NINA VUORELA

Body Mass Index, Overweight and Obesity Among Children in Finland

A Retrospective Epidemiological Study in Pirkanmaa District Spanning Over Four Decades

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ACADEMIC DISSERTATION
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for public discussion in the Jarmo Visakorpi Auditorium,
of the Arvo Building, Lääkärinkatu 1, Tampere,
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UNIVERSITY OF TAMPERE

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A Retrospective Epidemiological Study in Pirkanmaa District Spanning Over Four Decades

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To my beloved family

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Appendix 1. Studies reporting the prevalence of overweight and obesity in children. Overweight and obesity defined primary by the International Obesity Task Force criteria (IOTF). 89

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List of Original Publications

This dissertation is based on original publications referred in text by their Roman numerals (I–IV):

I Vuorela N, Saha MT, Salo M (2009). Prevalence of overweight and obesity in 5- and 12-year-old Finnish children in 1986 and 2006. Acta Paediatr 98: 507–512.

II Vuorela N, Saha MT, Salo MK (2011). Change in prevalence of overweight and obesity in Finnish children – comparison between 1974 and 2001. Acta Paediatr 100: 109–115.

III Vuorela N, Saha MT, Salo MK (2011). Toddlers get slimmer while adolescents get fatter – BMI distribution in five birth cohorts from four decades in Finland. Acta Paediatr 100: 570–577.

IV Vuorela N, Saha MT, Salo MK (2010). Parents underestimate their child's overweight. Acta Paediatr 99: 1374–1379.

In addition, some unpublished data is presented.

Abbreviations

AHLS	Adolescent Health and Lifestyle Survey
BIA	Bioelectrical impedance analysis
BMI	Body mass index, kg/m^2
BMI SDS	Body mass index Standard Deviation Score
CDC	the US Centers for Disease Control and Prevention
CRF	Cardiorespiratory fitness
CT	Computed tomography
DEXA	Dual energy x-ray absorptiometry
E%	Daily energy intake
HBSC	Health Behavior in School-aged Children Study
IOTF	International Obesity Task Force
MC4R	Melanocortin 4 receptor
MRI	Magnetic resonance imaging
POMC	Pro-opiomelanocortin
SD	Standard deviation
SES	Socioeconomic status
SF	Skinfold thickness
STRIP	Special Turku Coronary Risk Factor Intervention Project for Children
TCOS	Tampere Children's Obesity Study
WC	Waist circumference
WHR	Weight-for-height ratio
WHTR	Waist to height ratio

Abstract

Body mass index, overweight and obesity among children in Finland

Increasing prevalence of overweight and obesity in childhood has been reported worldwide. The prevalence figures vary; approximately 30% in the USA and the Mediterranean countries, 20% in other parts of Europe with lower rates, under 10%, in Africa and Asia. The aims of present studies were to evaluate the secular trends in BMI distribution and the prevalence of overweight and obesity of children in birth cohorts from four decades in Pirkanmaa district, Finland. The ability of parents to assess the weight class of their children was also analysed.

The first part of this Tampere Children's Obesity Study (TCOS) consists of three retrospective studies of children representing birth cohorts from years 1974, 1981, 1991, 1995 and 2001. Studies I and II were epidemiological studies of the prevalence of overweight and obesity in 2- to 15-year-old children. Study III was a longitudinal growth study from birth to the age of 15 years. The second part of the TCO study (Study IV) was a cross-sectional study of 5- and 11- to 12-year-old children. The study was based on clinical examination of these children and the analysis of their parents' ability to perceive their children's weight status. Most of the data collected from health records and the children studied were from the city of Tampere, and the rest from three rural municipalities in the same region: Virrat, Vilppula and Ruovesi. Data was analysed mainly by cross-sectional methods, additional analyses of growth trends between birth cohorts were performed utilizing longitudinal methods.

Difference in the growth of the children in the five birth cohorts began to emerge starting from the age of one year. Instead, changes in the mean BMI of newborns or in 0.5-year-old children between birth cohorts were not obvious in the longitudinal analysis. During the past four decades, in contrast to the obesity epidemic, the entire BMI distribution of toddlers has shifted to a lower level and toddlers have become slimmer. The negative slope of BMI was significantly steeper in later birth cohorts than in birth cohort 1974 in 1- to 5-year-old children. Instead, no marked change

was seen in BMI distribution or the prevalence of overweight and obesity at the age of 5 years. After 5 years of age the slope turned positive and mean BMI increased more in other birth cohorts than in birth cohort 1974, except in birth cohort 1995 in girls. Getting closer to puberty the BMI distribution started to skew to the right. In teenagers the upper parts of BMI distribution have risen to higher levels while lower BMI percentiles have remained quite stable. Young adolescents, especially boys, have become taller and heavier.

Overweight seems to be more common in children living in rural than in urban areas. The rural vs. urban difference was greater in children over 5 years than at younger ages.

The falling BMI seen in toddlers might indicate that the age of adiposity rebound now occurs earlier. Furthermore, obesity in early childhood seems to track to teenage years as obesity at the age of 2 years implies a high probability for overweight and obesity at the age of 15 years. Accurate perception of the weight class of their children is difficult for parents. Most parents of 5-year-old children and every second parent of 11-year-old children underestimated the overweight of their children

An obesity prevention programme is needed in public health and education should start early in childhood. The skills of health care professionals are needed to help parents to build up a realistic perception of their child`s weight status.

Tiivistelmä

Ylipaino, lihavuus ja BMI suomalaisilla lapsilla

Lasten ylipainon ja lihavuuden yleisyyden on raportoitu lisääntyneen maailmanlaajuisesti. Yleisyysluvut vaihtelevat; noin 30 % USA:ssa ja Välimeren maissa, 20 % muissa Euroopan osissa ja vähemmän, alle 10 %, Afrikassa ja Aasiassa. Tämän väitöskirjatyön tutkimusten tavoite oli selvittää lasten painoindeksijakauman (BMI, kg/m²) sekä ylipainon ja lihavuuden esiintyvyyden ajallisia muutoksia neljän viimeisen vuosikymmenen ajan Pirkanmaan alueella. Myös vanhempien kykyä arvioida lastensa painoluokka analysoitiin.

Ensimmäinen osa Tampereen lasten lihavuustutkimuksesta koostui kolmesta retrospektiivisestä tutkimuksesta koskien syntymäkohorttien 1974, 1981, 1991, 1995 ja 2001 lapsia. Tutkimukset I ja II olivat epidemiologisia tutkimuksia ylipainon ja lihavuuden yleisyydestä 2–15-vuotiailla lapsilla. Tutkimus III oli lasten kasvun pitkittäistutkimus syntymästä 15 vuoden ikään asti. Toinen osa Tampereen lasten lihavuustutkimuksesta (tutkimus IV) oli poikittaistutkimus 5- ja 11–12-vuotiaista lapsista. Tutkimusaineisto perustui lasten kliiniseen tutkimukseen, jonka tuloksia verrattiin vanhempien arvioon lapsensa painosta. Suurin osa terveyskertomusten tiedoista ja tutkituista lapsista oli Tampereen kaupungista, loput Virroilta, Vilppulasta ja Ruovedeltä. Kasvutiedot analysoitiin pääasiassa poikittaismetodeilla, lisäksi syntymäkohorttien välisten kasvutrendien analysointiin käytettiin pitkittäismetodeja.

Erot lasten kasvussa viiden eri syntymäkohortin välillä alkoivat erottumaan yhden ikävuoden iässä. Sen sijaan vastasyntyneiden tai puolen vuoden ikäisten lasten BMI keskiarvon muutokset syntymäkohorttien välillä eivät olleet ilmiselviä pitkittäisanalyysien perusteella. Viimeisten neljän vuosikymmenen aikana taaperoikäisten BMI jakauma on siirtynyt alemmalle tasolle ja lapset ovat hoikistuneet. BMI:n negatiivinen kulmakerroin oli merkittävästi suurempi myöhemmissä syntymäkohorteissa kuin 1974 syntymäkohortissa 1–5-vuotiailla lapsilla. Sen sijaan 5-vuotiaiden ikäryhmässä BMI jakaumassa ei ole tapahtunut merkittäviä muutoksia ja

ylipainon ja lihavuuden yleisyys on säilynyt vakaana. Viiden ikävuoden jälkeen kulmakertoimet muuttuivat positiivisiksi ja kasvoivat enemmän muissa syntymäkohorteissa kuin 1974 syntymäkohortissa, paitsi tyttöjen 1995 syntymäkohortissa. Murrosiän lähestyessä BMI jakauma on alkanut vinoutua oikealle. Teini-ikäisillä BMI jakauman yläosa on noussut korkeammalle tasolle viimeisten vuosikymmenien aikana kun taas alemmissa persentiileissä ei näy merkittäviä muutoksia. Nuorista, erityisesti pojista, on kasvanut pidempiä ja painavampia painoindeksillä arvioituna.

Ylipaino on maaseudun lapsilla yleisempää kuin kaupunkilaisilla. Ero maaseudun ja kaupungin välillä oli suurempi yli 5-vuotiailla lapsilla kuin nuoremmilla lapsilla.

Painoindeksin pieneneminen taaperoikäisillä ajan kuluessa voi viitata siihen, että normaaliin kasvuun liittyvä painoindeksin palauttava nousu (adiposity rebound) on saattanut varhaistua. Varhaislapsuuden lihavuudella on taipumus jatkua teini-ikään. Vanhempien on vaikeaa arvioida lapsen painoluokka. Useimmat 5-vuotiaiden lasten vanhemmista ja joka toinen 11-vuotiaiden lasten vanhemmista aliarvioivat lapsensa ylipainon.

Terveydenhuoltoon tarvitaan lihavuuden ehkäisyohjelma ja ohjaus olisi suositeltavaa aloittaa varhaislapsuudessa. Terveydenhuoltohenkilöstön taitoa tarvitaan auttamaan vanhempia rakentamaan realistinen käsitys oman lapsensa koosta.

1 Introduction

Overweight and obesity in childhood have been reported to be a worldwide epidemic in recent decades (Lobstein and Frelut 2003, Wang and Lobstein 2006, Wang and Beydoun 2007). In Finland overweight has increased 3- to 4-fold in adolescents in the past 30 years (Kautiainen et al. 2009). Recent studies in several countries have reported that this obesity trend seems to be levelling off (Sundblom et al. 2008, Sjöberg et al. 2008, Ogden et al. 2008, Ekblom et al. 2009, Peneau et al. 2009, Olds et al. 2010, Bluher et al. 2010, Aeberli et al. 2010).

Childhood obesity is a significant public health concern. Overweight and obesity in childhood increase the risk of comorbidity and persistent obesity in adulthood (Must and Strauss 1999, Laitinen et al. 2001, Janssen et al. 2005, Neovius et al. 2008). Nor should the consequences of heavy economic burden be underestimated, as high BMI has been shown to be associated with elevated risk of disability pension and early loss of productive years (Neovius et al. 2008).

People assess their body size by comparing themselves with others. While overweight and obesity have become more common, adolescents tend to perceive themselves as not being overweight (Kaltiala-Heino et al. 2003). On the other hand, lifestyle interventions may be impaired if parents fail to recognize the overweight of their children or themselves. Several international studies have reported high rates in parents' misperceptions of their child's overweight status, ranging from 6.2% to 73% (Parry et al. 2008).

It is important to follow secular trends of overweight and obesity nationally in Finnish children. Following obesity prevalence figures in different age groups and regions would help to focus the resources of obesity prevention work and the cost-effectiveness of programme would be observable. International comparison is possible by using commonly accepted definitions of overweight and obesity. Furthermore, it is advisable for obesity prevention and treatment to analyse how accurately Finnish parents assess their children's weight class.

2 Review of the Literature

2.1 Definition of obesity

Obesity is usually defined as a medical condition where excess of body fat is associated with impaired health (WHO 2000, Haslam and James 2005).

2.2 Assessment of body composition in a child

Growth in children is followed to detect illnesses or nutritional and social disorders. The assessment of the status of a child's growth and development is based on periodical health examinations in well-baby clinics and in school health services. To assess the current status of any child age related physiological variations in body composition during the growth period need to be taken into account (Maynard et al. 2001).

Simple methods for measuring adiposity

The clinical assessment of a child's status is based on auxological methods; measurements of weight and height. These measurements are simple, cheap and non-invasive. However, removal of shoes and clothing is required for accurate measuring. The height of children should be measured with an accurate measuring device while the child is standing upright with the head directly forward and fully extended against a wall (Grimberg and Lifshitz 2007). In infants and toddlers the measure of length is taken having the child lying supine on a measuring board. Two people are needed to measure the child properly. It is important to calibrate the measuring devices and scales. The child's weight and growth patterns are estimated by plotting the results of weight and height measurements on age and gender specific national growth charts and comparing them with previous measurements and reference standards.

Body mass index (BMI), a measure of body weight relative to height (kg/m^2), is a standard method for assessing the body shape and the average level of adiposity in children (Rolland-Cachera et al. 1982, Dietz and Bellizzi 1999, Mei et al. 2002). BMI shows age-related variation. During the first year of life BMI increases and adiposity is related to the increase in the size of the adipocytes (Rolland-Cachera et al. 1984). After that toddlers slim and adipocytes remain stable (Rolland-Cachera et al. 1984). The second rise in adiposity follows between 3 and 7 years of age, when fat cells start to increase in size and number. Thus the calculated BMI increases linearly. This rise continues to adulthood (Rolland-Cachera et al. 1984). The cut-off values for under and overweight are based on age, since the body composition of children varies with age (Rolland-Cachera et al. 1982). BMI is a suitable index for clinical use since weight and height are easy to measure and retrieve. Although BMI correlates to body fat, it does not distinguish between fat and lean mass (Dietz and Bellizzi 1999, Maynard et al. 2001). Furthermore, BMI does not give information of body fat distribution. However, BMI has been deemed a good parameter in estimating the risk for metabolic syndrome and cardiovascular diseases (Freedman et al. 2001, Maffeis et al. 2001, Maffeis et al. 2008, Zimmet et al. 2007).

Since centralized or upper body fat carries an increased risk for metabolic complications it is essential to assess obesity and evaluate body fat distribution. A measurement of waist circumference (WC) serves well as an index of central adiposity in children (Taylor et al. 2000). WC measurement could be even more sensitive than BMI alone in estimating health consequences (Maffeis et al. 2001, Maffeis et al. 2008, Zimmet et al. 2007). Furthermore, it is practical, safe, easy and inexpensive. WC increases linearly with growth and girls have lower WC than boys (McCarthy and Ashwell 2006). Age and gender-specific WC reference values are recommended for the assessment of mid-section obesity in children. Children with a WC above the 90th percentile are considered more likely to have multiple risk factors for cardiovascular disease than those with a WC below this level (Maffeis et al. 2001, Maffeis et al. 2008, Zimmet et al. 2007). However, the lack of specific guidance for measuring WC properly has led to incomplete use of WC in routine clinical work (Barlow et al. 2007).

The lack of population specific WC reference values has necessitated the use of WC in conjunction with height (waist to height ratio (WHTR)). This index of proportionality shows whether the amount of upper body fat accumulation in relation to height is appropriate (McCarthy and Ashwell 2006). The cut-off value of 0.5 is recommended to differentiate low (≤0.5) WHTR from high (>0.5) WHTR (McCarthy and Ashwell 2006). Both WC and WHTR are valuable in detecting overweight children with a higher likelihood of having metabolic and cardiovascular risks (Maffeis et al. 2008, Kahn et al. 2005). However, there is no compelling evidence for the use WC or WHTR in preference to the use of national BMI percentiles in obesity definitions based on high BMI for age (Reilly et al. 2010).

More accurate information on fat mass can be obtained by measuring skinfold thicknesses (SF) (Paineau et al. 2008). However, BMI has been considered to be at least as accurate as SF in identifying children who are at metabolic risk (Freedman et al. 2009). SF measurements are performed with a caliper, and usually measured at triceptal, sub-scapular and supra-iliac sites. These measurements require observers with careful training and skills. Population-specific reference is also required. The limitations of SF measurements for clinical use are the need for careful training and poor reproducibility of the results (Paineau et al. 2008, Freedman et al. 2009).

Additional tools for measuring adiposity

Additional tools may offer better assessment of adiposity with greater accuracy when compared to the simpler methods. However, these methods have limited applicability in routine clinical use or when screening large populations since they are expensive, special laboratory conditions are needed and availability is limited. Primarily laboratory methods are useful tools for small studies when the number of measurements needed is limited.

Dual energy x-ray absorptiometry (DEXA) is based on variable absorption of x-ray in different tissues. With a small dose of ionizing radiation DEXA directly provides data on fat mass, fat-free mass, bone mineral content and thereby percentage body fat. DEXA is a relatively accurate technique for the assessment of body composition, but reference data is needed (Wells and Fewtrell 2006, L'Abee et al. 2010). DEXA is a suitable method for over 4-year-old children and it is safe since the amount of radiation exposure is comparable to the low levels of background radiation (Wells et al. 2010). Scanning of severely obese people may, however, be challenging (Wells and Fewtrell 2006, Wells et al. 2010).

Bioelectrical impedance analysis (BIA) is a test where a harmless electrical current is passed through the body. By measuring the flow electricity, body fat percent can be estimated. The percentage fat mass measured with BIA has been shown to be slightly lower than when measured by DEXA (L'Abee et al. 2010). The disadvantage of this method is the need for special equipment and population-specific equation (Paineau et al. 2008, Mast et al. 2002).

In underwater weighing (hydrodensitometry) the weight of the subject is divided by the volume of water displaced by the subject when immersed in water and corrected for residual air in the lungs. The estimation of the body composition is based on the assumed densities of fat mass and fat-free mass. Hydrodensitometry correlates well with DEXA in assessing body composition (Lockner et al. 2000). The limitations of this method include the need for immersion requiring good co-operation. Additionally, a correction calculation for the residual lung volume is needed (Lockner et al. 2000). Therefore hydrodensitometry may be inconvenient as a reference method for children (Lockner et al. 2000).

Air displacement plethysmograph is more comfortable since air is used instead of water in displacement of body volume. Air displacement plethysmograph and DEXA have been shown to have strong correlation although the former method may underestimate the body fat (Lockner et al. 2000, Elberg et al. 2004).

Isotope dilution method is based on the estimation of liquid in body composition and dilution of isotope. Deterium dilution could estimate whole body lean mass if the hydration status of the child is normal (Wells and Fewtrell 2006). A limitation for the use of this method is the variation of water concentration in children (Wells and Fewtrell 2006).

Magnetic resonance imaging (MRI) is superior to other techniques for estimating regional body composition and intra-abdominal adipose tissue (Wells and Fewtrell 2006). Computed tomography (CT) reveals abdominal fat mass as well, but the radiation exposure has to be considered (Yu et al. 2010).

2.3 Classification of overweight and obesity

BMI is widely accepted in the definition of obesity and overweight. Adults have health-based BMI classification for overweight and obesity and BMI cut-off values are <18.5 for underweight, 18.5–24.9 for normal weight, 25.0–29.9 for overweight and >30 for obesity (WHO 2000). In children there is no single BMI value corresponding to overweight or obesity, since BMI varies with age. Furthermore no evidence-based universally accepted classification exists distinguishing normal and unhealthy levels of adiposity. Mostly overweight and obesity are defined with acceptable accuracy at the upper end of the BMI distribution (eg. above 85^{th} and 95^{th} percentiles for age and gender) (Krebs et al. 2007). Another statistical definition is to standardize age-specific BMI percentiles to BMI Standard Deviation Scores (SDS) or BMI Z-scores by mathematical transformation (Krebs et al. 2007). An individual's BMI scores quantify the distance (SD units) above or below the BMI median of a reference population (whether national or international) (Krebs et al. 2007).

The BMI cut-off point reference of the International Obesity Task Force (IOTF) and the US Centers for Disease Control and Prevention (CDC) are widely accepted for classifying overweight and obesity in children (Kuczmarski et al. 2002, Cole 2000). IOTF reference values for 2- to 18-year-old children have been obtained by averaging six nationally representative cross-sectional samples (Brazil, Hong Kong, the Netherlands, Singapore, the United Kingdom and the United States) to BMI percentile curves that were linked to the adult cut-off points for overweight (BMI >25 kg/m²) and obesity (BMI >30 kg/m²) at the age of 18 years (Cole 2000). The CDC reference is preferred to define growth of US children (Kuczmarski et al. 2002). These CDC references are based on nationally representative surveys conducted over the last three decades (Kuczmarski et al. 2002). Accordingly, the CDC references define overweight in children aged from 2 to 19 years as the 85th to 95th percentile of BMI-for-age. Obesity is defined as the 95th percentile or greater for BMI-for-age (Kuczmarski et al. 2002). For children under two years of age the weight-for-recumbent length percentiles are used and overweight is defined as being over the 95th percentile (Kuczmarski et al. 2002). Both the CDC and IOTF BMI cut-off points have been shown to be strong predictors of obesity and coronary heart disease risk factors in young adulthood (Janssen et al. 2005).

The WHO has issued growth standards showing children's growth under optimal conditions and recommended universal use of these standards (WHO 2006). These growth charts are based on growth studies in six countries (Brazil, Ghana, India, Norway, Oman and the USA), including only children of high social class breastfed according to recommendations (except Norway and the USA) and of non-smoking mothers. Recent reports have, however, stated that the growth of Belgian and Norwegian children deviates significantly from the WHO growth standards (Juliusson et al. 2010). Discrepancies have moreover been reported between IOTF reference and WHO standard in defining overweight and obesity in preschool aged children (Monasta et al. 2010). However, the use of the WHO growth standard is recommended as a suitable reference for international comparison and a tool for growth monitoring should a local reference be unavailable (Juliusson et al. 2010).

Population-based BMI reference growth curves for children have been published for several countries (Cole et al. 1995, Juliusson et al. 2009, Roelants et al. 2009). These national references may be locally more appropriate for clinical decision-making (Reilly et al. 2010, Juliusson et al. 2010). Traditionally the weight status of Finnish children has been estimated by weight-for-height ratio (WHR) (Sorva et al. 1990). Weight-for-height and BMI-for-age have been reported to correlate similarly with total body fat mass (Mei et al. 2002). According to the Finnish Current Care guidelines overweight cut-off values using WHR are +10% and +20% for children under school-age (under 7 years of age) and at school-age respectively (Child Obesity. Current Care Guideline 2005). The corresponding values for obesity are +20% and

+40% respectively. The first Finnish BMI growth curves were published in 2005 and they are based on the growth of children born between 1954 and 1972. Recently a new BMI growth reference has been published in Finland. These growth charts are based on mixed cross-sectional/longitudinal data of 74 000 healthy subjects aged 0–20 years (born 1983–2008) (Saari et al. 2010). The use of age adjusted BMI growth charts could detect adiposity more sensitively than weight-for-height.

2.4 Origin of obesity

Obesity is a complex disorder influenced by the interaction of genetic (endogenous) and environmental (exogenous) factors. Childhood has been suggested to include certain critical periods of increased susceptibility for the development of obesity (Dietz 1994). Obesity during these periods increases the risk for persistent obesity and its complications (Dietz 1994).

Genetic factors

Obesity seems to run in families. Twin studies have demonstrated how genetic factors play a significant role, 50–90% of the variance leading to individual differences in BMI (Maes et al. 1997). Furthermore the weighted mean correlations between relatives in BMI have been reported by 0.74 and 0.32 for mono- and dizygotic twins, 0.25 for siblings, 0.19 for parent-offspring pairs, 0.06 for adoptive relatives and 0.12 for spouses (Maes et al. 1997).

The role of genetics is most evident in rare single gene defects associated with marked and early onset obesity. Monogenic obesity is most often due to mutations in genes of the leptin signalling pathways in brain. Disorders in genes coding for leptin, leptin receptor, pro-opiomelanocortin (POMC), pro-hormone convertase 1 and melanocortin 4 receptor (MC4R) are characterised by hyperphagia leading to morbid obesity (Farooqi and O'Rahilly 2000, Farooqi and O'Rahilly 2009).

A well known form of early-onset obesity is a loss of function mutations of the MC4R (Mergen et al. 2001, Farooqi et al. 2000). Further features of the MC4R pheonotype are increased linear growth and bone density (Mergen et al. 2001, Farooqi et al. 2000). Further studies on gene polymorphism have shown that the combined effect of MCR4 and FTO genes increase the susceptibility to developing obesity during childhood (Cauchi et al. 2009).

There are numerous genetic syndromes presenting with obesity, developmental delay and dysmorphic features. Patients with Prader-Willi syndrome are characterized by hyperphagia, developmental delay, short stature, hypotonia and hypogonadism. This syndrome is due to loss of imprinted genes on 15q11–13 (Goldstone et al. 2008). Other genetic syndromes that include obesity are Alström, Bardet-Biedl, Carpenter, Cohen, Fragile X syndrome, Börjeson-Forssman-Lehman syndrome and Albright's hereditary osteodystrophy (Goldstone and Beales 2008).

Environmental factors

Diet

Infant feeding practices and diet have been shown to be closely linked to growth (Robinson and Godfrey 2008). In a review article Owen et al. reported that breastfed subjects had slightly lower mean BMI than formula-fed subjects in later life (Owen et al. 2005). Several eating patterns have been positively associated with overweight status: consumption of sweetened beverages, sweets, meats and low-quality foods (Ludwig et al. 2001, Bowman et al. 2004, Nicklas et al. 2007). Furthermore, an appetitive profile characterized by more food responsiveness and enjoyment of food, more emotional eating and lower responsiveness to internal satiety cues and lower fussiness have been reported to be associated with weight gain in a study of British 7- to 12-year-old children (Webber et al. 2009). Linearly in a Finnish study of school beginners habitual overeating and skipping breakfast were risk factors for obesity (Vanhala et al. 2009). Frequent consumption of food away from home has been linked with excess weight gain, since fast food tends to be high energy-dense and available in large portion sizes (Ritchie et al. 2005). By contrast, according to the epidemiological evidence cereal products, starchy food, fruits, vegetables, nuts, seeds as well as milk and dairy products are not associated with obesity (Summerbell et al. 2009).

Many changes in nutrition have taken place in recent decades in Finland. During the past 30 years both the rate and the duration of breastfeeding have increased; under 10% of 6-month-old children were breastfed in the 1970's compared to every other child in 2005 (Erkkola et al. 2005). At the same time the introduction of solid food has been postponed to later months (Erkkola et al. 2005). Intake of fat has decreased substantially in Finnish children. At the beginning of the 1970s, the proportion of fat in the daily energy intake (E%) was high in children (39–40E%) (Seppänen and Räsänen 2001). In the 1980s a nationwide trend for low fat foods started. Fat intake of toddlers was reported to decrease (33E%) without energy deficiency (Räsänen and Ylönen 1992). In the 1990s, fat intake was shown to decrease to 28–29% of energy intake in infants (Niinikoski et al. 1997). Recently, the diet of 1-year-old children (born in 2003) was reported to consist predominantly of commercial baby foods, potatoes and cereal products and thereafter children start to eat the same food as older children (Kyttälä et al. 2008). The intake of energy among 1- to 2-year-old children is today less than in the late 1980s (Räsänen and Ylönen 1992, Kyttälä et al. 2008). After 2 years of age the consumption of sugar-containing juices, chocolates and sweets has been shown to exceed the recommended level in Finland (Kyttälä et al. 2008).

Changes in the diet of Finnish 11- to 15-year-old children from 1986 to 2002 have been reported by the Health Behavior in School-aged Children Study (HBSC) (Ojala 2004). Accordingly, the consumption of vegetables and fruits has decreased in the last two decades (Ojala 2004). Simultaneously, low daily intake of fresh vegetables has been reported among 7^{th} and 8^{th} grade pupils (28% of boys and 40% of girls respectively) in 2007–2008 (Hoppu et al. 2008). Instead, eating hamburgers, hot dogs and potato crisps and drinking soft drinks at least weekly has become more common among adolescents from 1994 onwards according to the HBSC study (Ojala 2004). Furhermore, a preference for fast food has been shown to start at younger age than in earlier HBSC studies (Ojala 2004). A remarkable thing was that 15-year-old girls seemed to do best with fast food since they ate hamburgers, hot dogs, potato crisps and pizza less frequently than younger girls or 11-, 13- and 15-year-old boys (Ojala 2004). Consistently with preschoolers, the diet of adolescents of both genders has been shown to include more sugar than recommended (<10E%) according to the study entitled Diet Young Finns in 1986 and a study on nutrition and wellbeing of secondary school pupils 2007–2008 (Räsänen et al. 1991, Hoppu et al. 2008). Finally around 40% of the daily energy intake of 7^{th} and 8^{th} grades was derived from snacks, which reflects changes in eating habits (Hoppu et al. 2008).

Physical activity pattern

Young children are active and motivated to spontaneous activity and play. Physical activity declines towards adolescence (Riddoch et al. 2004). Boys are more active than girls across all age groups (Fogelholm et al. 1999, Riddoch et al. 2004, Raustorp et al. 2004, Tammelin et al. 2007, Pahkala et al. 2007). The recommendation for health promoting physical activity is at least two hours for young children (Recommendations for physical activity in early education 2005). Consistently in school-age moderate to vigorous activity is recommended at least one hour daily (Strong et al. 2005, Tammelin and Karvinen 2008).

Low physical activity predisposes to weight gain. Overweight has been shown to be more common in 2- to 13-year-old girls whose leisure-time physical activity was lower than that of their active peers (Pahkala et al. 2010). The role of parents is significant concerning childhood activity patterns since parent inactivity is a strong predictor of child inactivity (Fogelholm et al. 1999). Overweight mothers tend more often to have sedentary daughters than do normal-weight mothers (Pahkala et al. 2010). Active mothers are physically active role models for their children (Pahkala et al. 2007).

A tendency towards increased leisure-time physical activity was reported among 11-, 13- and 15-year-old Finnish schoolchildren from 1986 to 2002. At the same time the number of inactive adolescents had decreased (Vuori et al. 2004). Towards the 2000s, about half of 15- to 16-year-old boys and girls have been shown to meet the recommended level of physical activity and about 10% of adolescents were classified as inactive (Tammelin et al. 2007). The intensity of the physical activity, together with frequency and duration, is also important to consider even in young children. Low active play has been shown to relate to high BMI in girls aged 4–7 years (Sääkslahti et al. 2004).

Physical activity attenuates obesity-related health risk. Accordingly normal, overweight and obese 8-year-old children with high cardiorespiratory fitness (CRF) have been reported to have lower WC and less overall and abdominal fatness than children with low CRF, independent of age, gender and BMI (Stigman et al. 2009).

Information and communication technology

The proliferation of computers, computer games and broadband connections during the last two decades has radically changed children's opportunities to spend leisure time on physically inactive electronic entertainment. A large amount of screen time has been shown to be associated with lower levels of physical activity in adolescents and to account for weight gain (Tammelin et al. 2007, Kautiainen et al. 2005). Consistently higher prevalence of obesity was shown in 2- to 17-year-old children with an average of 4.7 hours per day of screen time (Stettler et al. 2004).

In the 2000s, nearly 50% of Finnish adolescents exceeded the recommended TV viewing time of 2 hours a day (American Academy of Pediatrics 2001, Tammelin et al. 2007). In addition, 35% of boys and 27% of girls were reported to spend eight or more hours a day on sedentary activities (Tammelin et al. 2007).

Sleep

Short sleep duration is less known as a risk factor for weight gain compared with poor diet, physical inactivity or ample screen time. A recent systematic review confirmed that children aged under 10 years with shorter sleep duration than recommended have higher risk for overweight or obesity than their peers who sleep longer (Chen et al. 2008). The inverse association between sleep and obesity seemed to be stronger in boys than girls (Chen et al. 2008). Consistent findings have been reported in Australian 5- to 10-year-old children (Shi et al. 2010).

Socioeconomic and demographic differences

Socioeconomic and demographic characteristics are related to health disparities between individuals and groups of people. The association between socioeconomic status (SES) and obesity is multidimensional. Wide international variation occurs in the distribution and magnitude of social inequality (Due et al. 2009). Overweight and obesity have been shown to have increased markedly in economically developed countries between the 1980's and the 2000's (Wang and Lobstein 2006). On the other hand, those children who live in urban environments and are able to afford a western lifestyle are also at risk of obesity in lower and middle-income countries (Wang and Lobstein 2006). The dominant pattern in Western countries and in the USA is for greater socioeconomic disadvantage to be associated with higher prevalence of overweight and obesity in children (Danielzik et al. 2004, Blomquist and Bergström 2007, Wake et al. 2007, Shrewsbury and Wardle 2008, Sjöberg et al. 2008, Sundblom et al. 2008, Lioret et al. 2009, Stamatakis et al. 2010). By contrast, in Russia and China, children from high-income families have been reported to be more likely to be obese (Wang 2001). In Europe there is also a positive social gradient in some central European countries (Due et al. 2009).

In Finland, SES of families has been shown to be associated with obesity from early life to adulthood (Laitinen and Soivio 2005). According to the study of the northern Finland birth cohort of 1966, overweight and obesity were more common among the offspring of lower social classes (Laitinen and Soivio 2005). Consistently, higher prevalence of overweight has been reported in the AHLS in adolescents from lower SES families compared with the respective reference groups between 1977 and 2005 (Kautiainen et al. 2009). Moreover, adolescents have been shown to be more often to be obese if their fathers were not employed outside home (Kautiainen et al. 2009). Similarly, girls living in non-nuclear families or with unemployed, retired or long-term sick leave mothers were more prone than their peers to develop obesity (Kautiainen et al. 2009). The association between low parental education and childhood obesity has been reported to be strong (Kautiainen et al. 2009, Kestilä et al. 2009). Furthermore, adolescents' low school achievement, attending vocational school or not going to school at all were associated with higher prevalence of overweight (Kautiainen et al. 2009). As expected in adulthood, the prevalence of obesity has been shown to be highest among adults with lowest education (Lahti-Koski et al. 2010).

The association of obesity rates to the place of residence has shown variation in several international reports. Obesity rates were higher in children in rural than in urban areas in Sweden (Ekblom et al. 2004, Neovius et al. 2006, Neovius and Rasmussen 2008). Higher prevalence of overweight and obesity was reported in Swedish military conscripts from rural compared to urban areas. The difference could not be explained by family-related factors such as intelligence test scores, parental education level or socioeconomic position (Neovius and Rasmussen 2008). In the USA overweight and obesity have been shown to increase at the highest rates since the 1980s in children from the rural South (Broyles et al. 2010). Almost half of the 5- to 17-year-old children have been reported to be at least overweight in Bogalusa in 2008/09 (Broyles et al. 2010). Likewise in Russia the prevalence of obesity was higher in rural areas (Wang 2001, Wang and Lobstein 2006). However, in China and Brazil urban children had higher rates of overweight than children living in rural areas (Wang 2001, Wang and Lobstein 2006).

In Finland, there were no marked regional differences in overweight among children in the 1980s (Nuutinen et al. 1991). However, higher prevalence of overweight was seen in adolescents from less urbanized areas compared to cities, among boys from Lapland and Western Finland and among girls from Oulu Province and Eastern Finland than in other geographic areas in recent decades (Kautiainen et al. 2009). According to the AHLS although the prevalence of overweight varied across SES subgroups, the increased prevalence of obesity seems to have affected the adolescent population in Finland over the last two decades (Kautiainen et al. 2009).

Critical periods for the development of overweight and obesity

Obesity may commence early in life or even prenatally (Eriksson et al. 2001). Parental obesity, high birth weight and rapid early weight gain are known risk factors for obesity during foetal life and early infancy (Fogelholm et al. 1999, Stettler et al. 2002, Danielzik et al. 2004, Reilly et al. 2005, Baird et al. 2005, Drenowatz et al. 2010). High maternal BMI before pregnancy has been shown to be a predictor of obesity even in adulthood; the heavier the mother, the heavier the child from birth and up to 31 years of age (Laitinen et al. 2001). Furthermore, early adiposity rebound is associated with higher adiposity levels in later life (Rolland-Cachera et al. 1984, Dietz 1994). Later in adolescence, the risk for the onset of obesity has been shown to be greater in girls than in boys (Dietz 1994).

In a recent Finnish report excessive weight gain started at the age of two to three years, followed by overweight at the age of five in girls and at the age of eight years in boys (Lagström et al. 2008). The age of adiposity rebound was reported to be earlier in children who were overweight at the age of 13 years than normal weight children (3.8 and 5.5 years in girls, 4.3 and 5.6 years in boys respectively) (Lagström et al. 2008). Correspondingly the age of adiposity rebound was 5.8 years in a study of Helsinki birth cohorts of 1934–1944 (Eriksson et al. 2003).

Obesity associated medical disorders

There are some medical disorders which predispose to weight gain. Obesity is associated with endocrine diseases (hypothyroidism, Cushing's syndrome, growth hormone deficiency, hyperinsulinemia and pseudohypoparathyroidism), congenital or acquired hypothalamic disorders and use of drugs affecting appetite regulation (for example anticonvulsant valproic acid). Careful clinical examination is recommended since short stature has been shown to be the most important symptom for endocrine disorder (Reinehr et al. 2007).

2.5 Epidemiology of overweight and obesity in children

Prevalence and trends

Overweight and obesity in childhood have been reported to be a worldwide epidemic in recent decades (Lobstein and Frelut 2003, Wang and Beydoun 2007). The prevalence of overweight and/or obesity has doubled in school-age children in Australia, Brazil, Canada, Chile, Finland, France, Germany, Greece, Japan, the United Kingdom and the USA between the 1970's and the end of 1990's while no increase has been seen in Poland and Russia (Wang and Lobstein 2006). However, the most prominent increase has been observered at the upper end of the BMI distribution indicating increasing numbers of obese individuals (Kautiainen et al. 2002, Ekblom et al. 2004, Eriksson et al. 2005, Werner and Bodin 2007, Wang and Beydoun 2007, Juliusson et al. 2007). Several obesity studies are presented in Appendix 1.

In Europe, there is a north-south gradient in the prevalence of overweight and obesity (Lobstein, Frelut 2003, Pigeot et al. 2009). Accordingly, in pre-school age children, the highest rates of overweight have been reported in the Mediterranean region and the British Isles, while the lowest rates were seen in middle, eastern and northern Europe (Cattaneo et al. 2009). The prevalence rates have been linear in 7- to 11-year-old children, 12–22% in middle and northern Europe, 10–18% in eastern Europe and 27–34% in southern Europe. Furthermore the prevalence of overweight and obesity in preschool age has been estimated to be twice as high in developed countries (11.7%) than in developing countries (6.1%) (de Onis et al. 2010).

In Finland, in a study of Helsinki school health service 3.5% of boys and 3.0% of girls were reportedly obese (weight-for-height over 2 SD) at the beginning of the 1970's (Helve et al. 1971). The corresponding figure was 10% for preschool age children (Kantero 1975). However, obesity was reported more generally in prepubertal children than in other age-groups (Helve et al. 1971). In the 1980's the prevalence of obesity (US90 reference values) was shown to be 6.9% and 17.3% in 6-year-old boys and girls respectively in the Multicenter study "Cardiovascular Risk in Young Finns" (Nuutinen et al. 1991). Correspondingly, 4.8% and 3.3% of 9- to 18-year-old boys and girls were obese (Nuutinen et al. 1991). According to the Multicenter study the prevalence of obesity did not change markedly from 1980 to 1986 while BMI increased from 20.8 to 21.8 kg/m² in a subsample of 15- and 18-year-olds of the same study between 1980 and 1992 (Nuutinen et al. 1991, Porkka et al. 1997). Consistent findings were reported from the study on northern Finland. Accordingly the prevalence of overweight was shown to double and of obesity triple between 1980 and 1992/93 (Laitinen and Soivio 2005). Furthermore in the 2000's, the overall prevalence of overweight was reported as 17.8% and 23.6% in 10-year-old boys and girls in the Special Turku Coronary Risk Factor Intervention Project for Children (STRIP) (Hakanen et al. 2006). According to the AHLS the corresponding prevalence figures were 26.5% and 17.9% in 12-year-old boys and girls and further 25.1% and 12.5% at age the of 18 years (Kautiainen 2009). Thus, the increase in the overall prevalence of overweight has been 2- to 3-fold between the 1970's and the 2000's or between the 1980's and the 2000's in adolescents (Kautiainen et al. 2002, Välimaa and Ojala 2004, Kautiainen et al. 2005, Kautiainen et al. 2009). In the 2000's on average every 10th of young children and 4^{th} of adolescents is at least overweight (Mäki et al. 2010).

Changes in waist circumference

The secular trend of WC gives more detailed information on changes in fat distribution. In a British study of 11 to 16-year-old adolescents WC increased 6.9 cm in boys between 1977 and 1997 and 6.2 cm in girls between 1987 and 1997 (McCarthy et al. 2003). Accordingly in 1997, 28% of boys and 38% of girls exceeded the 91^{st} centile of WC while the corresponding figures had previously been 9% for both genders (McCarthy et al. 2003). Although both BMI and WC increased, the increase in WC was faster (McCarthy et al. 2003). A significant increase in WC was reported in 9-year-old Norwegian children from 1999 to 2005, while no change was seen in mean BMI (Kolle et al. 2009).

2.6 Prevalence of underweight

In Sweden very few or no small changes were seen in lower BMI percentiles (5^{th}, 10^{th}) in 2- to 18-year-old children born between the 1970's and the 1980's (Eriksson et al. 2005, Werner and Bodin 2007). Thus the prevalence of underweight was reported to stay quite stable in 10-year-old Swedish children between 1984 and 2005 in Gothenburg and between 1999 and 2003 in Stockholm County (Sundblom et al. 2008, Sjöberg et al. 2008). However, a tendency of increase in extreme underweight was seen among girls living in Gothenburg (Sjöberg et al. 2008). In Norway the fraction below the 10^{th} percentile of weight-for-height was shown to be almost equal in young children from 1971/75 to 2003/05 (Juliusson et al. 2007). Furthermore in China the 5^{th} BMI percentile was shown to be quite stable in 7- to 18-year-old children between 1995 and 2005 while higher percentiles of the BMI distribution increased rapidly (Zhang and Wang 2010).

In Finland there has been little or no change at the lower (5^{th}, 15^{th}) percentiles and the median in 12- to 18-year-old adolescents from 1977 to 1999 (Kautiainen et al. 2002). Linear findings of the stable 15^{th} percentile have been reported in 13- and 15-year-old children between 1984 and 2002 in the study of HBSC study (Välimaa and Ojala 2004). In younger age weight-for-height has been shown to be lower in 6-month-old to 3-year-old boys and in 6-month-old to 4-year-old girls born between 2003–2004 compared to Finnish growth data from 1959–1971 (Harjunmaa 2009).

2.7 Perception of weight class

Several international studies have reported high rates in parents' misperceptions of their child's overweight status, ranging from 6.2% to 73% (Parry et al. 2008). Instead, parents have been shown to be able to perceive the weight class of their normal weight children correctly (Doolen et al. 2009). Parents' awareness of the overweight or obesity of their child is independent of the child's age (Parry et al. 2008, Doolen et al. 2009). Furthermore, mothers seem to identify overweight in their daughters more correctly than in their sons (Maynard et al. 2003, Manios et al. 2009). The low educational level of parents is a possible risk factor for failure to perceive their offspring's weight class (Baughcum et al. 2000, Genovesi et al. 2005).

People assess their body size by comparing themselves with others. While overweight and obesity have become more common adolescents tend to perceive themselves as not being overweight (Kaltiala-Heino et al. 2003). Measuring waist circumference could diminish the discrepancy between measured and perceived weight class at least in teenage girls (van Vliet et al. 2009). Parents have shown to be more accurate in identifying obesity in teenagers than the teens themselves (Goodman et al. 2000). In adults obese mothers have been reported to quite correctly perceive their own overweight (Baughcum et al. 2000). However, a third of normal weight women have been shown to perceive themselves as overweight (Baughcum et al. 2000). Jeffery et al. reported that 45% of overweight fathers and 40% overweight mothers failed to perceive their own overweight; further, fathers (61%) expressed more unconcern about their weight than mothers (27%) (Jeffery et al. 2005).

2.8 Consequences of childhood obesity

Obesity in childhood should not be underestimated since increasing amount of fat affects the physical and psychosocial health of children and predisposes them to health risks as adults (Must and Strauss 1999). The social and emotional aspects of obesity may reflect on the well-being of children. Obese children have been reported to be more likely to experience low self-esteem and social isolation compared to normal weight children (Dietz 1998, Strauss 2000, Reilly et al. 2003, Strauss and Pollack 2003). Overweight children are known to become targets of early discrimination (Dietz 1998).

Obesity is related to the development of metabolic consequences already in childhood. Cardiovascular risk factors; hyperlipidemia (raised LDL cholesterol and triglycerides, lowered HDL cholesterol), hypertension, insulin resistance and abnormal glucose tolerance have been reported with increased frequency in obese children (Dietz 1998, Must and Strauss 1999).

In a recent Finnish study of the Northern Finland Birth Cohort 1986 the overall prevalence of metabolic syndrome was 3.5% and 1.2% in 16-year-old boys and girls respectively while the corresponding figures were 44.2% and 17.1% in obese adolescents (Pirkola et al. 2008).

Changes in the growth pattern of the child and the time of weight gain may also have an effect on subsequent healthiness in adulthood. Accordingly the study of the Helsinki Birth Cohort showed that poor growth in foetal life and infancy rapid increases in BMI after the age of 2 years, above-average BMI at the age of 5 years and thereafter continuing rise of BMI were risks for subsequent development of type 2 diabetes and coronary heart disease (Barker et al. 2005, Eriksson et al. 2006). Bhargava et al. reported consistently that thinness at around 2 years of age followed by rapid increase in BMI was subsequently associated with an increased risk of impaired glucose tolerance and type 2 diabetes (Bhargava et al. 2004).

Additional obesity associated medical conditions are asthma, sleep apnea, polycystic ovary disease, idiopathic intracranial hypertension, slipped capital epiphyses, Blount's disease, gallstones and non-alcoholic fatty liver (Dietz 1998, Reilly et al. 2003).

Fatness in a child is a risk factor for persistent obesity in childhood and further in adulthood (Must and Strauss 1999, Freedman et al. 2005, Wright et al. 2010). High BMI has been shown to be traceable to childhood as well as there seems to be a tendency for children in the obese category to progress upwards (Fuentes et al. 2003, Ekblom et al. 2004, Wright et al. 2010). According to Laitinen and Sovio (2005) 40–50% of overweight and 70–80% of obese 7-year-old children were still reported to be overweight or obese at age of 16 years. Correspondingly, almost 80% of overweight and obese 7-year-old British children were at least overweight at the age of 11 years (Wright et al. 2010). Furthermore, 60–80% of overweight teens remain at least overweight in their adulthood (Laitinen et al. 2001).

Obesity in childhood is associated with long-term morbidity like cardiovascular illness and mortality in adulthood, even partly independently of adult weight status (Must and Strauss 1999, Reilly et al. 2003, Baker et al. 2007). Furthermore, obesity is associated with heavy economic burden. The influence of obesity status, especially morbid obesity, has an impact on productive costs (Neovius et al. 2008). Accordingly, high BMI has been shown to be associated with elevated risk of disability pension and early loss of productive years (Neovius et al. 2008).

2.9 Secular trends in growth and maturation

Adult height has increased in most European countries by 1–3 cm per decade (Cole 2000, Karlberg 2002). In Finland a secular increase in height was recently reported in children born between 1959–1971 and 1983–2008 leading to an increase in adult height by 1.8 cm in boys and 1.9 cm in girls respectively (Saari et al. 2010). In a recent growth study height has been shown to increase faster after the age of one year in a growth study of 0–4 year-old children born between 2003–2004 compared to Finnish growth data from 1959–1971 (Harjunmaa 2009). At the age of four boys were 1.4 cm and girls 1.0 cm taller than three decades previously. Similar results were seen in earlier studies in Finnish adolescents and Swedish school aged children (Porkka et al. 1997, Kautiainen et al. 2002, Werner and Bodin 2007). Children have also been shown to grow faster and subsequently their pubertal onset has been reported to occur earlier during the last two decades in Europe and the USA (Karlberg 2002, Toppari and Juul 2010). In breast maturation this means 1–2 years and in menarche 0.3–0.6 years earlier development (Toppari and Juul 2010). Although the role of genes is significant in final height and pubertal development, these changes in growth and pubertal development reflect better health, nutrition and affluence in society but possible also changes in environmental compounds (Cole 2000, Karlberg 2002, Toppari and Juul 2010).

Overweight children tend to be taller since excess weight gain is followed by acceleration of height (Dietz 1998). Furthermore, overweight girls have been reported to proceed through puberty faster than normal weight girls (Dietz 1998, Lagström et al. 2008). Concomitantly, early menarche is associated with obesity in adulthood (Laitinen and Soivio 2005).

3 Aims of the Study

The specific aims of Tampere Children's Obesity Study (TCOS) were:

1. to analyse whether the prevalence of overweight and obesity had changed in Finnish birth cohorts from four different decades.
2. to analyse the secular trends in BMI distribution of Finnish children in birth cohorts from four decades.
3. to analyse how accurately Finnish parents could assess the weight class of their children

4 Subjects and Methods

4.1 Study design of the Tampere Children's Obesity Study (TCOS)

Study I: Prevalence of overweight and obesity in 5- and 12-year-old Finnish children in 1986 and 2006

Study II: Change in prevalence of overweight and obesity in Finnish children – comparison between 1974 and 2001

Study III: Toddlers get slimmer while adolescents get fatter – BMI distribution in five birth cohorts from four decades in Finland

Study IV: Parents underestimate their child's overweight

The first part of the TCO study consists of three retrospective studies of children representing birth cohorts from the years 1974, 1981, 1991, 1995 and 2001 (Studies I–III). The anthropometric data of these studies was collected from health records in well baby and school nurse clinics. The main aim was to provide data on the prevalence of overweight and obesity in younger Finnish children, and changes therein over the last three decades using the international BMI cut-off values of Cole et al. (Studies I and II). In Study I, the population sample was expanded to comprise the entire 5- and 12-year-old cohort in urban and three rural populations. In Study II the time and age spans were extended by studying the changes of prevalences of underweight, overweight and obesity in 2-, 5-, 7-, 12- and 15-year-old children utilizing longitudinal data based on the same birth cohorts from four different decades.

The second aim was to study growth (BMI, height and weight) from birth to the age of 15 years analysing longitudinal data based on the same birth cohorts 1974, 1981, 1991, 1995 and 2001 (Study III).

The third aim of the TCO study (Study IV) was to analyse how accurately Finnish parents could assess the weight class of their 5- and 11- to 12-year-old children.

4.2 Subjects

In Studies I–III subjects of the birth cohorts were born in 1974, 1981, 1991, 1995 or 2001. Most of the children studied were from the city of Tampere, and the rest from three rural municipalities in the same region: Virrat, Vilppula and Ruovesi. The anthropometric data of the subjects was collected from all available health records and growth charts from local public health centres. Considering the data from the 1970s to the 1980s, only half of the health records were available. Instead, in the 1990's and the 2000's the study groups represented about 90% of the eligible study localities. All subjects with unclear anthropometric data were excluded from the study.

Study I was a cross-sectional study of the prevalence of overweight and obesity focusing also on the possible geographical differences between urban and rural areas in 2006. The health examination of 5- and 12-year-old children were performed between the ages of 4.5 and 5.5 years (the birth year 1981 or 2001) and between the ages of 10.5 and 13.1 (the birth year 1974, 1994 or 1995), respectively (Table 1).

TABLE 1. Numbers of subjects in Study I

	Tampere			Ruovesi, Vilppula and Virrat		
Birth cohort	Population	Missing growth data	Available growth data	Population	Missing growth data	Available growth data
5-year-old						
1981	1815	943	872	260	177	83
2001	1804	122	1682	178	9	169
12-year-old						
1974	1887	916	971	277	95	182
1995[1]	2083	112	1971	208	17	191

Studies II–III were retrospective longitudinal growth pattern studies on 0- to 15-year-old children from five birth cohorts: 1974 (n=1109), 1981 (n=987), 1991 (n=586), 1995 (n=856) and 2001 (n=766). The children were included provided anthropometric data was available from birth and seven routine health checkups (6 months, 1, 2, 5, 7, 12 and 15 years) (Table 2–3). For data analysis, the age limits were set as follows: 0.5yr: 0.4–0.6yrs, 1yr:0.75–1.25yrs, 2yrs: 1.75–2.5yrs, 5yrs: 4.5–5.5yrs and in school-age 7yrs: 6.5–8.5yrs, 12yrs: 10.5–13.5yrs, 15yrs: 13.5–16.5yrs. The age distribution in each birth cohort was normal. The range of the calendar age at health examinations was 17 days in children under seven years and 39 to 63 days in children over seven years of age.

At the age of 12 years numbers of growth data differed between Study II and Study III (Table 2–3). In the former study only one measurement in the age range of 10.5 years to 13.5 years was accepted. In the latter study there were some subjects with two measurements in the same age range. The number of subjects from rural area is presented separately (Table 3).

TABLE 2. The overall numbers of growth data in the health checkups within age limits by birth cohorts: 1974, 1981, 1991, 1995 and 2001 in Studies II and III

	1974		1981		1991		1995[1]		2001	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Newborn	608	501	576	411	309	277	411	445	404	362
0.5-year-old	606	500	575	411	309	277	410	445	402	362
1-year-old	584	483	570	407	303	273	402	446	400	354
2-year-old	579	474	567	406	304	271	403	444	399	354
5-year-old	521	442	539	381	292	265	399	426	398	360
7-year-old	601	495	564	406	297	267	390	422		
12-year-old	605	496/499	567/584	407/420	305/306	275/276	403	430		
15-year-old	605	488	546	392	304	275				

[1]1995 also includes children born in 1994

TABLE 3. Numbers of growth data in the health checkups within age limits by birth cohorts: 1974, 1981, 1991, 1995 and 2001 in Studies II and III in rural areas

	1974		1981		1991		1995[1]		2001	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Newborn	78	78	60	26	108	86	87	100	87	82
0.5-year-old	77	77	60	26	108	86	87	99	87	82
1-year-old	78	74	59	26	106	85	85	100	87	81
2-year-old	68	73	60	26	106	86	84	99	84	81
5-year-old	65	60	55	24	103	84	86	95	85	82
7-year-old	76	74	55	23	106	83	83	93		
12-year-old	78	72/77	58	26	107	85/86	85	99		
15-year-old	76	72	56	25	105	85				

[1]1995 also includes children born in 1994

The study population in Study IV consisted of 5-year-old children (boys n=166, girls n=144) and 11- to 12-year old pupils (boys n=140, girls n=156) of a comprehensive school in the southern part of the city of Tampere and in three rural municipalities: Virrat, Vilppula and Ruovesi (Table 4). Altogether 629 children and their parents participated representing 47% of the total invited. The written consent was given mostly by mothers (96%) and the nurses requested the child's spoken consent. Five children were excluded because the consent was returned without the signature of the parent. A further 18 replies were excluded (one 5-year-old boy, ten 11-year-old boys and seven 11-year-old girls), because the parent in the questionnaire had chosen both normal and overweight categories for their child.

TABLE 4. Numbers of study cohort and participants in Study IV

	Study cohort in southern part of Tampere, Ruovesi, Vilppula and Virrat		
	Population	Excluded participants	Participants
5-year-old			
2001	725	4	310
11-year-old			
1995[1]	649	20	296

[1]1995 also includes children born in 1994

4.3 Methods

The public health nurses had measured the lightly clad and barefoot children with standard scales and stadiometers on their routine visits for health examination in well-baby and school health clinics. The weight had been noted to the nearest 0.1 kilograms and the height to the nearest millimeter. In addition, in Study IV the WC was measured midway between the lowest rib and the iliac crest and was noted to the nearest 0.1 cm. The pubertal stage was assessed according to the Tanner classification, but simplified for nurses into two categories: prepubertal (Tanner stage 1) and pubertal (Tanner stage 2 or above) (Tanner and Whitehouse 1976). The presence of acanthosis nigricans, if any, was noted. In Study IV the nurses also measured the height and weight of the parents (indoor clothes and without shoes) on their visit to the well baby clinic. The ethnic origin of the parents was noted.

Decimal age and BMI (weight (kg) / height (m^2)) were calculated. In Studies I, II and IV normal weight, overweight and obesity were defined by International Obesity Task Force criteria (Cole 2000). In this classification, underweight was included in normal weight. In Study II the change in the prevalence of underweight was analysed using the definition for thinness presented by Cole et al. (Cole et al. 2007). For the analysis of the association between weight classes (underweight, normal weight and obesity) at the age of two years the Finnish classification based on the weight for height ratio and international BMI classifications published by Cole et al. were used (Cole 2000, Sorva et al. 1990). The same methods were utilized for the analyses of children at the age of 15 years. In Study IV the British cut-off points were used for WC classification and the 90^{th} percentile was chosen for the cut as for abdominal obesity (McCarthy et al. 2001). The waist circumference to height ratio was calculated and a cut-off of 0.5 was used to differentiate low (<0.5) WHTR from high (>0.5) WHTR (Maffeis et al. 2001, McCarthy and Ashwell 2006). The BMI of the parents was calculated (kg/m^2) and adults' cut-off points of 25 kg/m^2 for overweight and 30 kg/m^2 for obesity were used for classification.

In Study IV the parents and older children completed a questionnaire. The parents' perception of the weight class of their children was elicited (do you consider your child underweight, normal weight, overweight or obese?). The school-aged children and parents also estimated their own weight class. Furthermore the structure of the family (both parents, single parent etc.), parents' level of education and employment status were asked. Parents' and grandparent's obesity associated consequences (high blood pressure, coronary heart disease, high cholesterol and type 2 diabetes) were elicited. The parents were also asked whether they thought the child should receive treatment for obesity. The backgrounds of the children (n=79) whose parents failed to recognize their child as being overweight were analysed. Explanatory variables examined were the gender and the age group of the child, the number of siblings, parents' BMI category, educational level, employment status and number of adults in family and parents' or grandparents' obesity related diseases all elicited.

4.4 Statistical analyses

The statistical analyses were performed using SPSS 15.0 and 16.0 (Statistical Package for the Social Sciences, versions 15 and 16) and statistical software R. The p-values <.05 were considered statistically significant.

In Studies I and II differences in the nominal variables were analysed using the chi-square test. In Study II binary logistic regression was used to test the influence of temporal change and place of residence on being overweight (including obesity). Birth cohort 1974 and urban place of residence were used as a reference class, and tests were performed separately for both genders.

In Study III the differences in the distributions between birth cohorts the 15^{th}, 50^{th} and 85^{th} percentiles of BMI, and the 50^{th} percentile of height and weight at the 8 age points were analysed with Pearson's chi-square test. Analysis of variance was used to focus the point of change in the mean BMI between birth cohorts. Linear mixed models for longitudinal data based on maximum likelihood estimation were used to analyse growth data. The influence of age, birth cohort, gender and residence on changes in BMI among children were studied. The likelihood ratio test was used to compare two models and choose the significant terms. Age, birth cohort, gender and residence were included in all models as a fixed effect. The interactions of these variables were studied.

In Study IV continuous variables were presented as means and SD. Categorical variables were given as percentages. Crosstabulation with Cohen's kappa was used to measure agreement. Explanatory variables associated with misclassification of overweight children as normal weight were analysed by logistic regression modelling.

4.5 Reliability and validity of the data

Completeness of data retrieval varied between birth cohorts in Studies I–III. In the 1970s and 1980s the poor availability of health records was most probably a result of internal migration in Finland; it was not possible to ascertain differences in socioeconomic backgrounds. Furthermore, the difference of the growth data availability between boys (57.3%) and girls (49.2%) could have caused selection bias in the same period. However, it is assumed that moving away is not selective concerning the children's or parents' physical characteristics, and does not compromise the validity of the data from the 1970's and 1980's. In the 1990–2000s growth data was readily available (>90%) on the eligible schools. In Studies II and III the sampling consisted the southern part of Tampere.

In Study I there was also a slight difference in the median ages of both the 5-year-old boys and girls between 1986 and 2006. The median age in 2006 was slightly less (0.1 year = 5.2 weeks) than in the children studied in 1986. In Studies II–III the mean age at the time of health examination differed slightly between the five birth cohorts, the maximum difference being 63 days in the 15-year-old group.

The interpretation of the results of Study IV is limited due to the low participation rate. To define the representativeness of the sample, the BMI percentiles 5, 50 and 95 of the study groups were calculated and compared with the Finnish BMI growth charts (Child Obesity. Current Care Guideline 2005). Lower percentiles were equal to the percentiles of the Finnish growth charts, but the 95th percentile was higher in 5-year-old boys and 11-year-old children linearly with the trend of increasing obesity.

More normal weight mothers and nearly as many fathers than are generally seen in Finland participated in Study IV (Utriainen et al. 2006, Lahti-Koski et al. 2010). Parents who participated had higher educational level than parents on average in Finland (Statistics Finland). Furthermore, mothers of 11-year-old children and all fathers were more likely to be employed than parents in Finland (Statistics Finland).

4.6 Ethics

The study was approved by the City of Tampere Research Permission Committee and the chief physicians of the health centres in the three municipalities.

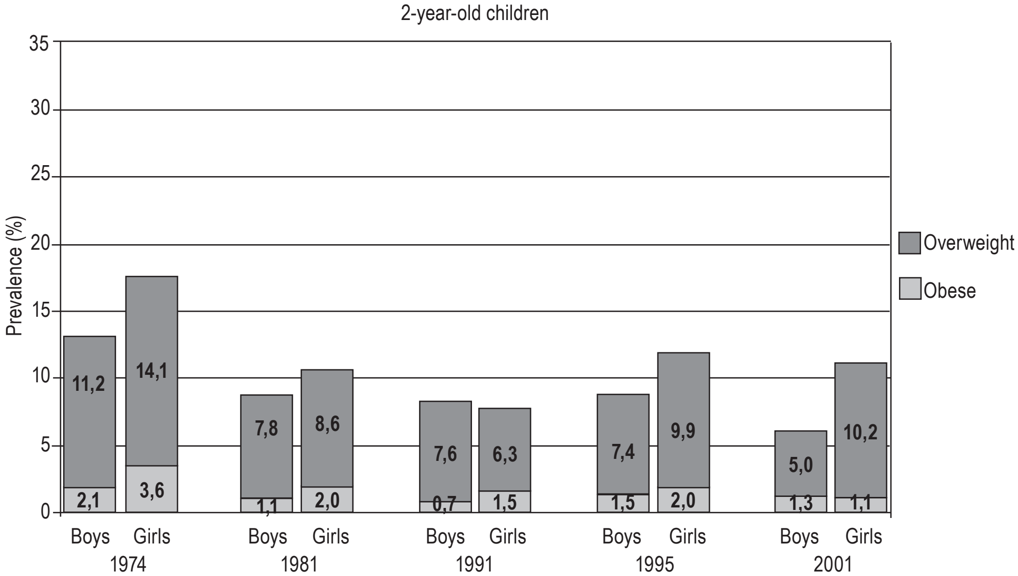
5 Results

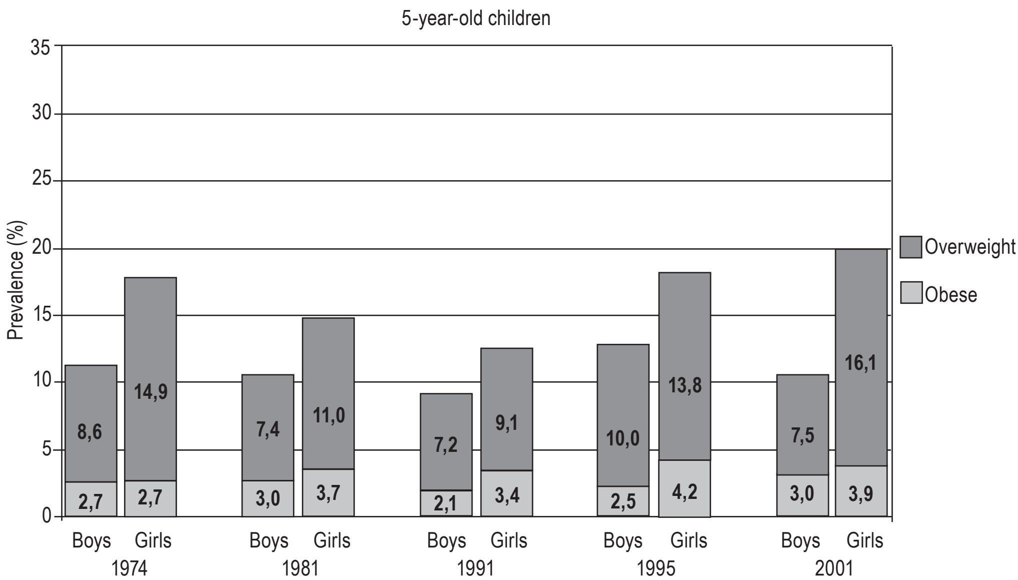
5.1 Prevalence of overweight and obesity

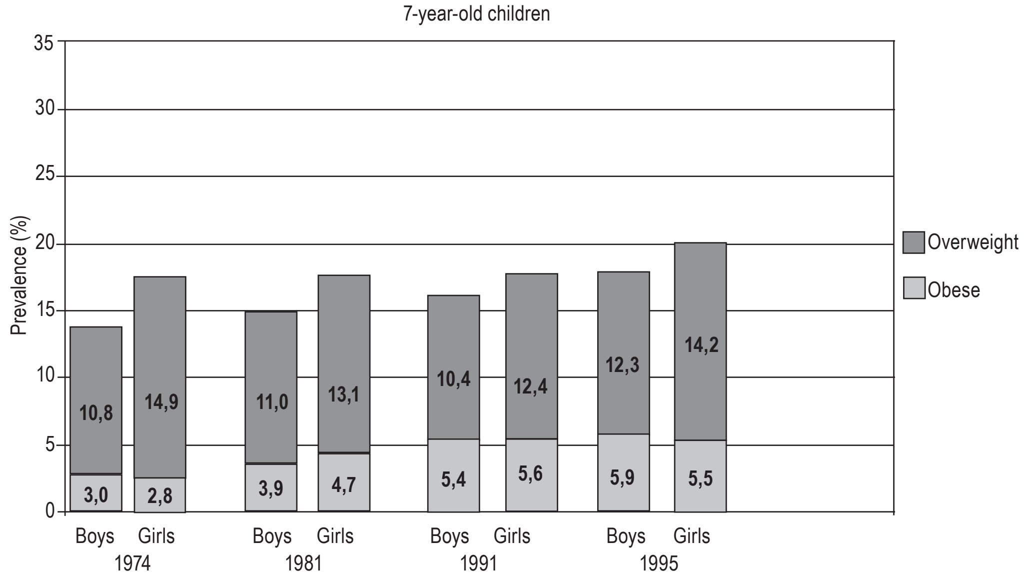
Cross-sectional Study I showed that the prevalence of overweight has remained almost unchanged in 5-year-old children, but has increased 1.8 fold in boys ($p<0.001$) and 1.5 fold in girls ($p=0.008$) aged 12 years between 1986 and 2006. The change of prevalence of overweight and obesity was specified among 2- to 15-year-old birth cohorts 1974, 1981, 1991, 1995 and 2001 are presented in Figures 1–5 (Study II). When comparing birth cohorts from 1974 to 2001, the combined prevalence of overweight and obesity had decreased significantly in 2-year-old boys ($p=0.009$) and girls ($p=0.002$). In 5- and 7-year-old children the combined prevalence of overweight and obesity showed fluctuation, but without significant trends ($p=0.70$ and $p=0.11$ in boys, $p=0.09$ and $p=0.45$ in girls, respectively). However, there was a slight increasing trend of overweight in 5-year-old girls born in the 1990s and later. In 12-year-old children the combined prevalence of overweight and obesity showed a significant increase, $p<0.001$ in boys and $p=0.023$ in girls respectively. The boys gained weight from teenage onwards and the combined prevalence of overweight and obesity increased significantly in 15-year-old boys ($p< 0.001$). No change was seen in 15-year-old girls.

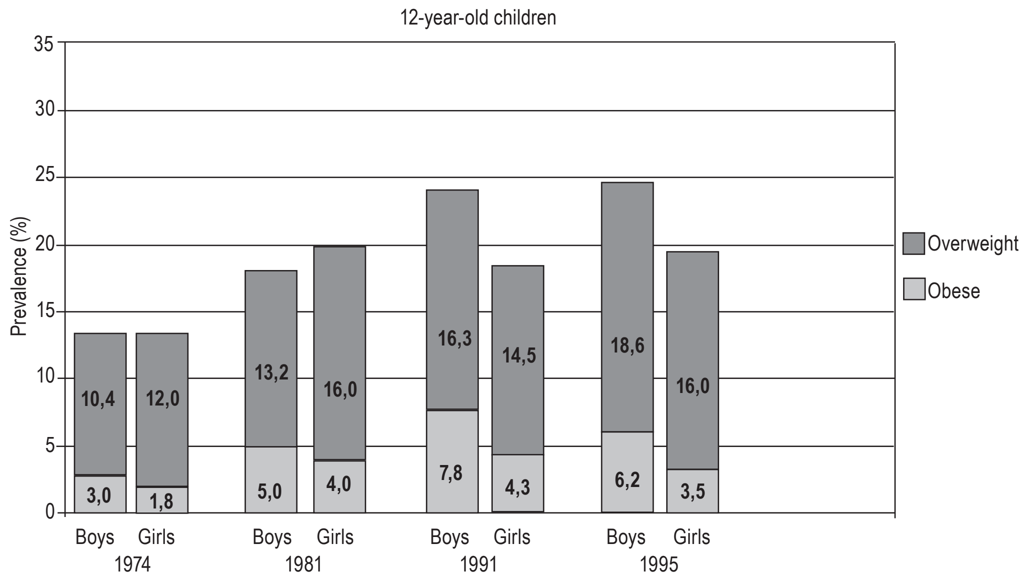
The prevalence of obesity remained quite stable in the past decades except in 12- and 15-year-old boys. In these age groups the prevalence of obesity increased and the change was statistically significant ($p=0.031$ and $p<0.001$ respectively). In teenage boys the rise in the prevalence of combined overweight and obesity was due to changes in both overweight and obesity. Instead, in 12-year-old girls change was seen only in prevalence of overweight.

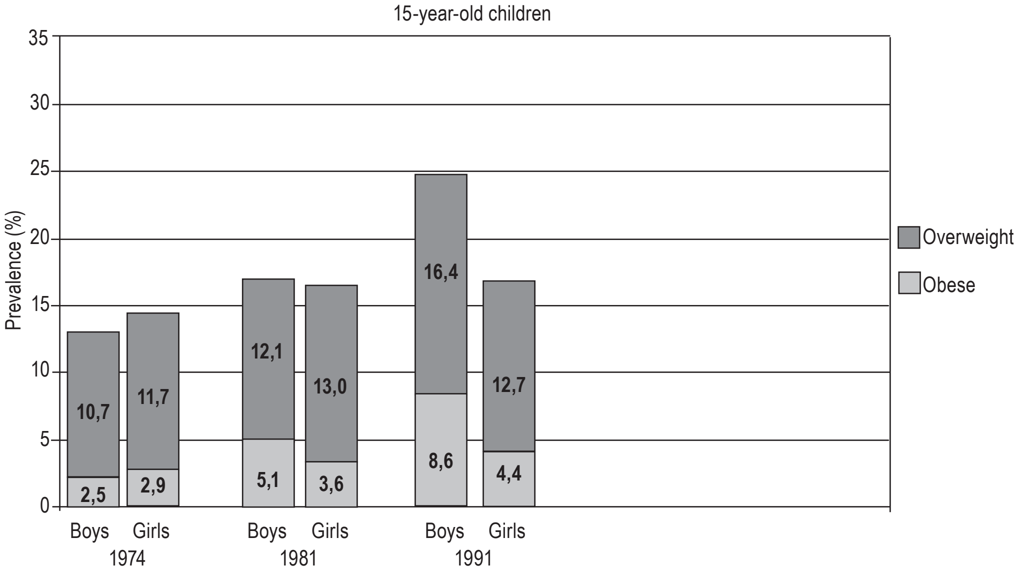
FIGURES 1–5. The prevalence of overweight and obesity in 2- to 15-year old children in birth cohorts 1974, 1981, 1991, 1995 and 2001






7-year-old children
35
30
25
20
15
10
5
0
Prevalence (%)
10,8
3,0
14,9
2,8
11,0
3,9
13,1
4,7
10,4
5,4
12,4
5,6
12,3
5,9
14,2
5,5
Boys Girls
1974
Boys Girls
1981
Boys Girls
1991
Boys Girls
1995
Overweight
Obese


12-year-old children
35
30
25
20
15
10
5
0
Prevalence (%)
10,4
3,0
12,0
1,8
13,2
5,0
16,0
4,0
16,3
7,8
14,5
4,3
18,6
6,2
16,0
3,5
Boys Girls
1974
Boys Girls
1981
Boys Girls
1991
Boys Girls
1995
Overweight
Obese



The regional difference of prevalence of overweight and obesity was studied in a cross-sectional study (I) in 2006. The prevalence of overweight and obesity were significantly more common in the rural area than in the urban area in 5- and 12-year-old children in 2006 (p<0.001 at the of 5 years (Figure 6), and p=0.002 at the age of 12 years (Figure 7)).

FIGURE 6. Prevalence of overweight and obesity in 5-year-old children in urban and rural areas in 2006

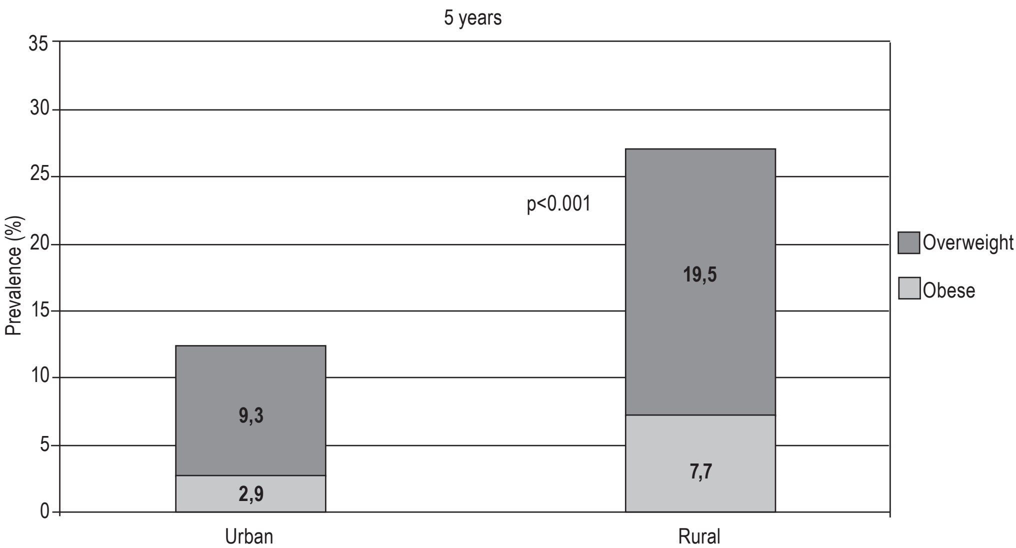
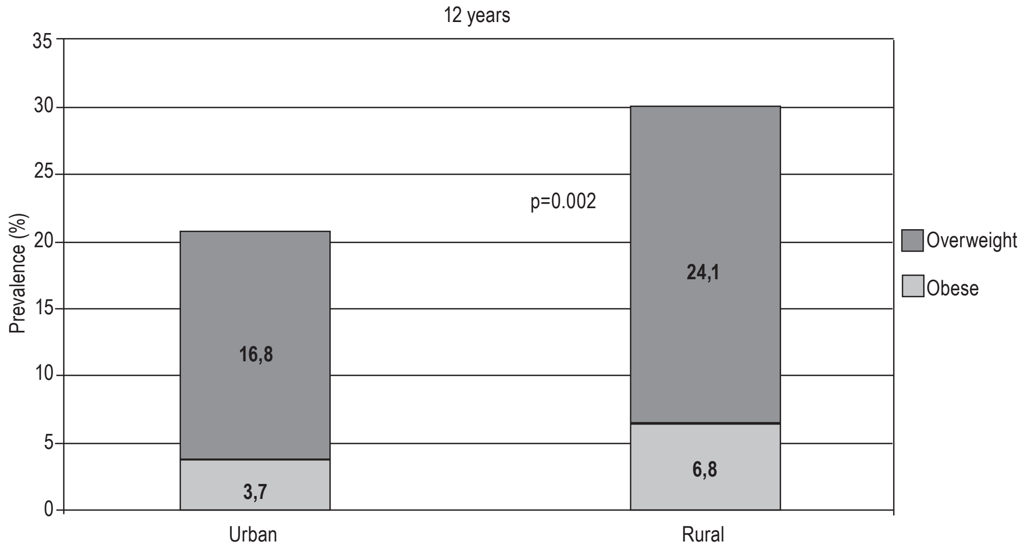


FIGURE 7. Prevalence of overweight and obesity in 12-year-old children in urban and rural areas in 2006



Furthermore, influence of place of residence and temporal change on being overweight (including obesity) was studied in Study II (Table 5). Parallel with the results of geographic difference of prevalence of overweight and obesity in 5- and 12-year-old children, the influence of rural over urban area as a place of residence was significant (OR 1.4–2.1), with exception of 15-year-old girls. In 2-year-old toddlers, odds ratio for overweight was significantly lower in birth cohorts 1981–2001 (OR 0.4–0.7) than birth cohort 1974. No clear trend over the birth cohorts was seen in 5- and 7-year-old children or in 12- and 15-year-old girls. By contrast, 12- and 15-year-old boys showed a consistent increasing trend over the birth cohorts. However, gender did not interact with impact on overweight of place of residence or birth cohort. Correspondingly, no interaction was seen between birth cohort and place of residence on the prevalence of overweight.

TABLE 5. Influence of temporal change, gender and place of residence on being overweight (including obesity) or normal weight (including underweight) in Study II analysed by binary logistic regression

	Boys		Girls	
	OR (95% CI)	p-value	OR (95% CI)	p-value
2-year-olds				
Place of residence[1]	2.1 (1.5–2.9)	<0.001*	1.5 (1.1–2.1)	0.020*
Year of birth		0.002*		0.001*
1974[2]				
1981	0.7 (0.5–1.0)	0.043*	0.6 (0.4–0.9)	0.010*
1991	0.5 (0.3–0.8)	0.008*	0.4 (0.2–0.6)	<0.001*
1995[3]	0.7 (0.4–1.0)	0.048*	0.6 (0.4–0.9)	0.020*
2001	0.4 (0.2–0.6)	<0.001*	0.6 (0.4–0.9)	0.025*
5-year-olds				
Place of residence[1]	1.9 (1.3–2.6)	<0.001*	1.8 (1.3–2.4)	<0.001*
Year of birth		0.49		0.09
1974[2]				
1981	0.9 (0.6–1.4)	0.69	0.9 (0.6–1.3)	0.53
1991	0.7 (0.4–1.1)	0.12	0.6 (0.4–1.0)	0.034*
1995[3]	1.1 (0.7–1.6)	0.80	1.0 (0.7–1.5)	0.91
2001	0.9 (0.6–1.3)	0.51	1.1 (0.8–1.7)	0.44
7-year-olds				
Place of residence[1]	1.7 (1.2–2.3)	0.002*	1.4 (1.0–1.9)	0.046*
Year of birth		0.11		0.47
1974[2]				
1981	1.1 (0.8–1.6)	0.48	1.0 (0.7–1.4)	0.93
1991	1.1 (0.7–1.6)	0.81	0.9 (0.6–1.3)	0.59
1995[3]	1.5 (1.1–2.1)	0.021*	1.2 (0.9–1.7)	0.26
12-year-olds				
Place of residence[1]	1.9 (1.5–2.5)	<0.001*	1.6 (1.2–2.2)	0.004*
Year of birth		<0.001*		0.025*
1974[2]				
1981	1.5 (1.1–2.1)	0.011*	1.6 (1.1–2.3)	0.008*
1991	1.9 (1.3–2.7)	0.001*	1.3 (0.9–1.9)	0.24
1995[3]	2.0 (1.5–2.9)	<0.001*	1.6 (1.1–2.3)	0.009*
15-year-olds				
Place of residence[1]	1.8 (1.3–2.5)	0.001*	1.1 (0.7–1.7)	0.71
Year of birth		0.001*		0.46
1974[2]				
1981	0.5 (1.0–2.0)	0.026*	1.2 (0.8–1.8)	0.30
1991	2.0 (1.4–2.9)	<0.001*	1.2 (0.8–1.9)	0.29

The results are presented as odds ratios (OR) and their 95% confidence intervals (95% CI)
*Statistically significant
[1]Urban place of residence as a reference class
[2] 1974 as a reference class
[3]1995 also includes children born in 1994

5.2 Prevalence of underweight

The changes in the prevalence of underweight during the past decades was analysed in Study II (Table 6). There was some fluctuation in the underweight prevalence figures from the 1970s to the 2000s, but no obvious trend was seen in either boys or girls.

TABLE 6. Prevalence of underweight in 2- to 15-year-old children by birth cohort: 1974, 1981, 1991, 1995 and 2001

	Boys			Girls		
	n	Underweight (%)	p-value	n	Underweight (%)	p-value
2-year-old						
1974	579	1.6	0.28	474	0.9	0.78
1981	567	1.2		406	1.5	
1991	304	1.0		271	1.5	
1995[1]	403	1.3		444	1.8	
2001	399	2.8		354	1.7	
5-year-old						
1974	521	1.5	0.53	442	2.3	0.34
1981	539	0.9		381	1.6	
1991	292	0.3		265	0.4	
1995[1]	399	1.5		426	1.4	
2001	398	1.0		360	1.1	
7-year-old						
1974	601	0.5	0.77	495	1.2	0.42
1981	564	0.9		406	1.7	
1991	297	1.0		267	0.4	
1995[1]	390	1.0		422	0.9	
12-year-old						
1974	605	0.7	0.73	496	2.4	0.20
1981	567	0.7		407	2.2	
1991	305	1.3		275	2.2	
1995[1]	403	1.0		430	0.7	
15-year-old						0.65
1974	605	1.3	0.55	488	2.0	
1981	546	1.6		392	2.8	
1991	304	2.3		275	1.8	

[1]1995 also includes children born in 1994

5.3 Growth of children in birth cohorts from four decades

Descriptive statistics of weight and height in each of the five birth cohorts (1974, 1981, 1991, 1995 and 2001) is presented in Table 7. The 50th percentile of weight varied significantly in both 1- and 2-year-old boys and girls between the 1970's and the 2000's (1yr: $p=0.002$ and $p=0.001$, 2yrs $p=0.02$ and $p=0.01$). Toddlers became lighter (0.2 kg in both age groups in boys, 0.3 kg in 1-year-old and 0.4 kg in 2-year-old girls) from the earliest to the latest birth cohort. In contrast, 12- and 15-year-old boys gained weight over three decades; 2.3 kg in younger and 4.1 kg in older boys and the variation 50th percentile of weight was significant ($p<0.001$ in both). No significant change was seen in adolescent girls or other age groups.

Variation of the 50th percentile of height was significant in 2-, 5-, 7-, 12- and 15-year-old boys (p<0.001 in all, except p=0.05 in 7-year-olds), but in girls only at the age of 5 years (p=0.01). The median height increased 0.7 cm, 1.0 cm, 1.0 cm, 2.5 cm and 3.2 cm in boys and 0.6 cm in 5-year-old girls between the earliest and latest birth cohorts.

TABLE 7. Boys' and girls' basic anthropometric data of five birth cohorts from 1974 to 2001 at birth and at 0.5, 1, 2, 5, 7, 12 and 15 years of age. Differences in 50th percentiles of height and weight between birth cohorts were tested with Pearson's chi-square test

	Boys	Height (cm)			Weight (kg)			Girls	Height (cm)			Weight (kg)		
	n	Mean (SD)	50th percentile	p-value	Mean (SD)	50th percentile	p-value	n	Mean (SD)	50th percentile	p-value	Mean (SD)	50th percentile	p-value
At birth				0.63			0.43				0.31			0.08
1974	608	50.6 (2.3)	51.0		3.5 (0.6)	3.5		501	49.8 (2.4)	50.0		3.4 (0.5)	3.4	
1981	576	50.8 (2.4)	51.0		3.6 (0.5)	3.6		411	50.1 (2.4)	50.0		3.5 (0.5)	3.5	
1991	309	50.9 (2.3)	51.0		3.7 (0.6)	3.7		277	49.8 (2.4)	50.0		3.5 (0.6)	3.5	
1995[1]	411	50.9 (2.4)	51.0		3.6 (0.5)	3.6		445	50.2 (2.3)	50.0		3.5 (0.6)	3.5	
2001	404	50.4 (2.7)	51.0		3.5 (0.6)	3.6		362	50.0 (2.1)	50.0		3.5 (0.5)	3.5	
0.5-year-old				0.25			0.06				0.44			0.54
1974	606	69.0 (2.4)	69.0		8.3 (0.9)	8.2		500	67.4 (2.5)	67.5		7.7 (0.9)	7.7	
1981	575	68.8 (2.4)	69.0		8.2 (0.9)	8.2		411	67.3 (2.6)	67.5		7.6 (0.9)	7.6	
1991	309	69.1 (2.5)	69.0		8.4 (1.0)	8.3		277	67.2 (2.3)	67.2		7.7 (0.9)	7.6	
1995[1]	410	69.4 (2.3)	69.2		8.4 (0.9)	8.4		445	67.2 (2.4)	67.3		7.7 (0.9)	7.7	
2001	402	69.2 (2.5)	69.0		8.4 (1.0)	8.3		362	67.5 (2.3)	67.5		7.9 (0.9)	7.8	
1-year-old				0.07			0.002*				0.73			0.001*
1974	584	76.8 (2.6)	77.0		10.5 (1.1)	10.4		483	75.5 (2.6)	75.5		9.9 (1.1)	9.9	
1981	570	76.6 (2.7)	76.5		10.3 (1.1)	10.3		407	75.2 (2.7)	75.0		9.6 (1.1)	9.6	
1991	303	77.0 (2.8)	77.0		10.3 (1.1)	10.2		273	75.1 (2.5)	75.5		9.6 (1.1)	9.5	
1995[1]	402	77.3 (2.5)	77.2		10.3 (1.1)	10.2		446	75.4 (2.5)	75.5		9.6 (1.1)	9.6	
2001	400	77.1 (2.6)	77.0		10.3 (1.2)	10.2		354	75.6 (2.6)	75.5		9.7 (1.1)	9.6	
2-year-old				<0.001*			0.02*				0.38			0.01*
1974	579	88.5 (3.1)	88.5		13.2 (1.5)	13.0		474	87.4 (3.2)	87.0		12.8 (1.5)	12.7	
1981	567	87.4 (3.3)	88.5		13.1 (1.5)	13.0		406	87.3 (3.2)	87.5		12.5 (1.4)	12.5	
1991	304	88.6 (3.3)	88.5		13.0 (1.5)	12.9		271	87.5 (3.1)	87.5		12.4 (1.5)	12.3	
1995[1]	403	89.1 (3.0)	89.0		13.1 (1.5)	13.0		444	87.4 (3.0)	87.5		12.5 (1.5)	12.4	
2001	399	89.1 (3.4)	89.2		13.0 (1.7)	12.8		354	87.7 (3.3)	87.5		12.5 (1.7)	12.3	
5-year-old				<0.001*			0.21				0.01*			1.00
1974	521	110.9 (4.3)	111.0		19.5 (2.7)	19.1		442	110.1 (4.4)	110.0		19.3 (2.8)	19.0	
1981	539	111.4 (4.6)	111.5		19.6 (2.8)	19.3		381	110.7 (4.6)	110.5		19.3 (3.1)	19.0	
1991	292	111.7 (4.7)	111.7		19.7 (2.9)	19.4		265	110.4 (4.2)	110.0		19.2 (2.9)	18.8	
1995[1]	399	112.1 (4.3)	112.0		19.9 (2.8)	19.5		426	110.5 (4.3)	110.5		19.4 (2.9)	18.9	
2001	398	111.9 (4.5)	112.0		19.8 (3.1)	19.4		360	110.7 (4.9)	110.6		19.6 (3.4)	19.0	
7-year-old				0.05*			0.72				0.62			0.89
1974	601	125.5 (5.3)	125.0		25.6 (4.4)	25.0		495	124.2 (5.3)	124.0		25.2 (4.4)	24.5	
1981	564	125.0 (5.6)	125.0		25.4 (4.4)	24.5		406	124.5 (5.6)	124.5		25.3 (5.2)	24.2	
1991	297	125.5 (5.7)	125.3		25.9 (5.0)	25.1		267	124.0 (5.5)	123.8		25.2 (4.8)	24.2	
1995[1]	390	125.9 (5.5)	126.0		26.1 (5.2)	24.9		422	124.0 (5.2)	124.0		25.4 (4.7)	24.4	
12-year-old				<0.001*			<0.001*				0.18			0.13
1974	605	148.4 (7.1)	148.0		40.5 (8.8)	38.5		499	150.4 (7.5)	150.0		41.9 (9.4)	40.6	
1981	584	149.7 (7.7)	149.2		42.0 (10.2)	40.0		420	150.9 (8.1)	150.5		43.1 (11.3)	41.0	
1991	306	150.1 (7.2)	149.6		43.7 (11.0)	41.0		276	150.6 (7.3)	150.3		42.8 (10.1)	41.0	
1995[1]	403	150.8 (7.1)	150.5		43.9 (11.0)	40.8		430	150.7 (7.5)	151.1		43.6 (10.2)	41.7	
15-year-old				<0.001*			<0.001*				0.12			0.48
1974	605	168.0 (8.9)	168.5		57.0 (11.7)	55.5		488	163.2 (6.2)	163.5		55.3 (9.4)	54.0	
1981	546	168.3 (9.0)	168.5		58.0 (13.1)	56.0		392	163.5 (6.7)	163.6		55.9 (12.2)	54.0	
1991	304	170.8 (8.2)	171.7		62.4 (14.4)	59.6		275	163.2 (6.2)	162.7		55.7 (10.7)	54.1	

[1]1995 also includes children born in 1994

The descriptive statistics of BMI distribution are presented in Tables 8 and 9. The distribution of BMI, represented by 5th, 15th, 25th, 50th, 75th, 85th and 95th percentiles at various ages in the five birth cohorts are presented in Figures 8 and 9. BMI distribution of newborns has been quite stable in recent past decades. However, the 50th percentile of BMI varied significantly in both genders between the birth cohorts ($p<0.001$ in boys, $p=0.02$ in girls). In boys some fluctuation was seen in mean BMI ($p=0.02$). In girls, the mean BMI was lower in newborn girls of birth cohort 1974 compared to 2001 ($p=0.001$). In spite of significant variation in the 15th and 85th BMI percentiles of boys ($p=0.02$ and $p<0.001$), in girls, an increasing trend was only observed in the 15th, 85th and 95th BMI percentiles ($p=0.04$, $p=0.03$, $p<0.001$ respectively).

BMI distribution of 6-month-old boys has remained nearly unchanged from the 1970's to the 2000's while in girls there has been some variation of the 50th, 85th and 95th percentiles of BMI ($p=0.04$, $p=0.02$ and $p=0.03$). Increase of mean BMI in girls was timed between 1981 and 1995 ($p=0.01$) and between 1981 and 2001 ($p<0.001$).

In toddlers, there has been a consistent shift of the entire BMI distribution to a lower level from the earliest to the latest birth cohort. The 50th percentile of BMI in 1- to 2-year-old children varied significantly in both genders ($p<0.001$ in all). Consistently, the 15th, 85th and 95th percentiles of BMI showed a decreasing trend in 1- and 2-year-old boys and girls ($p<0.001$–0.04) from the 1970's to the 2000's, except the 95th BMI percentile at 1 year in boys. The mean BMI at 1 and 2 years was clearly the greatest in the 1974 ($p<0.001$–0.01 in both genders).

At ages 5 and 7 years the BMI distribution has remained quite stable according to the constant mean as well as the 15th, 50th and 85th percentiles of BMI. However, the 95th percentile of BMI increased in 7-year-old boys ($p=0.01$) in three decades.

In young adolescent boys the BMI distribution showed an upward shift throughout. At ages 12 and 15 years the 50th, 85th and 95th percentiles of BMI changed significantly (12yrs: $p=0.002$, $p<0.001$ and $p=0.01$, 15yrs: $p<0.001$ in all). In detail, the increase of mean BMI was seen in the 1974–1991 and 1974–1995 cohorts ($p=0.001$ in both) in the 12-year-old age group. A corresponding increase in 15-year-olds was seen between 1974 and 1991 ($p<0.001$) and further between 1981 and 1991 ($p=0.004$). In 12-year-old girls the variation of the 50th percentile of BMI was insignificant. However, mean BMI increased between the 1974–1995 cohorts ($p=0.01$), as well as that of the 85th percentile of BMI ($p=0.03$). Parallel to this, the proportion of girls under the 15th percentile of BMI decreased ($p=0.01$). In 15-year-old girls the mean BMI as well the 15th, 50th, 85th and 95th BMI percentiles remained unchanged.

TABLE 8. Boys' mean, 15th, 50th, 85th and 95th percentiles of BMI of five birth cohorts from 1974 to 2001 at birth and at 0.5, 1, 2, 5, 7, 12 and 15 years of age. Differences in 15th, 50th, 85th and 95th percentiles of BMI between birth cohorts were tested with Pearson's chi-square test

	Boys	BMI							
	n	Mean (SD)	15th percentile	p-value	50th percentile	p-value	85th percentile	p-value	95th percentile	p-value
Newborn				0.02*		<0.001*		<0.001*		0.11
1974	608	13.6 (1.4)	12.5		13.6		15.0		15.8	
1981	576	13.9 (1.2)	12.7		13.9		15.1		15.8	
1991	309	14.1 (1.4)	12.7		14.2		15.4		16.1	
1995[1]	411	13.8 (1.3)	12.5		13.7		15.1		15.8	
2001	404	13.9 (1.4)	12.6		14.0		15.2		15.9	
0.5-year-old				0.74		0.85		0.07		0.14
1974	606	17.3 (1.3)	16.0		17.3		18.7		19.6	
1981	575	17.3 (1.4)	15.9		17.3		18.8		19.8	
1991	309	17.5 (1.4)	16.0		17.3		19.1		19.8	
1995[1]	410	17.5 (1.4)	16.1		17.4		18.8		20.1	
2001	402	17.5 (1.6)	16.0		17.4		19.1		20.0	
1-year-old				<0.001*		<0.001*		0.003*		0.26
1974	584	17.7 (1.3)	16.4		17.7		19.1		20.0	
1981	570	17.4 (1.4)	16.0		17.4		18.9		19.8	
1991	303	17.3 (1.3)	16.1		17.3		18.6		19.5	
1995[1]	402	17.3 (1.3)	16.1		17.1		18.5		19.7	
2001	400	17.3 (1.4)	15.9		17.1		18.6		19.7	
2-year-old				<0.001*		<0.001*		<0.001*		0.002*
1974	579	16.9 (1.4)	15.5		16.7		18.3		19.4	
1981	567	16.7 (1.3)	15.3		16.6		18.0		19.0	
1991	304	16.6 (1.2)	15.4		16.4		17.8		18.8	
1995[1]	403	16.5 (1.3)	15.2		16.3		17.7		18.7	
2001	399	16.3 (1.4)	15.0		16.1		17.6		18.6	
5-year-old				0.29		0.30		0.36		0.21
1974	521	15.8 (1.4)	14.5		15.6		16.9		18.3	
1981	539	15.8 (1.5)	14.5		15.5		17.0		18.4	
1991	292	15.7 (1.4)	14.5		15.5		17.0		18.2	
1995[1]	399	15.8 (1.5)	14.3		15.5		17.3		18.9	
2001	398	15.7 (1.7)	14.3		15.4		17.0		18.8	
7-year-old				0.10		0.47		0.27		0.01*
1974	601	16.2 (1.9)	14.6		15.9		17.8		19.5	
1981	564	16.2 (1.9)	14.4		15.7		18.0		20.3	
1991	297	16.3 (2.1)	14.6		15.9		18.1		20.9	
1995[1]	390	16.4 (2.3)	14.4		15.7		18.5		21.2	
12-year-old				0.48		0.002*		<0.001*		0.01*
1974	605	18.3 (2.9)	15.8		17.6		20.7		24.4	
1981	584	18.6 (3.4)	15.7		17.7		21.9		25.4	
1991	306	19.2 (3.6)	15.8		18.3		23.5		26.6	
1995[1]	403	19.1 (3.6)	15.9		18.3		22.9		26.3	
15-year-old				0.19		<0.001*		<0.001*		<0.001*
1974	605	20.1 (3.1)	17.4		19.5		22.7		25.7	
1981	546	20.3 (3.6)	17.3		19.6		23.4		28.1	
1991	304	21.2 (4.0)	17.8		20.2		25.2		29.6	

[1]1995 also includes children born in 1994

TABLE 9. Girls' mean, 15th, 50th, 85th and 95th percentiles of BMI of five birth cohorts from 1974 to 2001 at birth and at 0.5, 1, 2, 5, 7, 12 and 15 years of age. Differences in 15th, 50th, 85th and 95th percentiles of BMI between birth cohorts were tested with Pearson's chi-square test

	Girls	BMI								
	n	Mean (SD)	15th percentile	p-value	50th percentile	p-value	85th percentile	p-value	95th percentile	p-value
Newborn				0.04*		0.02*		0.03*		<0.001*
1974	501	13.7 (1.3)	12.4		13.7		14.9		15.5	
1981	411	13.8 (1.3)	12.6		13.9		15.0		15.8	
1991	277	13.9 (1.4)	12.6		13.8		15.4		16.3	
1995[1]	445	13.8 (1.4)	12.6		13.9		15.1		15.9	
2001	362	14.0 (1.5)	12.7		14.1		15.2		16.3	
0.5-year-old				0.11		0.04*		0.02*		0.03*
1974	500	17.0 (1.4)	15.5		16.9		18.4		19.3	
1981	411	16.8 (1.3)	15.5		16.7		18.1		18.9	
1991	277	16.9 (1.5)	15.4		16.8		18.4		19.7	
1995[1]	445	17.1 (1.5)	15.6		17.0		18.6		19.8	
2001	362	17.2 (1.4)	15.7		17.1		18.7		19.6	
1-year-old				<0.001*		<0.001*		<0.001*		0.04*
1974	483	17.4 (1.4)	15.9		17.3		18.9		19.7	
1981	407	16.9 (1.4)	15.6		16.8		18.5		19.1	
1991	273	16.9 (1.4)	15.5		16.8		18.1		19.5	
1995[1]	446	16.9 (1.4)	15.6		16.8		18.2		19.6	
2001	354	17.0 (1.4)	15.5		16.9		18.3		19.4	
2-year-old				0.003*		<0.001*		0.002*		<0.001*
1974	474	16.8 (1.5)	15.2		16.7		18.2		19.6	
1981	406	16.4 (1.3)	15.1		16.4		17.7		18.7	
1991	271	16.2 (1.5)	14.9		16.0		17.5		18.4	
1995[1]	444	16.4 (1.5)	14.9		16.2		17.7		19.1	
2001	354	16.2 (1.4)	14.9		16.1		17.7		18.5	
5-year-old				0.72		0.27		0.09		0.60
1974	442	15.8 (1.6)	14.4		15.7		17.2		18.3	
1981	381	15.7 (1.7)	14.2		15.5		17.1		18.8	
1991	265	15.7 (1.6)	14.2		15.4		17.0		18.3	
1995[1]	426	15.8 (1.6)	14.3		15.6		17.4		18.6	
2001	360	15.9 (1.9)	14.4		15.5		17.6		18.9	
7-year-old				0.37		0.24		0.94		0.26
1974	495	16.3 (2.0)	14.4		16.0		18.4		20.1	
1981	406	16.3 (2.4)	14.2		15.7		18.3		20.7	
1991	267	16.3 (2.2)	14.3		15.9		18.4		21.2	
1995[1]	422	16.4 (2.2)	14.5		16.0		18.5		21.0	
12-year-old				0.01*		0.62		0.03*		0.35
1974	499	18.4 (3.1)	15.7		17.8		21.1		24.4	
1981	420	18.7 (3.7)	15.4		17.9		22.3		25.3	
1991	276	18.7 (3.4)	15.7		17.9		22.4		25.5	
1995[1]	430	19.0 (3.4)	15.8		18.2		22.7		25.8	
15-year-old				0.10		0.65		0.63		0.10
1974	488	20.8 (3.3)	17.9		20.2		23.4		26.8	
1981	392	20.8 (3.9)	17.4		20.1		24.3		27.9	
1991	275	20.9 (3.5)	17.9		20.0		24.0		27.9	

[1]1995 also includes children born in 1994

FIGURE 8. BMI distribution (5th, 15th, 25th, 50th,75th, 85th and 95th percentiles) of boys at birth and at 0.5, 1, 2, 5, 7, 12 and 15 years of age in five birth cohorts from 1974 to 2001

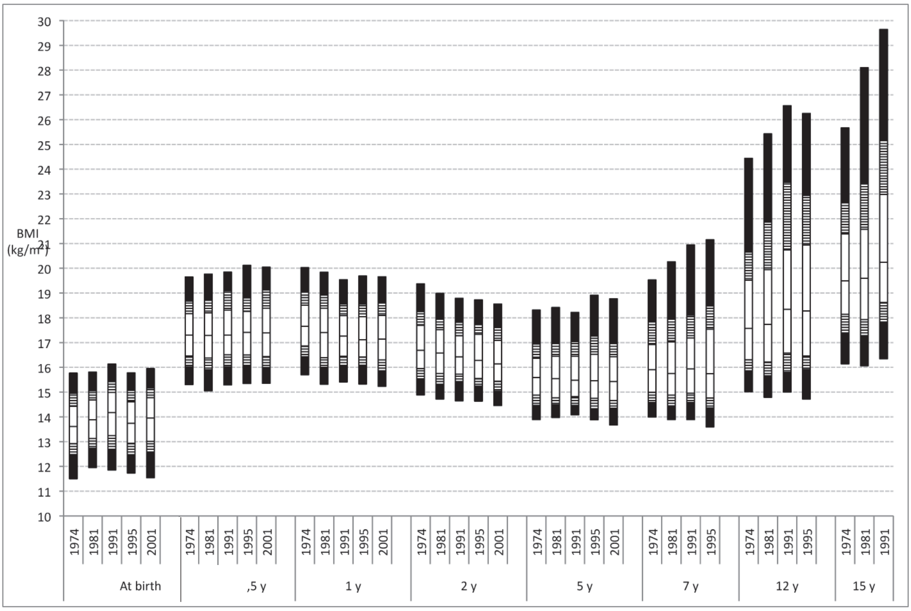
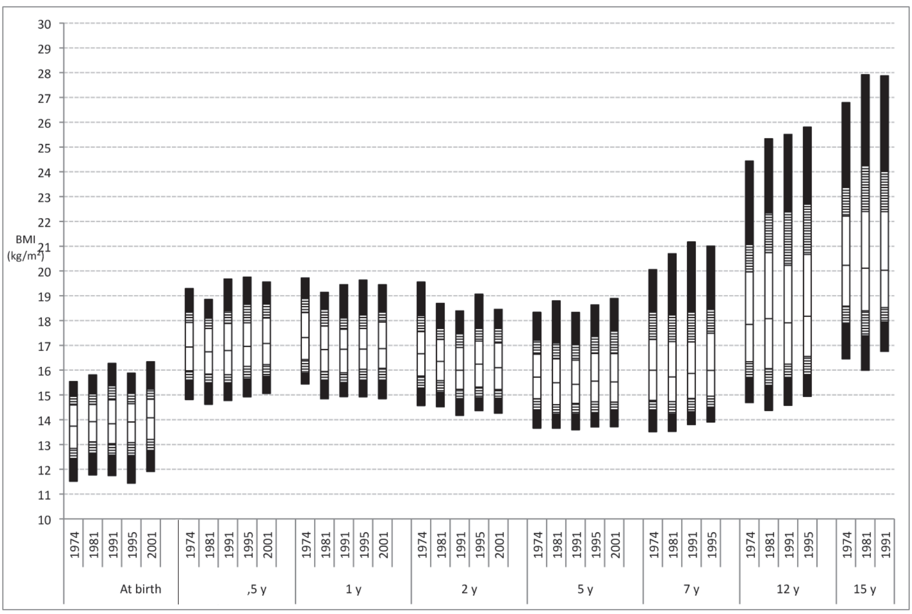


FIGURE 9. BMI distribution (5th, 15th, 25th, 50th,75th, 85th and 95th percentiles) of girls at birth and at 0.5, 1, 2, 5, 7, 12 and 15 years of age in five birth cohorts from 1974 to 2001



Growth and trends were studied further by longitudinal analysis. Changes in BMI by age in 0- to 15-year-old children in five study birth cohorts are presented in Figures 10–17. These illustrate three main physiological periods of growth. At first BMI increases during the first year of life. Between 1 and 5 years mean BMI declines. Then comes the second rise in BMI which continues until adulthood.

FIGURE 10. Mean BMI of 0- to 15-year-old boys in five birth cohorts from 1974 to 2001

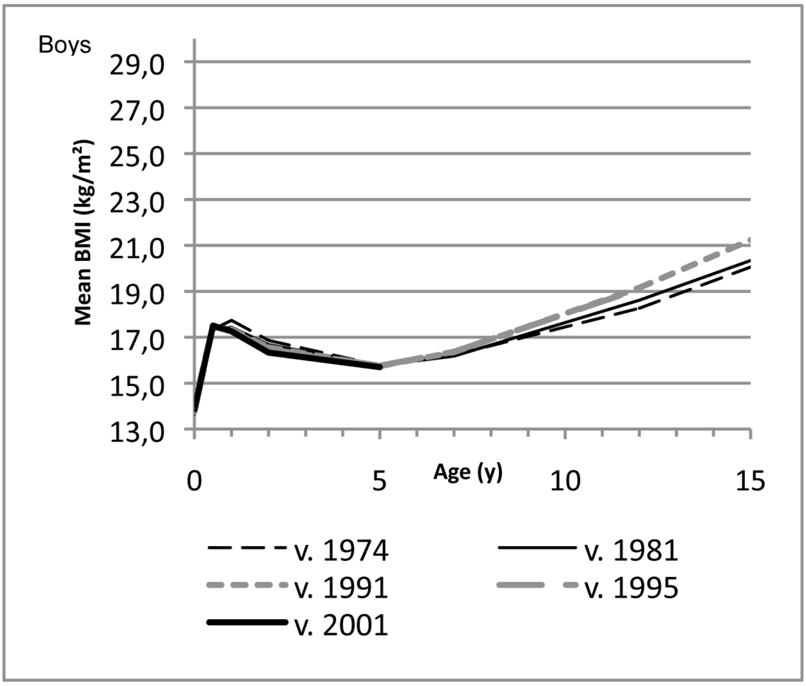


FIGURE 11. Mean BMI of 0- to 15-year-old girls in five birth cohorts from 1974 to 2001

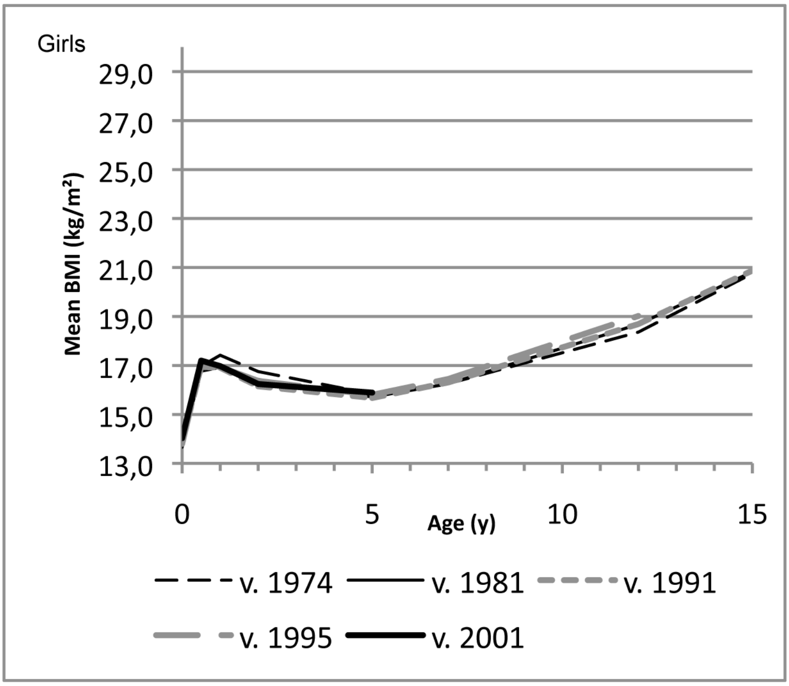


FIGURE 12. 50th BMI percentiles of 0- to 15-year-old boys in five birth cohorts from 1974 to 2001

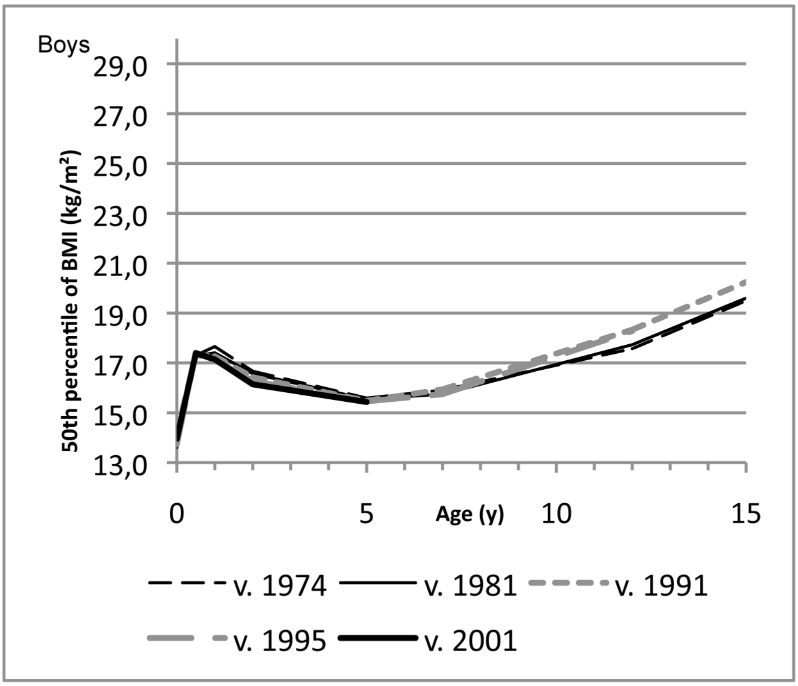


FIGURE 13. 50th BMI percentiles of 0- to 15-year-old girls in five birth cohorts from 1974 to 2001

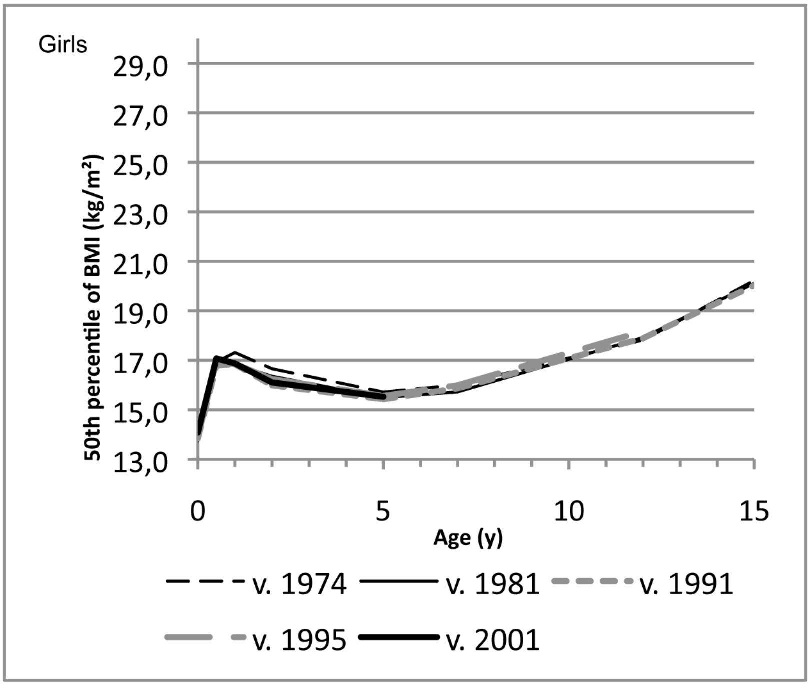


FIGURE 14. 85th BMI percentiles of 0- to 15-year-old boys in five birth cohorts from 1974 to 2001

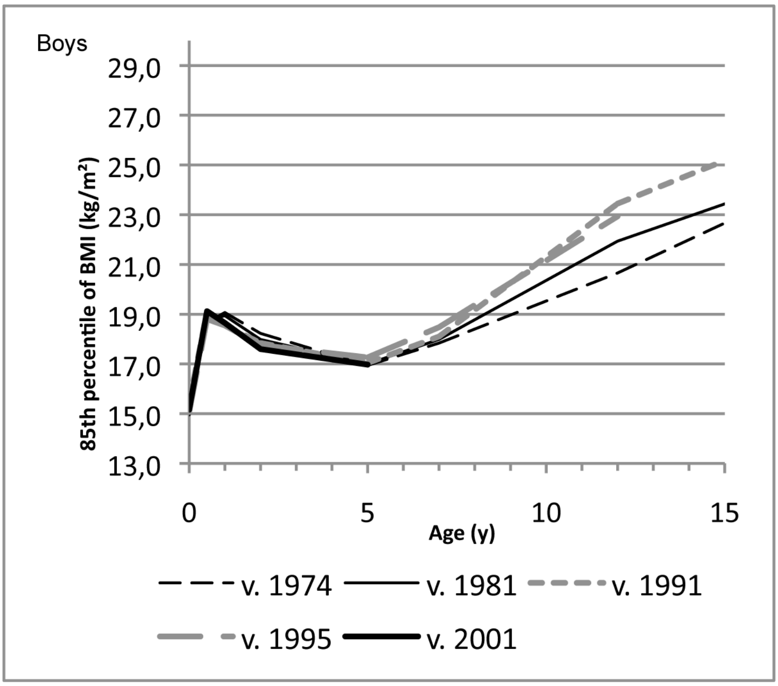


FIGURE 15. 85th BMI percentiles of 0- to 15-year-old girls in five birth cohorts from 1974 to 2001

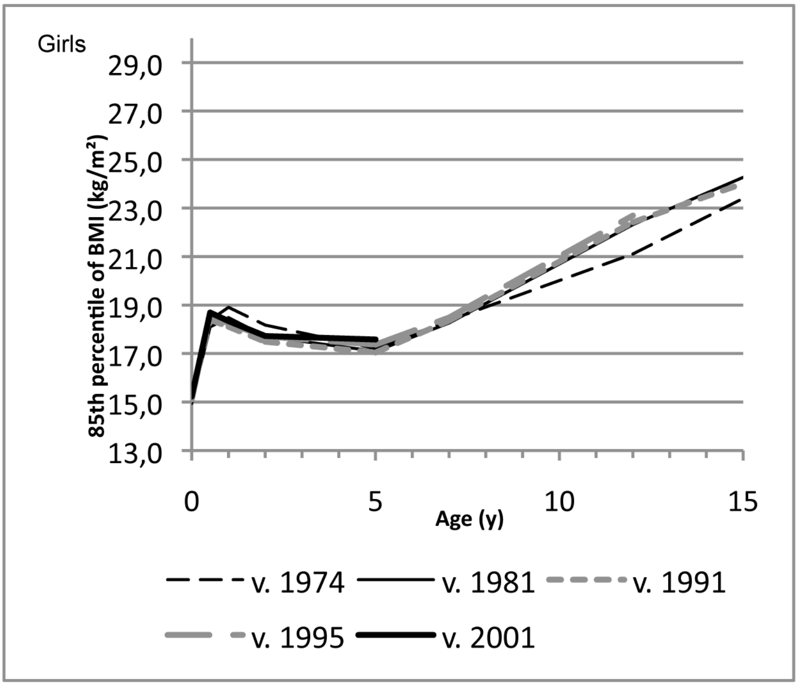


FIGURE 16. 95th BMI percentiles of 0- to 15-year-old boys in five birth cohorts from 1974 to 2001

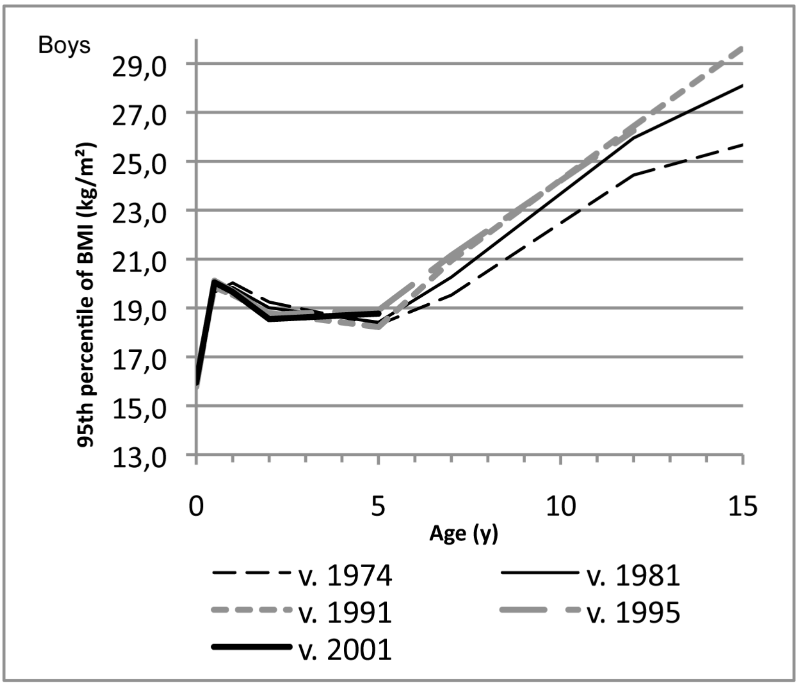
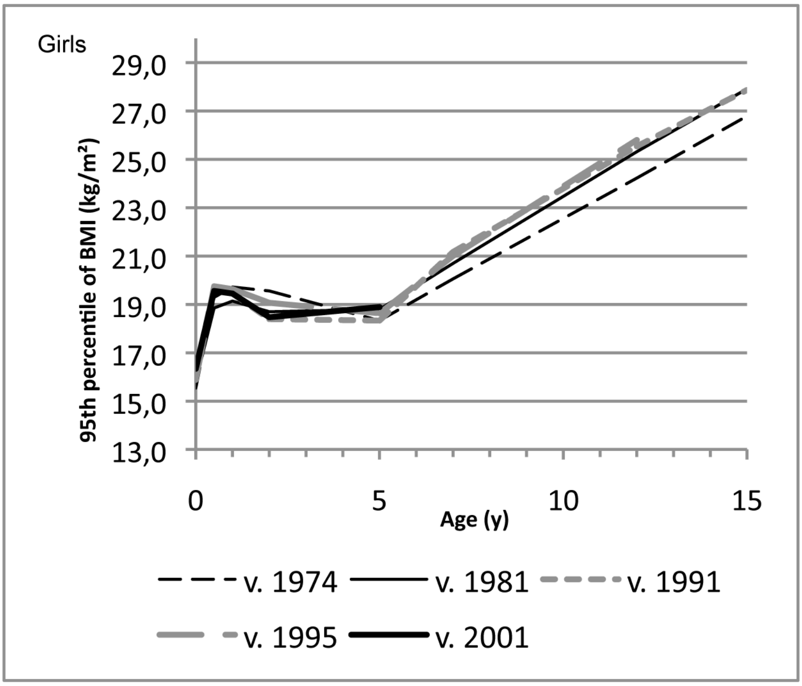


FIGURE 17. 95th BMI percentilse of 0 to 15-year-old girls in five birth cohorts from 1974 to 2001



Trends of age in different birth cohorts over three age periods (0–1, 1–5 and 5–15 years) for boys and girls are shown in Table 10. According to longitudinal analysis, the mean BMI of boys was slightly higher than girls in newborns ($p<0.001$). Although mean BMI increased from birth to the age of one year, increase in BMI was 0.4 unit slower in girls than in boys ($p<0.001$). Consistently at the age of 1 year boys were bigger than girls ($p<0.001$). Toddlers got slimmer (mean BMI 0.3 unit/y) between 1 and 5 years, even more in boys (in boys 0.1 mean BMI unit/y more than in girls). Mean BMI was lower in 5-year-old boys than in girls ($p<0.001$). After the age of 5 years, mean BMI started to increase with age (0.5 mean BMI unit/y) ($p<0.001$). However, in girls weight gain was 0.03 mean BMI units higher than in boys.

Birth cohort did not have any influence on mean BMI in children younger than one year ($p=0.26$). However, the growth of the children in the five birth cohorts began to differ according to the analysis of interaction of age and birth cohort ($p<0.001$). In 1- to 5-year-old children the negative slope of BMI was significantly bigger in later birth cohorts than in birth cohort 1974 ($p<0.001$). After 5 years of age the slope turned positive and the mean BMI increased more in other birth cohorts than in birth cohort 1974 except in birth cohort 1995 in girls ($p<0.001$ in boys, $p=0.01$ in girls).

Rural residence had a significant impact on mean BMI over urban residence throughout childhood (p<0.001 in all). The rural vs. urban difference was greater in children over 5 years than at younger ages.

TABLE 10. Trends of age in different birth cohorts over three age periods (0–1, 1–5 and 5–15 years) for boys and girls analysed by linear mixed model. Significance of trends between birth cohorts and comparison between birth cohort 1974 cohort and four other birth cohorts

	0–1 year		1–5 years		5–15 years	
	Coefficient (95% CI[1])	P-value	Coefficient (95% CI[1])	P-value	Coefficient (95% CI[1])	P-value
Boys		<0.0001		<0.0001		<0.0001
1974	4.00 (3.80 to 4.20)		-0.46 (-0.49 to -0.44)		0.45 (0.44 to 0.47)	
1981	3.52 (3.36 to 3.68)	0.0001[2]	-0.38 (-0.41 to -0.36)	<0.0001[2]	0.50 (0.48 to 0.51)	0.0012[2]
1991	3.22 (2.99 to 3.44)	<0.0001[2]	-0.37 (-0.40 to -0.34)	<0.0001[2]	0.59 (0.57 to 0.62)	<0.0001[2]
1995	3.49 (2.29 to 3.70)	0.0001[2]	-0.34 (-0.37 to -0.32)	<0.0001[2]	0.53 (0.50 to 0.56)	0.0001[2]
2001	3.39 (3.17 to 3.61)	<0.0001[2]	-0.35 (-0.38 to -0.32)	<0.0001[2]		
Girls		<0.0001		<0.0001		0.010
1974	3.69 (3.53 to 3.86)		-0.37 (-0.40 to -0.34)		0.52 (0.50 to 0.54)	
1981	3.10 (2.92 to 2.27)	<0.0001[2]	-0.29 (-0.32 to -0.26)	<0.0001[2]	0.55 (0.53 to 0.57)	0.015[2]
1991	2.98 (2.75 to 3.21)	<0.0001[2]	-0.27 (-0.31 to -0.23)	<0.0001[2]	0.55 (0.53 to 0.58)	0.031[2]
1995	3.08 (2.89 to 3.27)	<0.0001[2]	-0.25 (-0.28 to -0.22)	<0.0001[2]	0.50 (0.47 to 0.53)	0.29[2]
2001	2.94 (2.73 to 3.15)	<0.0001[2]	-0.23 (-0.26 to -0.20)	<0.0001[2]		

[1]95% Confidence Interval
[2]Significance of difference between birth cohort 1974 and subsequent birth cohort

5.4 Association between weight class at the age of 2 years and overweight at the age of 15 years

Significance of slimming toddlers for weight gain was evaluated by investigating the association between the weight class at the age of 2 years and overweight at the age of 15 years. Prevalence of underweight, normal weight, overweight and obesity in 2- and 15-year-old boys and girls are presented in Table 11. Prevalence of overweight and obesity in 15-year-old boys and girls according to the individual's classification at the age of 2 years are presented in Figures 18–21.

TABLE 11. Prevalence of underweight, normal weight, overweight and obesity in 2- and 15-year-old boys and girls

	Finnish classification based on weight for height ratio				International BMI classification			
	Underweight n(%)	Normal weight n(%)	Overweight n(%)	Obese n(%)	Underweight n(%)	Normal weight n(%)	Overweight n(%)	Obese n(%)
2-year-old								
Boys	32 (2.3)	1219 (87.3)	122 (8.7)	24 (1.7)	35 (2.5)	1251 (89.5)	126 (9.0)	20 (1.4)
Girls	38 (3.4)	957 (86.4)	85 (7.7)	27 (2.4)	28 (2.5)	963 (87.0)	115 (10.4)	29 (2.6)
15-year-old								
Boys	65 (4.7)	1096 (78.5)	149 (10.7)	87 (6.2)	24 (1.7)	1137 (81.4)	169 (12.1)	67 (4.8)
Girls	36 (3.3)	839 (75.8)	156 (14.1)	76 (6.9)	26 (2.3)	907 (81.9)	136 (12.3)	38 (3.4)

FIGURES 18–21. Prevalence of overweight and obesity in 15-year-old boys and girls according to the individual's classification at the age of 2 years. Prevalence according to WHR at left and according to BMI criteria at right (Boys in Figures 18 and 19 and girls in Figures 20 and 21)

Figure 18

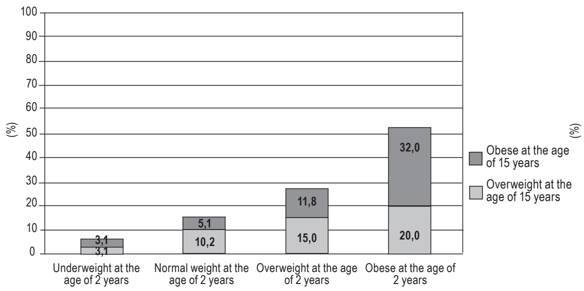


Figure 19

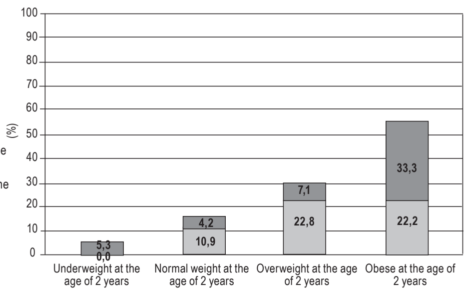


Figure 20

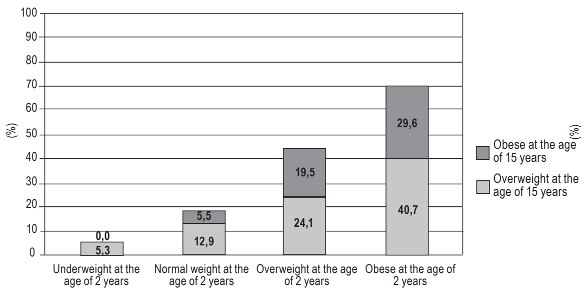


Figure 21

Underweight toddlers were very unlikely to be overweight in teens (OR 0.3, p=0.02 and OR 0.2, p=0.11 weight for height and BMI classification respectively). Instead obesity at the age of 2 years implied a high probability for overweight or obesity at the age of 15 years (OR 3.2, p<0.001 and OR 3.5, p<0.001 weight-for-height and BMI classification respectively). The probability was higher in girls than in boys (OR 1.4, p=0.002) according to the Finnish classification. However, no gender difference was seen using the BMI classification (OR 1.2, p=0.22).

5.5 Perception of the weight class

The measured clinical characteristics of the Study IV subjects; 310 5-year-old (boys n=166 and girls n=144) and 296 11-year-old (boys n=140 and girls n=156) children are presented according to age and gender (Table 12). By the age of 11 years 28.7% of the boys and 62.6% of the girls had entered puberty. Acanthosis nigricans was found in one school age boy (0.7%).

TABLE 12. Measured clinical characteristics of 5- and 11-year-old children

	5-year-old		11-year-old	
	Boys	Girls	Boys	Girls
n	166	144	140	156
Age (years)				
Mean (SD)	5.0 (0.1)	5.0 (0.1)	11.5 (0.5)	11.6 (0.5)
Weight (kg)				
Mean (SD)	20.0 (3.6)	19.5 (2.9)	42.5 (9.3)	43.7 (10.2)
Height (cm)				
Mean (SD)	111.9 (4.3)	110.5 (4.7)	149.9 (6.6)	150.9 (7.4)
Height SD[1]				
Mean (SD)	0.3 (1.0)	0.2 (1.1)	0.5 (1.0)	0.4 (0.9)
BMI (kg/m^2)				
Mean (SD)	15.9 (2.0)	15.9 (1.5)	18.8 (3.0)	19.1 (3.4)
Waist (cm)[2]				
Mean (SD)	53.6 (5.6)	52.5 (4.2)	67.0 (8.7)	65.9 (7.7)
Waist/Height ratio				
Mean (SD)	0.48 (0.04)	0.48 (0.04)	0.45 (0.05)	0.44 (0.05)

[1]Height SD (height standard deviation score)
[2]Waist (waist circumference), not reported: 5 boys and girls respectively

The prevalence of overweight (including obesity) was 13.3% and 22.2% in 5-year-old boys and girls. At the age of 11 years, the corresponding figures were 20.0% and 23.1%. The waist was above the 90th percentile cut-off point in 21.6% and 22.3% of the 5-year-old boys and girls respectively. The corresponding figures for 11-year-old boys and girls were 39.9% and 38.5% respectively. The waist-to-height ratio was above the cut-off point at 5 years in 84.6% of the boys and in 82.7% of the girls and at 11 years in 43.9% of the boys and in 32.3% of the girls.

Parents perceived 5.5% of their 5-year-old children as underweight, 91.6% as normal weight, 2.9% as overweight, but no children were as obese. The corresponding figures for 11-year-old children were 4.7%, 84.1%, 10.8% and 0.3%. These results are presented in two weight categories: normal weight (including underweight) and overweight (including obesity). The parents perceived the weight class of their normal weight children accurately. Accordingly, young adolescents and parents were well aware of their own shape (Table 13). Instead, overweight was more often underestimated; 73% of boys and 94% of girls aged 5 years and 46% of boys and 56% of girls aged 11 years were classified incorrectly as normal weight (Table 14).

TABLE 13. Perception of weight class compared with measured normal weight class

	Normal weight[1]	
	Normal weight[1] (%)	Overweight[2] (%)
Perceived weight class of the child		
5-year-old		
Boys	144 (100)	0
Girls	111 (99.1)	1 (0.9)
11-year-old		
Boys	111 (99.1)	1 (0.9)
Girls	119 (99.2)	1 (0.8)
Perceived own weight class		
11-year-old		
Boys	101 (94.4)	6 (5.6)
Girls	107 (91.5)	10 (8.5)
Parents		
Fathers	82 (100)	0
Mothers	190 (97.9)	4 (2.1)

[1]Including underweight
[2]Including obese

TABLE 14. Perception of weight class compared with measured overweight (including obese) class

	Overweight[2]	
	Normal weight[1] (%)	Overweight[2] (%)
Perceived weight class of the child		
5-year-old		
Boys	16 (72.7)	6 (27.3)
Girls	30 (93.8)	2 (6.3)
11-year-old		
Boys	13 (46.4)	15 (53.6)
Girls	20 (55.6)	16 (44.4)
Perceived own weight class		
11-year-old		
Boys	14 (43.8)	18 (56.3)
Girls	13 (35.1)	24 (64.9)
Parents		
Fathers	59 (48.4)	63 (51.6)
Mothers	18 (16.2)	93 (83.8)

[1]Including underweight
[2]Including obese

There was moderate overall agreement between the parents' perceived and measured normal weight and overweight classes of the 5-year-old boys (Kappa (95% CI): 0.39 (0.17–0.62), agreement 90.3%, $p<0.001$). The discrepancy was more common in the younger girls; most of the parents classified their overweight or obese 5-year-old girls incorrectly as normal weight (Kappa (95% CI): 0.08 (-0.05–0.20), agreement 78.5%, $p=0.061$). The parents perceived their 11-year-old children's weight class slightly better, since the overall agreement was moderate in boys and girls (Kappa

(95% CI): 0.63 (0.45–0.80), agreement 90.0%, p<0.001 and Kappa (95% CI): 0.54 (0.37–0.70), agreement 86.6%, p<0.001 respectively).

The school-age boys and girls perceived their own weight class moderately (Kappa (95% CI): 0.56 (0.38–0.73), agreement 85.6%, p<0.001 and Kappa (95% CI): 0.58 (0.43–0.73), agreement 85.1%, p<0.001 respectively). Mothers had an almost perfect perception of their own weight class in this study (Kappa (95% CI): 0.84 (0.78–0.90) agreement 85.6%, p<0.001). By contrast, fathers perceived their own weight class lower than their measured weight class (Kappa (95% CI): 0.46 (0.36–0.56) agreement 85.6%, p<0.001).

Using WC for weight status classification did not improve parents' performance in identifying their child's weight status. Parents perceived 83% of the 5-year-old boys and 94% of girls with waist circumference above the 90th percentile as normal weight. Correspondingly, 71% of both boys and girls aged 11 years were underestimated as normal weight.

The logistic regression model showed that age and gender of the child and the number of parents in the family were associated with the correct perception of the child's weight class (Table 15). According to the odds ratios (OR), being parents of 5-year-old children (OR (95%CI): 9.0 (2.5–32.3), p=0.001) and girls (OR (95%CI): 5.3 (1.7–16.5), p=0.004) as well as being in a two-parent family (OR (95%CI): 4.5 (1.2–17.6), p=0.031) were the significant risk factors for incorrect classification. The educational level and the employment status as well as the weight class of the fathers and mothers, obesity related diseases of parents and grandparents or number of siblings and family members were not significantly associated with misclassification.

TABLE 15. Characteristics of the misclassified overweight children's parents and family structure. The effect of explanatory variables associated with misclassification of overweight children as normal weight were analysed by a logistic regression modelling

	5-year-old		11-year-old			
	Boys n(%)	Girls n(%)	Boys n(%)	Girls n(%)	OR (95% CI)[1]	p-value
n	16	30	13	20		
Age group					9.0 (2.5–32.3)	0.001*
Gender					5.3 (1.7–16.5)	0.004*
Family members						
n=2	0	4 (13.3)	0	2 (10.0)	1.3 (0.2–10.1)	0.783
n>3	16 (100.0)	26 (86.7)	13 (100.0)	18 (90.0)		
Education of the fathers						
Comprehensive school up to 16 years	4 (25.0)	4 (13.3)	2 (16.7)	7 (35.0)	3.7 (0.6–21.5)	0.152
More education than comprehensive school	12 (75.0)	26 (86.7)	10 (83.3)	13 (65.0)		
Not reported	0	0	1	0		
Education of the mothers						
Comprehensive school up to 16 years	1 (6.3)	2 (6.7)	1 (8.3)	6 (30.0)	1.0 (0.2–6.3)	0.998
More education than comprehensive school	12 (93.8)	28 (93.3)	11 (91.7)	14 (70.0)		
Not reported	0	0	1	0		
Employment status of the fathers						
Employed	14 (93.3)	28 (100.0)	11 (100.0)	16 (84.2)	2.1 (0.2–25.8)	0.549
Others (housewives, long sick-leave, students,unemployed, retired)	1 (6.7)	0	0	3 (15.8)		
Not reported	1	2	2	1		
Employment status of the mothers						
Employed	14 (87.5)	18 (60.0)	11 (91.7)	14 (82.4)	0.7 (0.2–3.3)	0.673
Others (housewives, long sick-leave, students,unemployed, retired)	2 (12.5)	12 (40.0)	1 (8.3)	3 (17.6)		
Not reported	0	0	1	3		
Parents' and grandparents' obesity related diseases						
No	1 (6.3)	1 (3.3)	3 (23.1)	4 (20.0)	2.0 (0.4–11.3)	0.415
Yes	15 (93.8)	29 (96.7)	10 (76.9)	16 (80.0)		
Parents' marital status						
One parent (divorced, single, widowed)	2 (12.5)	7 (23.3)	3 (23.1)	8 (40.0)	4.5 (1.2–17.6)	0.031*
Two parents (cohabiting, married)	14 (87.5)	23 (76.7)	10 (76.9)	12 (60.0)		
Siblings						
n=0	3 (18.8)	4 (13.3)	1 (7.7)	2 (10.0)	1.5 (0.2–10.5)	0.684
n>1	13 (81.3)	26 (86.7)	12 (92.3)	18 (90.0)		
Weight class of the fathers (asked)						
Normal weight[2] (BMI <25)	4 (28.6)	10 (34.5)	3 (33.3)	5 (26.3)	0.6 (0.2–2.4)	0.521
Overweight or obese (BMI >25)	10 (71.4)	19 (65.5)	6 (66.7)	14 (73.7)		
Not reported	2	1	4	1		
Weight class of the mothers (asked)						
Normal weight[2] (BMI <25)	6 (37.5)	15 (50.0)	5 (45.5)	6 (31.6)	1.4 (0.5–4.2)	0.565
Overweight or obese (BMI >25)	10 (62.5)	15 (50.0)	6 (54.4)	13 (68.4)		
Not reported	0	0	2	1		

[1]OR (95% CI), Odds ratio (95% confidence interval)
[2]Including underweight

6 Discussion

General discussion

The present study showed that a marked increase has occurred in the prevalence of overweight in Finnish juvenile population. However, an opposite change was seen in toddlers compared to adolescents. The results on the fattening tendency of adolescents confirmed those reported earlier by Kautiainen et al. and slimming among toddlers reported by Harjunmaa (Kautiainen et al. 2002, Kautiainen et al. 2009, Harjunmaa 2009). Whilst overweight has become more common, most parents seem to have difficulties in perceiving their own child's overweight. The main results of these growth studies, slimming between 1 and 5 years of age and gaining weight in school age, were linear utilizing both cross-sectional and longitudinal methods. Instead, changes in the mean BMI of newborns or in 0.5-year-old children between birth cohorts were not obvious in the longitudinal analysis. Thus variation in size between birth cohorts until the age of one year did not seem to be significant in this study.

Finnish toddlers have become markedly slimmer in recent decades as the whole distribution of BMI has shifted to a lower range during the past four decades. The probable explanation for slimming in toddlers is the changes in infant feeding habits. In Finland during the past 30 years both the rate and the duration of breastfeeding have increased and the introduction of solid foods has come later (Erkkola et al. 2005). However, according to the present results, these changes in infant nutrition have had no impact on BMI at 6 months. Nevertheless, longer breastfeeding time may have an effect later in infancy and childhood, as it has been reported to be associated with lower fat mass at the ages of 2 and 4 years (Karaolis-Danckert et al. 2007, Robinson et al. 2009). Nowadays the intake of energy among 1- to 2-year-old children has been shown to be less than in the late 1980s (Räsänen and Ylönen 1992, Kyttälä et al. 2008). This is linear with the findings on the growth of young children in the present study.

The falling BMI in toddlers might indicate effective nutrition counselling in well baby clinics or that the age of adiposity rebound is now earlier. Should the latter phenomenon exert influence, the boys especially of the latest birth cohorts studied would have another three years during childhood for excess weight gain. The results of the longitudinal analysis suggest this phenomenon. Thus the health consequences could be more serious as reported by Bhargava et al. (Bhargava et al. 2004). However in the present study underweight at the age of two years did not seem to be a risk factor for being overweight at the age of 15 years. Instead obese 2-year-olds were more likely to be at least overweight in teenage.

The distribution and prevalence of overweight in 5- and 7-year-old children has remained stable over the past 30 years. As similar finding of constant or downward trend in prevalence of overweight has been reported in young children in the Czech Republic, France and the Netherlands during the past 10–20 years as well as in Denmark, Germany, Sweden and the United Kingdom in the late 2000's (Cattaneo et al. 2009, Pearson et al. 2010, Bluher et al. 2010, Blomquist and Bergström 2007, Bergström and Blomquist 2009, Stamatakis et al. 2010). In the USA Wang et al. reported an increasing prevalence of overweight in young children, but with slower rate of change when compared to older children or adolescents (Wang and Beydoun 2007). Consistent with earlier reports, overweight in the present study material was more prominent in younger girls than in boys (Nuutinen et al. 1990, Hakanen et al. 2006, Vanhala et al. 2009, Kautiainen et al. 2010, Padez et al. 2005, Blomquist and Bergström 2007, Ogden et al. 2010).

Younger children may be more resistant than other age groups to the obesogenic environment. The protecting factor against excessive weight gain is unclear. The amount of physical activity is probably one mechanism. Younger children are active and motivated to spontaneous activity and play. Boys do better, as they are more active than girls across all age groups (Riddoch et al. 2004, Raustorp et al. 2004). Sääkslahti et al. have shown that the intensity of play is important. Accordingly, low active play is related to a higher BMI in girls aged 4–7 years (Sääkslahti et al. 2004). Differences in physical activity might explain at least partly why overweight was more common in 2- to 7-year-old girls compared to boys in the present study.

Considering young adolescents overweight is more common today than 20 years ago. Twelve and 15-year-old boys have become both taller and heavier, but weight has increased more than height. Their median BMI has increased and the distribution has skewed more to the upper range. The shift has been considerable from the 1970s to the 2000s, since the 85th percentile point (22.7 kg/ m^2) is nowadays placed under the 75th percentile in the current BMI distribution. On average, 13% of the boys from the birth cohort of 1974 were overweight or obese, whereas the corresponding figure in the 1991 cohort was 25%. However, the proportion of slim boys remained unchanged since there was no marked shift in the lower BMI percentiles. In teenage girls the secular trend of overweight has been less prominent. In 12-year-old girls the mean BMI and the 85th percentile of BMI increased as well as the prevalence of overweight from 13% to 19% between the birth cohorts of 1974 and 1995, but no significant change was seen in 15-year-old girls. Nor was there any obvious trend in prevalence of underweight.

The present findings agree with earlier reports of increasing BMI in Finnish adolescents during the period 1980–1992 (Porkka et al. 1997) and increasing prevalence of overweight in children in northern Europe as well as worldwide during the last three decades until the early 2000's (Strauss and Pollack 2001, Ekblom et al. 2004, Kim et al. 2006, Wang and Beydoun 2007, Juliusson et al. 2007, Chen 2008, Kautiainen et al. 2009). Parallel to earlier Finnish studies, overweight in 12 and 15-year-old boys was more prevalent than in teenage girls (Nuutinen et al. 1991, Laitinen and Soivio 2005, Välimaa and Ojala 2004, Kautiainen et al. 2009). On the contrary, most studies from other Nordic countries have reported higher prevalence of overweight in girls compared to boys throughout childhood (Blomquist and Bergström 2007, Holmbäck et al. 2007, Bergström and Blomquist 2009, Juliusson et al. 2007, Kolle et al. 2009, Pearson et al. 2010). Why boys seem to be more susceptible than girls to excess weight gain in school age is unsolved. However, boys' obesity trend is not unique. Similar findings have been reported among 13- to 18-year-old boys in China (Chen 2008). Furthermore, in the USA the rising trend has been reported to have continued in the heaviest 6- to 19-year-old boys (> the 97th BMI percentile for age) in the 2000's (Ogden et al. 2010).

The present results on the prevalence of overweight are consistent with those reported from Sweden and the United Kingdom, but higher than the figures from Norway (Lobstein and Frelut 2003, Neovius et al. 2006, Juliusson et al. 2007). Much higher figures have been reported from the USA and the Mediterranean countries (Lobstein and Frelut 2003, Wang and Beydoun 2007). Although findings of fatter adolescents are well known, in recent reports from the 2000's the trend of increasing overweight in children seems to level off in several high income countries such as Australia, France, Germany, Sweden and Switzerland and the United Kingdom (Olds et al. 2010, Peneau et al. 2009, Bluher et al. 2010, Aeberli et al. 2010, Ekblom et al. 2009, Sundblom et al. 2008, Lioret et al. 2009, Stamatakis et al. 2010). Even in the USA signs of stabilization of obesity have been seen among 2- to 19-year-old children except in the heaviest school age boys in the 2000's (Ogden et al. 2010). Similar results were also seen in 5- and 7-year-old children and in 15-year-old girls in the present study.

The aetiology of obesity is complex; interaction between an individual's genotype and lifestyle. Probably changes in eating and physical activity behaviours predispose genetically at-risk individuals to weight gain. Early life has been proposed to have a major impact on susceptibility to weight gain. Both undernutrition and hypernutrition in foetal or early postnatal life, with birth weight's relationship U- or J-shaped, may alter later risk of developing obesity (Gluckman and Hanson 2008). In the present study the variation in birth weight or during the first year of life was so slight that foetal or infant growth hardly explains the growing trend of overweight in school age children.

Overweight was more common among children living in rural areas than in urban areas in the present study. According to the longitudinal analysis the difference seemed to increase in school age. Although small sample size from the rural area hampers drawing definite conclusions, the regional difference is noteworthy. In the 1980's no significant urban-rural gradient was seen in the prevalence of overweight among 9- to 18-year-old youngsters in Finland (Nuutinen et al. 1990). However, later reports of higher prevalence of overweight in rural areas were consistent with the present results (Kautiainen et al. 2009). According to several studies overweight tends to be more prevalent in children of lower socioeconomic status and living in rural areas in developing countries (Laitinen et al. 2001, Ekblom et al. 2004, Neovius et al. 2006, Shrewsbury and Wardle 2008, Neovius and Rasmussen 2008, Broyles et al. 2010). Socioeconomic gradient may be more prevalent in boys than girls as was reported in 10-year-old boys in Stockholm in the 2000's (Sundblom et al. 2008).

Secular increase in height was shown in this study, especially in boys. Consistently an increasing trend in height has been reported over the past century in Europe as well as in Finnish children (Cole 2000, Karlberg 2002, Porkka et al. 1997, Kautiainen et al. 2002, Saari et al. 2010). Increase in height has recently been reported to be more marked in Finnish boys than in girls (Saari et al. 2010).

The parents were able to perceive the weight class of their children correctly provided their children were of normal weight. This finding concurs with a review article by Doolen et al. (Doolen et al. 2009). The majority of parents of 5-year-old children and every second parent of 11-year-old children failed to recognize their children's overweight or obesity. The parents' inaccuracy of perception of children's overweight was consistent with earlier reports (Parry et al. 2008, Doolen et al. 2009, Vanhala et al. 2009). Although misperception seemed to be independent of the child's age, some studies have shown that parents of younger children especially tend to misperceive overweight in their child (Campbell et al. 2006, Eckstein et al. 2006). In contrast to earlier studies overweight girls were more prone to be incorrectly estimated compared to boys (Maynard et al. 2003, Manios et al. 2009).

Using WC for body size classification did not improve parents' performance in identifying their child's overweight although a recent study reported that measuring

WC helped teenage girls to perceive their own weight class (van Vliet et al. 2009). The use of WC is recommended being a valuable body size measurement providing indirect information about visceral adiposity.

Teenage children were better aware of their own actual weight status than their parents, as 61% of adolescents recognized their own overweight or obesity, while 49% of parents correctly indentified the overweight of their child. The better performance of adolescents compared to their parents in identifying obesity does not substantiate the findings reported by Goodman et al. (Goodman et al. 2000).

Mothers' accurate perception of their own weight class was obvious, but almost half of the overweight or obese fathers failed to identify weight class correctly. Linearly with this result overweight fathers have been reported to more often fail to perceive their own overweight (Baughcum et al. 2000, Jeffery et al. 2005). It may be that men tend to misclassify their weight because they prefer large body size over small and slim. Young boys in 4^{th} and 7^{th} grades have been shown to select larger ideal adult body size silhouette than girls (Adams et al. 2000).

The low education level of parents is a possible risk for the development of obesity in their children if the parents are unable to recognize the size of their offspring, (Baughcum et al. 2000, Genovesi et al. 2005). Accordingly, in the present study parents with lower education performed slightly worse when estimating the weight class of their children. Surprisingly, in this study two-parent families were at a risk of underestimating their child's overweight. However, the sample size was too small to interpret the results of the logistic regression model more indicatively.

Parents were not concerned about the weight status of their child. Only 30% of parents of overweight children and 40 % of those of obese children perceived any need for intervention. It has been reported that parents consider their overweight children healthy as long as they are active, eat with a good appetite, eat healthily and have no social problems (Jain et al. 2001). Parents may also mistrust the growth charts (Jain et al. 2001). The concern of the parents may not arise until the child's BMI is high and the child is grossly overweight (Lampard et al. 2008). The mothers' perception of the correct weight class of her infant may affect the child's favorable weight development (Kroke et al. 2006). Accurate weight status perception is a challenge for health care to make lifestyle interventions possible.

The strengths of the Studies I–III are the fairly large study sample from the same locality of residence and wide time range, as well as objective anthropometric measurements performed by qualified public health nurses. The services of the well-baby and school nurse clinics cover the whole infant and child population. By using measured and routinely recorded anthropometric data obtained from the health records, it was possible to avoid the bias that may affect self-reported data.

It has been shown that BMI based on self-reported height and weight is on average 2.5 kg/m^2 lower than clinically measured values in adolescent population (Brener et al. 2003). Although cross-sectional data-analysis showed significant changes in the growth of children, longitudinal analyses in a linear mixed model with coefficients were used for more accurate analyses of growth trends.

The weakness of these studies is the issue of selection bias. In Studies I–III availability of growth data from the 1970's and 1980's was poor. Internal migration in Finland is assumed to be the most probable explanation for missing growth data. As neither exact population figures according to birth cohorts from different decades nor the socioeconomic characteristics of study cohorts or missing subjects were available, more exact analysis of sampling estimation bias was not possible. However, since the prevalence numbers of overweight and obesity in Studies I–II were linear with earlier Finnish studies concerning children born in the same time period and partly same region (Helve et al. 1971, Nuutinen et al. 1991, Kautiainen et al. 2002, Kautiainen et al. 2009, Stigman et al. 2009), the results of the present sudies are considered reliable. The weakness in the statistical methods was the use throughout of cross-sectional analyses in Studies I–III. These methods were chosen to compare the changes in growth between different birth cohorts based on growth data available. To complete the statistical analyses longitudinal methods were added.

The main novelty in Studies I–III was to provide information on secular changes in growth from birth to the age of 15 years in Finnish children during the past four decades. The results of these studies are generalized to the Finnish region of Pirkanmaa. Furthermore, the migration gain of the region of Pirkanmaa has been the biggest in Finland and the population of the city of Tampere has increased 1.4 fold since the 1980's. It is assumed that Tampere accurately reflects the whole of Finland and that these results also reliable reflect national changes in growth.

In Studies I–III there was a slight difference in mean age between the birth cohorts. However it is assumed that these differences in age will not give rise to a significant bias in comparisons of the cohorts. Study IV was small including 118 overweight or obese children. However, this sample size is comparable to those of earlier studies (Parry et al. 2008). Furthermore, the BMI percentiles 5, 50 and 95 of study groups were compared with the Finnish BMI growth charts and they were quite linear (Child Obesity. Current Care Guideline 2005). The defined cut-off points of BMI classification may lead to variation in accuracy between age-groups explaining at least partly the difference in agreement in the two age-groups. Ethnicity was not taken into account in the results because very few children (2.6%) of non-Finnish origin participated in the study. Since more normal weight and higher educated parents than average in Finland took part of the present study selection bias improving the results is possible.

Although BMI does not measure body fat directly, BMI-for-age is a valid screening test in clinical use and population-based applications (Must and Anderson 2006, Freedman et al. 2009). The widely used IOTF reference was chosen as weight classification in all studies for international comparison although the use of Finnish BMI growth reference might have been nationally the best classification. In the study of perception of weight status (Study IV) Finnish weight-for-height classification was also used.

Future considerations

Every third preschool-age and every second school-age obese children have been reported to become obese adults (Wang and Beydoun 2007). Increasing and tracking obesity has contributed to the awareness of obesity and knowledge of its negative health consequences. However well-educated groups with high socioeconomic status may have better opportunities to adopt healthy diet and physically active lifestyle, since obesity seems to increase more in lower socioeconomic groups in many countries. However, the effect of parental lower education may be attenuated by own education (Kestilä et al. 2009). Health education is an opportunity for obesity prevention in health care services and in schools.

Physical activity has beneficial effects on cardiovascular and musculoskeletal health and adiposity in all, but even more in overweight children (Strong et al. 2005). Adequate daily physical activity is probably one of the best ways to resist excess weight gain or negative health consequences of obesity.

In future, more research is needed to study slim toddlers in Finland and ascertain the aetiology of the changing pattern of growth in the early years of life. Further studies should focus on overweight demographic and gender differences in Finland.

7 Conclusions

Finnish toddlers have become slimmer. This may be an indication of effective nutrition counselling in well baby clinics. On the other hand BMI falling over time may indicate that age of adiposity rebound and thereby weight gain now occur earlier.

Children aged 5 and 7 years seem to do better than other age groups in the obesogenic environment, since their prevalence of overweight or obesity has remained stable. It may be that 5- and 7-year-old children have retained their need for spontaneous physical activity and are not so much tempted by sedentary electronic entertainment.

Young adolescent boys especially have become taller and heavier during the past four decades. Increased prevalence of overweight and obesity may be associated with changes in social environment. Boys could be more susceptible than girls to these changes or boys may not have the same strong social pressure as girls to be slim.

Most parents of 5-year-old children underestimated the overweight of their children. Every second parent of an 11-year-old child had difficulties in perceiving their child's overweight. It is worrying that, with the increasing prevalence of overweight, people tend to underestimate their own and their children's overweight or do not have any concerns about excess weight gain.

Overweight persists from early childhood to teenage. Weight gain in childhood may have effects on wellbeing and subsequent healthiness. An obesity prevention programme is needed in public health and it should start in preschool age. The skills of health care professionals are needed to help parents to build up a realistic perception of their child's weight status.

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Appendix 1.

Studies reporting the prevalence of overweight and obesity in children. Overweight and obesity defined primary by the International Obesity Task Force criteria (IOTF).
Other definitions used are the US Centers for Disease Control and Prevention (CDC) and national definitions.

Reference	Study years	Number (n)	Measurements	Definition	Age (y)	Prevalence of overweight and obesity (%)		Prevalence of obesity (%)	
						Boys	Girls	Boys	Girls
FINLAND									
Helve A et al. 1971	1969–1970	32 000	Measured	Weight-for-height >2SD	7–15			3.5	3.0
Dahlström S et al. 1982	1978–1979	189 258 236	Measured	Weight-for-height >2SD	3 8 12			0.5[1] 5.0 8.5	
Nuutinen EM et al. 1991	1980, 1983, 1986	3 596	Measured	US 90th percentile	6			6.9	17.3
Hyppönen E et al. 2000	1986–1989	571	Measured	Relative weight >120%	2 4 6 8 10 12			0.7 1.3 4.0 6.8 9.9 8.8	0.4 2.7 5.3 6.9 7.9 8.5
Fogelholm M et al.1999	1998	269	Measured	Weight-for-height	7–12	11.4	14.5	4.6	3.6
Laitinen J and Sovio U 2005	1980	12 231	Self-reported	IOTF	14	7.7	5.5	1.2	0.6
	2001–2002	9 479	Measured		16	16.1	13.7	4.1	3.0
Kaitosaari T et al. 2005	1997–1999	684	Measured	Weight-for-height	7	3.7	9.0		
Hakanen M et al. 2006	2000–2002	585	Measured	IOTF	10	17.8	23.6		
Lagström H et al. 2008	2003–2005	541	Measured	IOTF	13	15.5[1]			
Vanhala M et al. 2009	2004	749	Measured	IOTF	7	15.4	18.0	0.04	0.05
Stigman S et al. 2009	2005–2006	304	Measured	IOTF	8	19.6	18.6	3.3	0.7

Reference	Study years	Number (n)	Measurements	Definition	Age (y)	Prevalence of overweight and obesity (%)		Prevalence of obesity (%)	
						Boys	Girls	Boys	Girls
Kautiainen S et al. 2002	1977	2 832	Self-reported	IOTF	12	8.2	6.9	2.0	0.9
	1999	8 219				19.0	12.6	3.0	1.3
Kautiainen S et al. 2009	2005	6 503				26.5	17.9		
	1977				14	6.3	4.2	1.5	0.0
	1999					16.9	10.0	3.1	1.7
	2005					21.7	14.9		
	1977				16	7.7	3.9	0.8	0.3
	1999					15.6	7.6	2.4	1.1
	2005					20.3	13.1		
	1977				18	6.5	1.2	0.0	0.3
	1999					15.3	9.0	2.4	1.3
	2005					25.1	12.5		
Välimaa R and Ojala K 2004	1984	1 145	Self-reported	IOTF	13	7	6	1	0
	2002	1 732				17	12	4	1
	1984	1 122			15	8	3	1	<1
	2002	1 745				18	9	3	1
Mäki P et al. 2010	2007–2008	1 540	Measured	Weight-for-height	0.5	15.3	16.6	1.8	2.8
					1	10.0	2.7	1.8	1.8
					3	6.5	15.2	0.9	3.6
					5	13.1	21.8	2.8	7.3
					7	13.6	9.3	3.0	1.3
					12	14.3	12.2	2.9	2.6
					15	28.3	34.3	15.2	11.4
EUROPE									
DENMARK									
Pearson S et al. 2010	2002	22 541	Measured	IOTF	5–8	14.0	17.8	3.2	4.3
	2007	10 704				11.6	15.9	2.6	3.7
	2002				14–16	15.8	22.7	3.3	3.8
	2007					18.9	25.4	4.2	4.7
FRANCE									
Peneau S et al. 2009	1996	1 947	Measured	IOTF	6–15	10.7	12.4		
	2001	2 649				13.9	15.9		
	2006	1 953				15.3	15.2		
Lioret S et al. 2009	1998–1999	1 016	Self-reported	IOTF	3–14	13.5	17.0		
	2006–2007	1 030	Measured			12.5	16.7	2.6	3.3
Plachta-Danielzik S et al. 2007	1996	4 217	Measured	German BMI reference	6	7.5	10.6	3.3	4.4
	2001	1 419			10	15.4	17.1	4.9	5.4

Reference	Study years	Number (n)	Measurements	Definition	Age (y)	Prevalence of overweight and obesity (%)		Prevalence of obesity (%)	
						Boys	Girls	Boys	Girls
GERMANY									
Bluher S et al. 2010	2000	5 524	Measured	IOTF	4–8	14.9	13.8	3.5	2.1
	2004	18 117				17.0	13.9	4.1	2.3
	2008	26 018				15.4	11.9	3.4	1.8
	2000	5 844			8–12	24.9	19.4	6.5	2.2
	2004	7 842				27.0	19.2	7.6	2.6
	2008	8 981				25.4	19.5	6.8	2.5
	2000	6 389			12–16	20.6	18.0	4.4	2.7
	2004	8 690				25.4	21.2	6.7	4.5
	2008	5 623				26.9	21.6	7.6	4.6
ITALY									
Binkin N et al. 2010	2008	44 676	Measured	IOTF	8–9	35.9[1]		12.3[1]	
NETHERLANDS									
Schokker DF et al. 2007	1980		Measured	IOTF	2–21	3.2–10.6	6.0–9.9	0.1–1.0	0.3–0.9
	1997				2–21	7.1–15.5	8.2–16.1	0.5–1.6	0.7–2.7
	2002–2004				4–15	9.2–17.3	14.6–24.6	2.5–4.3	2.3–6.5
NORWAY									
Juliusson P et al. 2007	1971–1974	3 068	Measured	Weight-for-height	3–17	18.0	20.1	8.0	7.2
	2003–2006	4 115		IOTF	4–15	12.5	14.8	2.1	2.9
Kolle E et al. 2009	1999–2000	410	Measured	IOTF	9	11.5	13.8	0.6	1.1
	2005	405				17.0	20.2	1.6	4.7
Juliusson P et al. 2010	2003–2006	170	Self-reported	IOTF	2	12.9	21.0	0	2.9
		198			5	8.6	14.0	2.0	1.6
		217			7	19.4	15.9	2.0	1.6
		158			12	15.2	12.2	0.6	1.9
		238			15	10.9	7.3	2.9	0.8
		152			18	15.1	8.5	1.3	2.1
PORTUGAL									
Padez C et al. 2005	2002–2003	621	Measured	IOTF	7	25.1	33.9	7.7	14.2
		631			9.5	28.7	36.3	9.1	12.1
SWEDEN									
Blomquist HK and Bergström E2007	1998–1999	4 407	Measured	IOTF	4	16.7	22.1	3.1	6.0
Bergström E and Blomquist HK 2009	2002–2003	4 507	Measured	IOTF	4	17.2	22.3	3.1	5.7
	2007–2008	4 381				14.2	19.0	2.3	3.1

Reference	Study years	Number (n)	Measurements	Definition	Age (y)	Prevalence of overweight and obesity (%)		Prevalence of obesity (%)	
						Boys	Girls	Boys	Girls
Holmbäck U et al. 2007	1982	180	Measured	IOTF	4	10.0	10.0	1.0	1.0
	2002	183				18.0	22.0	2.0	6.0
	1982	180			10	8.0	14.0	2.0	1.0
	2002	169				21.0	30.0	1.0	5.0
	1982	180			16	15.0	11.0	1.0	1.0
	2002	175				9.0	11.0	1.0	2.0
Petersen S et al. 2003	1986	507	Measured	IOTF	6–11	13.0	9.8	2.1	0.2
	2001	465				17.6	27.4	3.3	9.0
Sundblom E et al. 2008	1999	2 416	Measured	IOTF	10	21.6	22.1	3.2	4.4
	2003	2 183				20.5	19.2	3.8	2.8
Sjöberg A et al. 2008	1984–1985	4 125	Measured	IOTF	10	7.2	8.6	0.7	0.8
	2000–2001	4 683				17.1	19.6	2.9	3.0
	2004–2005	4 193				17.6	15.9	2.8	2.5
Ekblom O et al. 2004	2001	508	Measured	IOTF	10	15.6	21.7	5.7	4.9
		637			13	13.3	16.2	6.2	2.9
		587			16	15.2	14.1	3.1	3.4
Ekblom OB et al. 2009	2001	588	Measured	IOTF	16	17.9[1]			
	2007	296				17.6[1]			
SWITZERLAND									
Aerberli I et al. 2010	2002	2 404	Measured	CDC reference	6–13	18.7	17.0	6.2	4.2
	2007	2 222				16.7	13.1	5.4	3.2
	2009	907				19.9	18.9	7.4	5.7
UNITED KINGDOM									
Wright CM et al. 2010	1998–1999	7 946	Measured	IOTF	7	11.9	17.1	2.5	4.1
	2002–2003	7 327			11	21.5	23.6	4.5	4.6
Stamakis E et al. 2005	1974	3 042	Measured	IOTF	5–7	7.6	9.4	1.3	1.4
Stamakis E et al. 2010a	1984	2 375				5.5	8.4	0.6	1.1
	1994	2 490				6.4	11.8	1.4	2.6
	2002–2003	1 648				13.7	20.5	4.1	6.6
	2006–2007	2 062				15.8	19.4	5.8	5.8
	1974	3 751			8–10	6.2	9.4	0.9	1.4
	1984	2 813				5.9	11.1	0.5	2.0
	1994	2 500				10.8	15.7	1.9	3.2
	2002–2003	1 844				18.8	25.8	5.2	7.1
	2006–2007	2 297				19.8	23.9	5.6	6.3

Reference	Study years	Number (n)	Measurements	Definition	Age (y)	Prevalence of overweight and obesity (%)		Prevalence of obesity (%)	
						Boys	Girls	Boys	Girls
Stamakis E et al. 2010b	1995 2005 2007	1 960 1 310 3 375	Measured	IOTF	2–5			2.9 7.1 6.4	4.4 8.2 7.0
	1995 2005 2007				6–10			3.3 6.3 7.3	5.8 9.8 7.6
	1995 2005 2007				11–15			2.5 6.7 4.9	4.6 7.7 6.2
	1995 2005 2007				16–18			3.0 6.9 4.7	4.8 7.0 5.2
OTHERS **AUSTRALIA**									
Booth ML et al. 2007	1985 1997 2004	1 227 5 518 5 402	Measured	IOTF	8–12	10.9 20.6 25.7	14.0 22.0 24.8	2.0 5.6 7.2	2.0 5.4 7.2
	1985 1997 2004				13–15	10.6 19.5 26.1	8.3 17.9 19.8	0.4 3.9 6.7	0.5 2.7 3.6
Wake M et al. 2007	2004	4 934	Measured	IOTF	4–5	19.2	22.3	5.2	5.8
Tremblay MS and Willms JD 2000	1981 1996	2 038 7 847	Measured Self-reported	85th and 95th percentile	7–13	15.0 28.8	15.0 23.6	5.0 13.5	5.0 11.8
Tremblay MS et al. 2010	2007–2009		Measured	IOTF	15–19	31	26	14	10
CHINA									
Chen CM 2008	1985 1995 2000			Chinese BMI reference	7–12	5.8/ 5.4/ 0.6[1] 17.5/ 20.5/ 4.0 29.0/ 28.9/ 11.8	4.3/ 2.2/ 2.2 12.0/ 11.8/ 2.9 17.3/ 15.3/ 6.2		
	1985 1995 2000				13–18	4.8/ 2.7/ 0.7 18.1/ 15.7/ 4.5 25.0/ 17.2/ 8.8	5.1/ 2.8/ 1.8 11.6/ 8.0/ 3.9 14.6/ 9.6/ 6.5		
Zhang Y and Wang S 2010	1995 2005		Measured	Chinese BMI reference	7–18	7.5 14.3	4,9 8,8	2,9 10,8	1,7 5,8
USA									
Kim J et al. 2006	1980–1981 2000–2001	7 962 27 453	Measured	2000 CDC	0–6	19.2 26.0	15.6 22.7	7.2 10.8	5.4 9.2

Reference	Study years	Number (n)	Measurements	Definition	Age (y)	Prevalence of overweight and obesity (%)		Prevalence of obesity (%)	
						Boys	Girls	Boys	Girls
Wang Y and Beydoun MA 2007	1999–2002		Measured	2000 CDC	2–5	23.0	22.3	9.9	10.7
					6–11	32.5	29.9	16.9	14.7
					12–19	31.2	30.5	16.7	15.4
Odgen CL et al 2006	2003–2004	3 958			2–5	27.3	25.2	15.1	12.6
					6–11	36.5	38.0	19.9	17.6
					12–19	36.8	31.7	18.3	16.4
Odgen CL et al 2008	2003–2006	8 165	Measured	2000 CDC	2–5	25.5	23.3	12.8	12.1
					6–11	33.9	32.6	18.0	15.8
					12–19	34.9	33.3	18.2	9.0
Odgen CL et al 2010	2007–2008	719	Measured	2000 CDC	0–2			10.0	9.0
		3 281			2–5	21.0	21.4	10.0	10.7
					6–11	35.9	35.2	21.2	18.0
					12–19	35.0	33.3	19.3	16.8
Broyles S et al. 2010	1973–1974	1 440	Measured	2000 CDC	5–9	12.6[1]		4.4[1]	
	1992–1994	1 037				28.0		13.8	
	1973–1974	1 917			10–14	15.9		6.1	
	1992–1994	1 429				34.5		18.6	
	2008–2009	317				51.0		33.6	
	1973–1974	1 013			15–17	16.4		5.7	
	1992–1994	607				29.8		14.8	
	2008–2009	192				48.4		29.1	

[1]Boys and girls combined
[2]Beiing/ Shanghai/ Inland cities

Original communications