than once a week

5 I am on strike or have quit smoking

6 I have never smoked

EXERCISE

21 HOW DO YOU PERCEIVE YOUR PRESENT PHYSICAL FITNESS? IS IT

1 very good

2 rather good

3 satisfactory

4 rather poor

5 very poor

22 HOW OFTEN DO YOU EXERCISE OR DO SPORTS DURING YOUR FREE TIME?

(SCHOOL PHYSICAL ACTIVITIES DON`T COUNT HERE)

1 not at all

2 less than once a month

3 1-2 times a month

4 about once a week

APPENDIX 1/7

5 2-3 times a week

6 4-5 times a week

7 about every day

ORIGINAL QUESTIONS AT AGE 24 (TRANSLATED FROM FINNISH)

HEALTH

19 HAVE YOU EVER HAD ANOREXIA NERVOSA?

1 Yes

2 no

3 I can’t say

20 HAVE YOU EVER HAD BULIMIA?

1 Yes

2 No

3 I can’t say

21 HAS SOMEONE ELSE TOLD YOU THAT YOU COULD HAVE AN EATING DISORDER (Anorexia, bulimia, or another eating disorder)?

1 Yes

2 No

27 DO YOU HAVE A LONG-TERM ILLNESS, DEFECT, OR INJURY THAT ENCUMBERS YOUR DAILY FUNCTION?

1 No, I haven`t

2 Yes; explain shortly what type

APPENDIX 1/8

28 DO YOU TAKE MEDICATION FOR THE TREATMENT OF AN ILLNESS REGULARLY OR SEASONALLY?

1 No I don’t

2 Yes I do; what kind of medication and what for

(for example, a regular insulin treatment, medication for asthma-attacks, or medication for seasonal hay-fever)

44 HOW DO YOU PERCEIVE YOUR PRESENT PHYSICAL FITNESS? IS IT

1 very good

2 rather good

3 satisfactory

4 rather poor

5 very poor

WEIGHT AND WEIGHTCONTROL

36 HOW TALL ARE YOU? __________cm

37 HOW MUCH DO YOU WEIGH? _________kg

Women: if you are now pregnant, state your weight before pregnancy __________kg

48 HOW OFTEN DO YOU EXERCISE OR DO SPORTS DURING YOUR FREE TIME?

(SCHOOL PHYSICAL ACTIVITIES DON`T COUNT HERE)

1 not at all

2 less than once a month

3 1-2 times a month

4 about once a week

5 2-3 times a week

6 4-5 times a week

APPENDIX 1/9

7 about every day

49 IS THE EXERCISE YOU DO IN YOUR FREE TIME ABOUT AS STRENOUS AS

1 walking

2 walking and light jogging

3 light jogging

5 running

79 WHICH OF THE FOLLOWING BEST DESCRIBES YOUR CURRENT SMOKING HABITS?

1 I smoke at least 20 cigarettes daily

2 I smoke 10-19 cigarettes daily

3 I smoke not more than 9 cigarettes daily

4 I smoke once a week or more; not every day, anyway

5 I smoke less than once a week

6 I am on strike or have quit smoking

7 I have never smoked

Finally, we ask that you measure your waist circumference with the enclosed measuring tape. Measure your waist circumference from the slimmest part of your waist or if you can’t find it, measure from the midpoint of the lowest part of the ribs and the upper part of hip bone, as you can see in the picture.

My waist circumference is _______ cm

APPENDIX 2

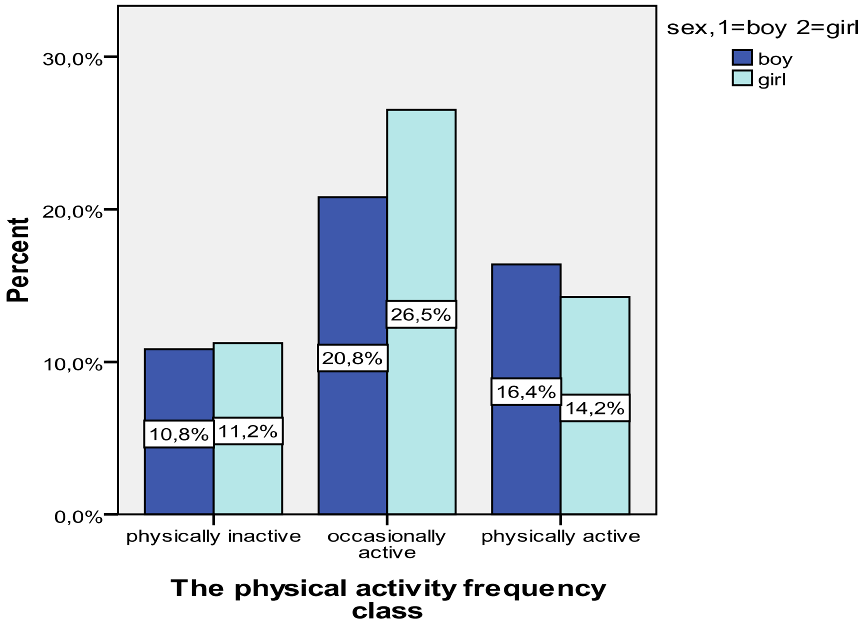

Figure 1. Percentages of boys and girls in different physical activity frequency groups at age 16.

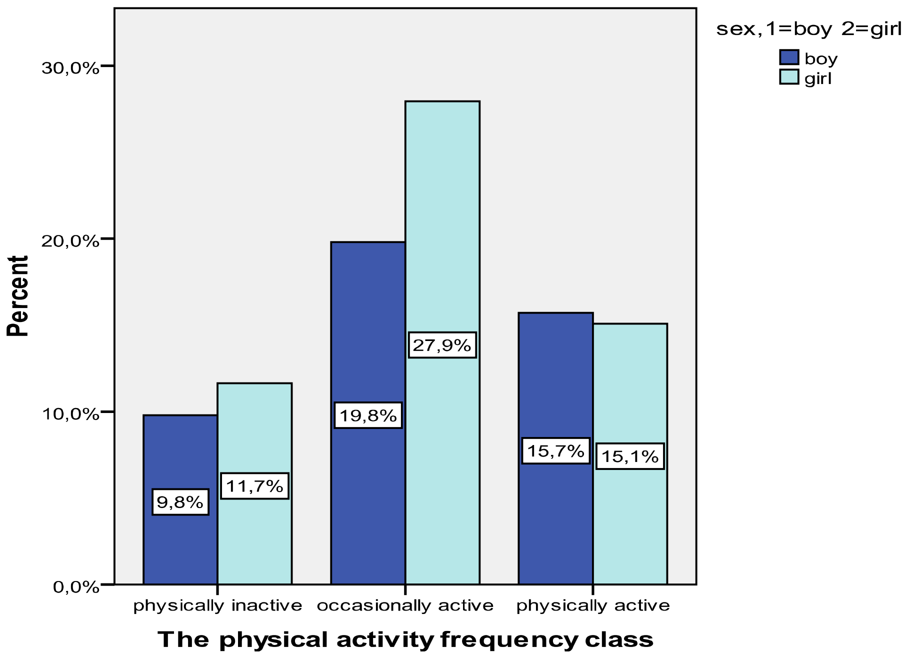

Figure 2. Percentages of boys and girls in different physical activity frequency groups at age 24.

APPENDIX 3

Table 1. BMI (means and 95% CL) and comparisons between different physical activity frequency groups among boys at age 16.

		Boys			
Physical activity frequency group	Number of boys (N)	BMI	(95 % CL)	Comparisons with different activity frequency groups[1]	p[2]
Physically inactive	594	20.2	19.9-20.4	Occasionally active Physically active	0.271 0.400
Occasionally active	1153	20.5	20.0-21.1	Physically inactive Physically active	0.271 0.798
Physically active	915	20.3	20.1-20.6	Physically inactive Occasionally active	0.400 0.798
Total	2662	20.4			

[1] One Way anova test (p-values from ln of BMI)
[2] Post- Hoc tests (LSD)

Table 2. BMI (means and 95% CL) and comparisons between different physical activity frequency groups among girls at age 16.

		Girls			
Physical activity frequency group	Number of girls (N)	BMI	(95 % CL)	Comparisons between different activity frequency groups[1]	p[2]
Physically inactive	627	22.0	19.9-24.1	Occasionally active Physically active	0.998 0.889
Occasionally active	1487	20.9	20.1-21.7	Physically inactive Physically active	0.998 0.521
Physically active	796	21.5	20.1-23.0	Physically inactive Occasionally active	0.889 0.521
Total	2910	21.3			

[1] one-way anova test (p-values from ln of BMI)
[2]Post- Hoc tests (Tamhane)

APPENDIX 4

Table 3. BMI (means and 95 % CL) and comparisons between different physical activity frequency groups among boys at age 24.

Boys					
Physical activity frequency group	Number of boys (N)	BMI	(95 % CL)	Comparisons between different activity frequency groups[1]	p[2]
Physically inactive	472	24.0	23.6-24.3	Occasionally active	0.556
				Physically active	0.903
Occasionally active	970	23.7	23.5-23.9	Physically inactive	0.556
				Physically active	0.052
Physically active	771	24.0	23.8-24.2	Physically inactive	0.903
				Occasionally active	0.052
Total	2213	23.8			

[1] one-way anova test (p-values from ln of BMI)
[2] Post- Hoc tests (Tamhane)

Table 4. BMI (means and 95 % CL) and comparisons between different physical activity frequency groups among girls at age 24.

Girls					
Physical activity frequency group	Number of girls (N)	BMI	(95 % CL)	Comparisons between different activity frequency groups[1]	p[2]
Physically inactive	572	22.3	21.2-22.6	Occasionally active	0.992
				Physically active	0.989
Occasionally active	1365	22.2	22.0-22.4	Physically inactive	0.992
				Physically active	1.0
Physically active	741	22.2	22.0-22.4	Physically inactive	0.989
				Occasionally active	1.0
Total	2678	22.2			

[1] one-way anova test (p-values from ln of BMI)
[2] Post- Hoc tests (Tamhane

APPENDIX 5/1

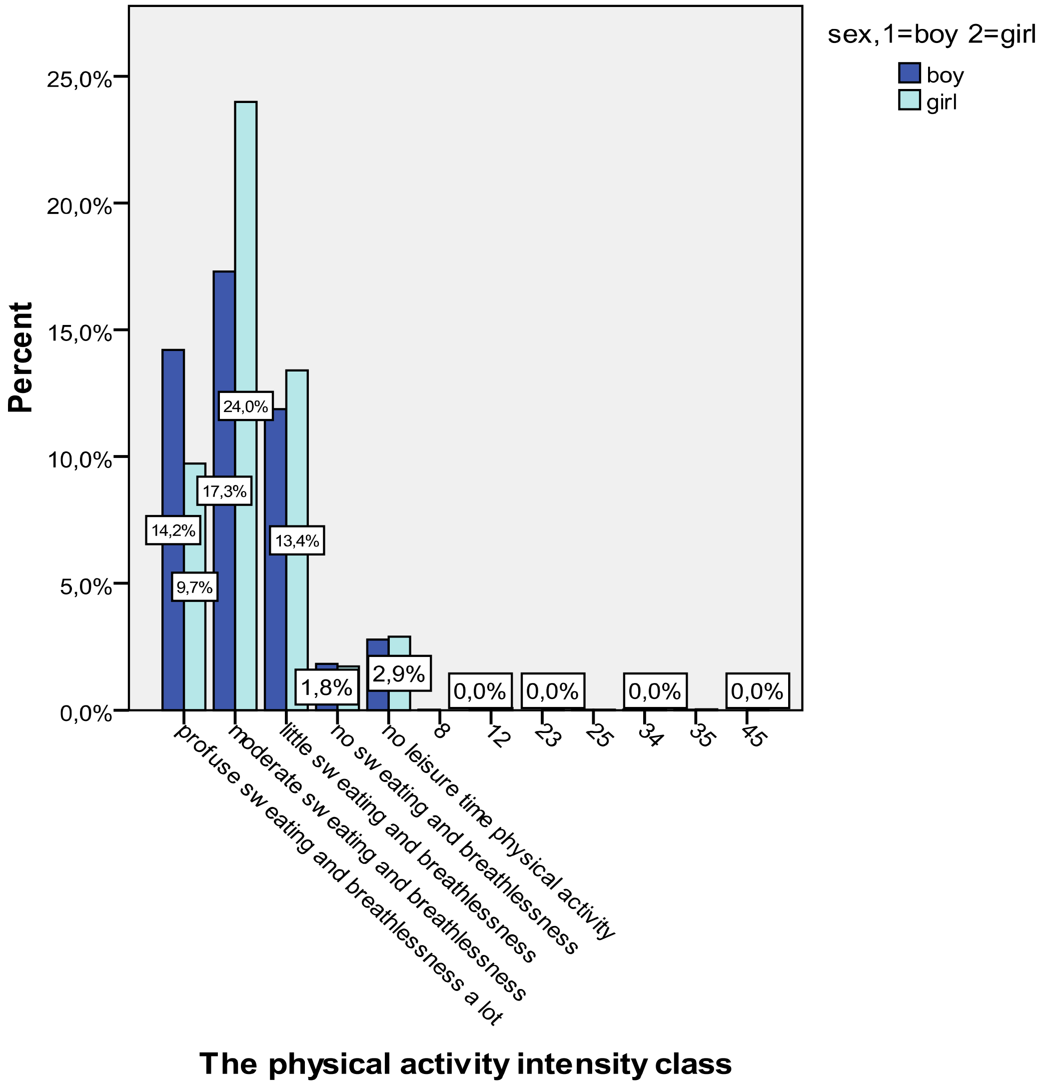

Figure 3. Percentages of boys and girls in different physical activity intensity groups at age 16.

APPENDIX 5/2

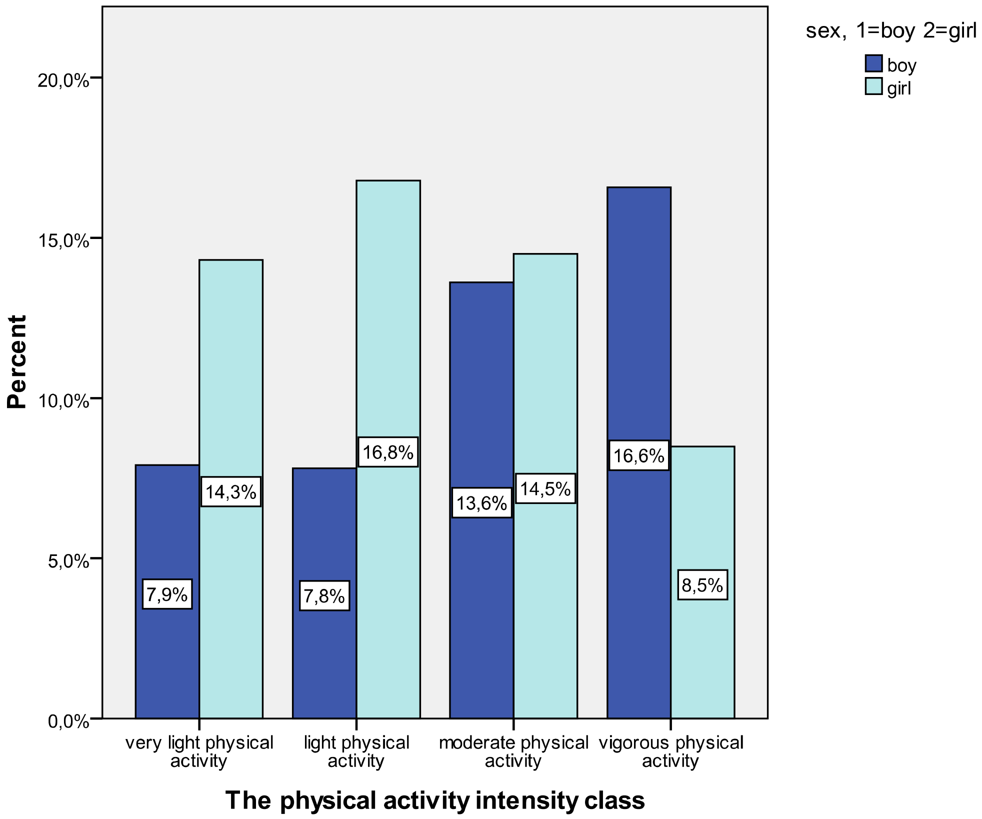

Figure 4. Percentages of boys and girls in different physical activity intensity groups at age 24.

APPENDIX 6

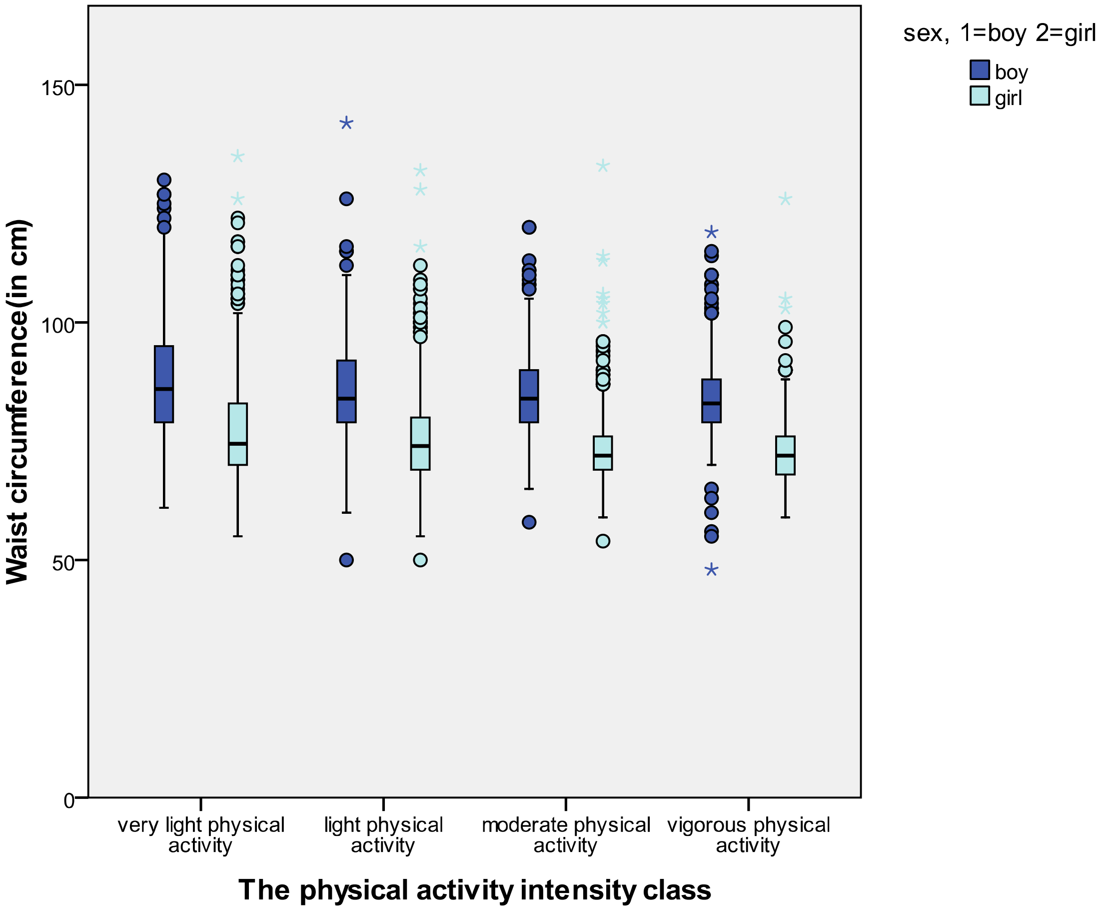

Figure 5. The waist circumference (means and 95 % CL) and SD of different physical activity intensity groups among girls and boys at age 24.

APPENDIX 7

Table 5. Comparisons in the waist circumference (means) of different physical activity intensity and frequency groups among boys at age 24.

Boys			
Physical activity intensity group	N	Frequency groups	The waist circumference[3] (cm)
1= very light physical activity	151	physically inactive	87.0
	133	occasionally active	88.6
	67	physically active	87.5
Total	351		
2= light physical activity	101	physically inactive	86.3
	172	occasionally active	86.4
	85	physically active	85.4
Total	358		
3= moderate physical activity	101	physically inactive	85.8
	305	occasionally active	84.5
	201	physically active	84.5
Total	607		
4= vigorous physical activity	79	physically inactive	83.7
	289	occasionally active	83.9
	377	physically active	83.9
Total	745		

N=number of subjects [3]2-way anova test

Table 6. Comparisons in the waist circumference (means) between different physical activity intensity and frequency groups among girls at age 24.

Girls			
Physical activity intensity group	N	Frequency groups	The waist circumference[3] (cm)
1= very light physical activity	208	physically inactive	78.1
	310	occasionally active	77.6
	124	physically active	76.5
Total	642		
2= light physical activity	169	physically inactive	74.7
	400	occasionally active	75.6
	202	physically active	75.5
Total	771		
3= moderate physical activity	109	physically inactive	73.3
	375	occasionally active	73.2
	197	physically active	74.1
Total	681		
4= vigorous physical activity	36	physically inactive	71.9
	191	occasionally active	72.8
	170	physically active	73.0
Total	397		

N=number of subjects [3]2-way anova test

APPENDIX 8

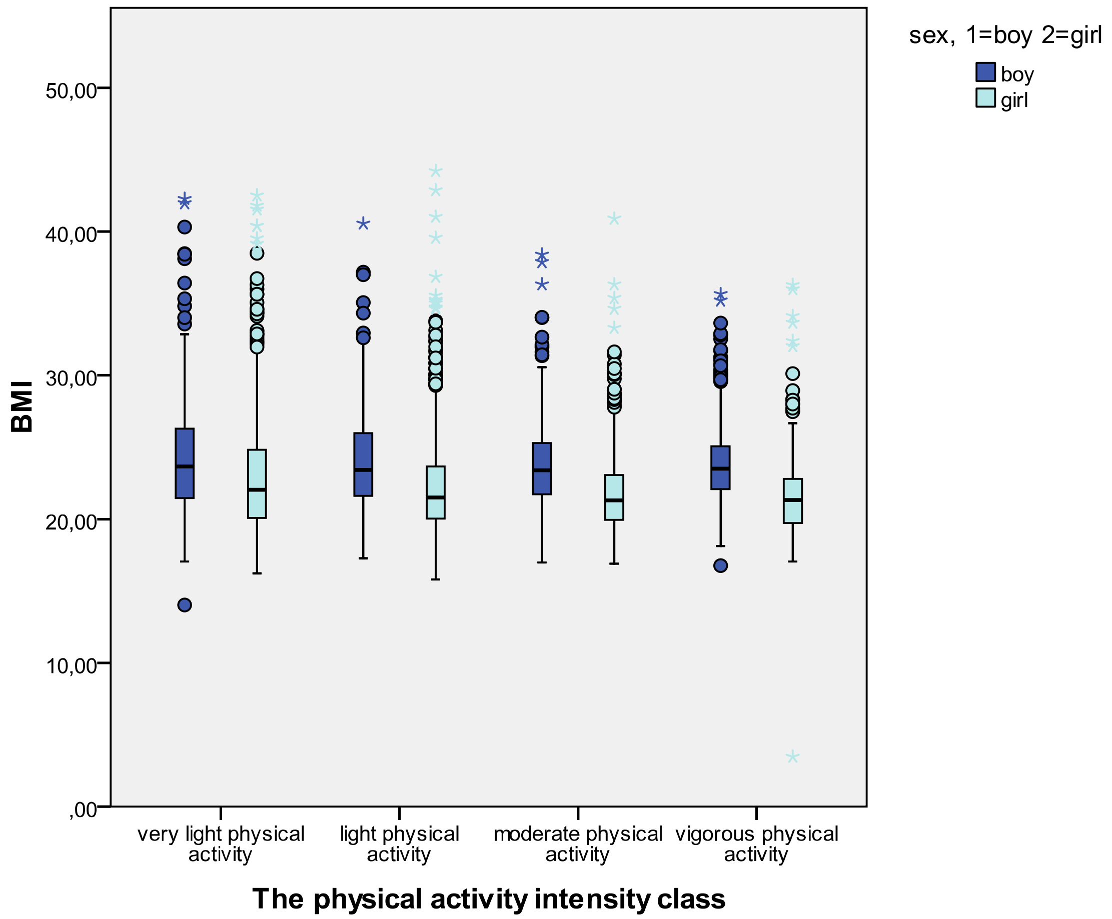

Figure 6. The BMI (means and 95 % CL) and SD of different physical activity intensity groups among girls and boys at age 24.