Socio-demographic predictors of childhood overweight and obesity in Norway – an epidemiological study

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CONTENTS

Abstract

Background: The increase in childhood overweight and obesity over the last decades means that we urgently need to broaden our understanding of current predictors of childhood adiposity. Monitoring of children's weight and height enables us to identify risk groups, follow trends and evaluate interventions, which in itself might have important implications for future public health.

Aims: The overall aim of the thesis was to identify current risk groups for overweight and obesity in Norwegian children, differentiated between general and abdominal obesity. We aimed to examine urban-rural differences in overweight and obesity, and whether these differed in terms of maternal education (paper II). In addition the thesis sought to investigate whether parental marital status was associated with overweight and obesity and potential gender differences (paper III). The methodological study aimed to assess the impact instrument error might have on prevalence estimates in surveys (paper I).

Methods: Height, weight and waist circumference (WC) were measured in a nationally representative sample of 3166 eight-year-olds in the 2010 Norwegian Child Growth study (NCG). The main outcome measures were general overweight and obesity (BMI≥25kg/m^2) and abdominal obesity (waist-to-height ratio≥0.5) in addition to BMI and WC as continuous variables. Prevalence ratio (PR) (equivalent with relative risk, RR) was estimated using log-binomial regression. In the methodological study, data from the 2008 NCG study were utilised. The coefficient of variation (CV) of instrument error was used in simulations in order to study the impact it had on the prevalence estimates.

Results: Children living rurally were on average more overweight and obese (general and abdominal) than children in more urban areas. Children of low-educated mothers were also at higher risk of being overweight and obese than children of high-educated mothers and children living rurally especially. Additionally, height was on average lower in children with lower educational backgrounds. Children of divorced parents had higher prevalence of general- and abdominal obesity compared to children of married parents. Although formal tests of the interaction terms parental marital status by gender were not statistically significant, gender stratified analyses showed that the prevalence of abdominal obesity was significantly higher only amongst boys of divorced parents compared to boys with married parents. Furthermore, general overweight and obesity were more prevalent among girls (21.6 %) than among boys (16.5 %), whereas abdominal obesity was not significantly different between genders. In our methodological paper it was demonstrated that instrument error might lead to overestimation of the prevalence of overweight and obesity.

Conclusions: Our findings indicate that rurally residing children, children with low-educated mothers and children of divorced parents are at a greater risk of being overweight or obese (general and abdominal). Based on findings of the methodological study we elucidate the importance of maintenance or recalibration of measuring instruments to reduce instrument error and to obtain more accurate estimates in population-based surveys. The cross sectional nature of our data precludes the possibility of making causal inferences regarding the findings of the socio-demographic predictors. Nevertheless, our findings are of importance for policy-makers and scientists in the planning of preventive strategies to combat overweight and obesity among children, and also point to the importance of continuous monitoring of school children's anthropometry in Norway.

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Jar, December 2013

Anna Månsson Biehl

Abbreviations

BMI	Body mass index
COSI	the European Childhood Obesity Surveillance Initiative
CV	Coefficient of variation
IOTF	International Obesity Task Force
NCG	Norwegian Child Growth Study
NIPH	Norwegian Institute of Public Health
PR	Prevalence ratio
RR	Relative risk
SEP	Socio economic position
WC	Waist circumference
WHtR	Waist-to-height ratio
WHO	World Health Organization

List of papers

I) Impact of instrument error on the estimated prevalence of overweight and obesity in population-based surveys. *BMC Public Health 2013, 13:146 **

II) Adiposity among children in Norway by urbanity and maternal education: a nationally representative study. *BMC Public Health 2013, 13:842 **

III) Parental marital status and childhood overweight and obesity: A nationally representative study. *Submitted for publication, Oct 2013*

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1. Introduction

In 380 B.C Hippocrates stated: "*Corpulence is not only a disease itself, but the harbinger of others*" (1). Childhood obesity has been referred to as "one of the most serious public health challenges of the 21st century" (2), and obesity is an increasingly important risk factor contributing to the global burden of disease (1). Overweight and obese children have higher risk of remaining overweight and obese into adulthood and a higher risk of developing non-communicable diseases later in life (3-5). Moreover, self-esteem among obese children is lower, which in itself may be detrimental to the child (6). Preventing childhood obesity is probably the most promising means of reversing the obesity epidemic (7). Therefore, the identification of groups at increased risk of being overweight and obese is integral (8), and is explored in the current thesis.

1.1 Epidemiology of childhood overweight and obesity

"Epidemiology is the study of the distribution and determinants of disease frequency in human populations." (9: p.1). One fundamental assumption of epidemiology is that disease does not occur at random but in subgroups at higher risk due to exposure to physical and genetic agents or social, economic and cultural factors (10). Monitoring children's anthropometric measures provides the means by which to understand how adiposity is distributed. Descriptive epidemiology is useful in order to follow the development over time and to compare populations, and to identify predictors of overweight and obesity in the paediatric population. Finally, monitoring gives a solid basis for evaluating interventions (7).

One general pattern is that the entire body mass index (BMI) distribution has moved to the right, reflecting increasing proportions of overweight and obesity (11). However, in the United States, Australia and some European countries, there are indications that the BMI increase might be leveling off (12-14). However, some developing countries have experienced nutritional transition and report a conflicting picture of both under nutrition and over nutrition, also among children (15). There has been a shift in patterns from traditional diets to more Western diets (high in sugars, fat, and animal-source food) and inactivity (16, 17).

1.1.1 A brief review of anthropometric measures of children in Norway

Annual systematic measures of the height and weight of the total population of school children in Oslo were collected in the period 1920-1975 (18). There was a distinct reduction in height and weight during the war (1940-1945), showing children's growth to be affected by their environment and societal circumstances (18, 19). Liestøl et al. repeated similar measurements in 1980 and 1985 but only in girls. The results from 1920 onwards are shown in the graphs below. Figure 1 shows a slight increase in mean height in most age groups up until 1985, i.e. as long as data were collected and centrally processed. The post-war figures show a trend of decreasing mean weight, with an increase in the period 1975 to 1985 (figure 2); mainly in the upper percentiles, which reflect an increase in the proportion of heavy girls (19).

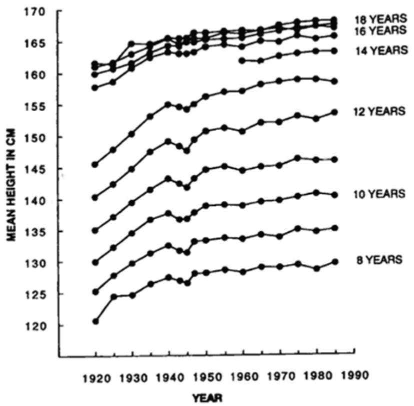

Figure 1: Mean height of 1-year age groups of **schoolgirls** in Oslo 1920 to 1985. (Liestøl *et al* 1995, reproduced with permission.)

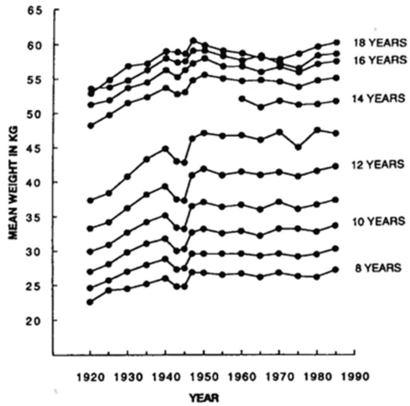

Figure 2: Mean weight of 1-year age groups of **schoolgirls** in Oslo 1920 to 1985. (Liestøl *et al* 1980, reproduced with permission.)

Sundal undertook a systemic collection of the anthropometric data of children aged 0 – 15 years living in Bergen in the 1950s (20); the basis for the first Norwegian growth charts, as did Waaler in the 1970s (21); and the latter forms the basis for comparison with recently collected data by Juliusson (further described in 1.1.2).

The latest example of comparable data over time in Norway is Young-HUNT; the adolescent part of the Nord-Trøndelag Health Study. Young-HUNT 1 was initiated in 1995-97 and followed by Young-HUNT 2 in 2000-01 and Young-HUNT 3 in 2006-08 (22). Young-HUNT data have been compared to systematic measurements of peers in the same geographical area in 1966-69, providing greater insight into growth-trends among adolescents over more than four decades. The data show a considerable increase in overweight and obesity amongst adolescents in Nord-Trøndelag, with a more pronounced increase in boys than in girls (22, 23).

1.1.2 Childhood overweight and obesity the last decades

Most of the available data on childhood overweight and obesity in Norway are based on either small samples, performed in urban areas or rely on self-reported measurements. An overview shows Norwegian studies and the prevalence estimates of overweight and obesity from 1995 onwards (22-33) (appendix I). The main findings of studies with objectively measured anthropometric data will be presented in the following.

The anthropometric data of children aged 0 – 19 years were collected in the Bergen Growth Study in 2003-06 (34). To enable comparison with similar data from 1971-74 (21) immigrant children, amongst others, were excluded. Increase in weight in this period was limited to the upper percentiles of weight-for-height in children aged between 6 and 11. In 2003-06 overweight and obesity was more prevalent amongst girls aged 6-11 years (18.4 %) than boys (15.7 %) , although this gender difference was not statistically significant (30).

In 2005-06 physical activity and anthropometric measurements were collected for Norwegian children aged 9 and 15 (35). This study also showed overweight and obesity to be more prevalent among girls than boys, whereas it was the opposite among the 15-year olds. Subsample data restricted to children from Oslo were compared with data collected in 2000 relating to 9 year-olds from Oslo (27). No changes in BMI were reported, whereas there was a significant increase in waist circumference (WC) for both genders from 2000 to 2005-06 (26). Furthermore, a follow-up of the nationwide sample (2005-06) was conducted in 2011, showing no significant increase of overweight and obesity among 9 year olds, whereas a borderline significant increase in overweight and obesity was found in 15 year old boys.

Finally, in 2007 anthropometric data were collected from 11 year olds in counties surrounding Oslo (31). The estimates of overweight and obesity were suspiciously low compared to the studies discussed above, but still consistent with findings regarding gender differences; with overweight and obesity more prevalent among girls. This indicates that overweight and obesity is more prevalent, and that it has increased the most among teenage boys (22, 23), whereas in younger children, overweight and obesity is more prevalent among girls (22, 30, 36).

In terms of abdominal obesity, data on WC of Norwegian children are scarce and restricted to the "Oslo-subsample" discussed above (26). A research group in Bergen has developed Norwegian reference values for WC and waist-to-height ratio (WHtR) (37) (further described in 1.3.1, *Abdominal obesity*).

The above overview of Norwegian studies illustrates the challenges inherent in the interpretation of results in terms of time trends and comparisons between subgroups and regions. Most data refer to restricted populations, small samples or data which have been obtained during different periods, which might imply that time trends are mixed up with geographic variations. Further, comparison might be limited to certain age groups and comparability impeded by different age categorisations. High-quality data of nationally representative samples and repeated measurements would therefore be preferable.

A review conducted in 2006 revealed that only 15 of 53 Member States in the World Health Organization (WHO) European Region had nationally representative and objectively measured weight- and height measurements of children aged 0-6 years, whereas 19 countries monitored overweight and obesity in adolescents (38). Another recent review based on objectively measured anthropometric measurements in nationally representative samples of European adolescents reported that data were identified for only half of the countries and that the quality of the studies and comparability varied greatly (39).

The WHO's European Childhood Obesity Surveillance Initiative (COSI) was established as a standard surveillance system to facilitate comparisons of nationally representative samples, examined according to common protocol. It was jointly developed by the WHO Regional Office for Europe and the participating member states. The Norwegian Child Growth study (NCG) (36) followed the protocol of COSI (40).

1.2 Factors that affect overweight and obesity among children

Whether obesity is a disease or not is still debated (41). Kopelman states that "Obesity is not a single disorder but a heterogeneous group of conditions with multiple causes." (42). Obesity is a complex condition with several causal contributors (41), and is determined by an interaction between genetic, environmental and psychosocial factors. Many of these factors are beyond the individuals' control (41), which might contribute to an even greater harm to children and young individuals. Still, overweight and obesity is considered preventable. A presentation of a range of factors that affect the development of overweight and obesity follows.

1.2.1 Genetics

Overweight and obesity tend to aggregate within families (43). If one parent is obese then the risk increases that the child will become an obese adult (44, 45). To determine whether this is due to genetic or environmental (lifestyle related) factors, or an interaction, is difficult for many reasons (42). The genetic contribution that explains the variance of BMI is significant, suggesting that genetic factors play an important role in determining individual differences in adiposity operating through susceptibility genes (46). This is consistent with Stunkard et al's study from 1990, which assessed the relative importance of genetic and environmental effects on BMI by studying twins who grew up apart. They concluded that the genetic influence on BMI was substantial and that childhood environment had a limited influence (47). The environment driven influence seems either to be attenuated or strengthened by susceptible genes. These genes are not essential or, by themselves, sufficient to explain the development of adiposity, but indicate that genetic factors determine who is most susceptible to becoming obese in any given environment (48). Genetic pathways that contribute directly to obesity have not yet been elucidated (49). Exceptions are some rare single gene defects, where obesity is a consistent finding (e.g. Prader-Willi syndrome) (42). Genome-wide association studies have identified common genetic variants associated with obesity (fatness), but each with a weak effect (50).

1.2.2 Environmental factors

From a historical perspective, natural selection has probably favoured those individuals with low metabolism (parsimonious energy metabolism). Radical societal changes in terms of nutrition and food availability, in combination with a reduced need to be physically active, is likely one part of the explanation behind the obesity epidemic; the concurrence of evolutionary heritage of biological factors interact with technological advances (51). Individuals (or tribes), who have not preserved traditional lifestyle, with greater genetic susceptibility are worse affected. For example, the dramatic environmental changes among American Indians tribes and Alaskan Natives, each with their own traditions, have caused poorer health status and higher prevalence of obesity than in the general US population (52).

Lifestyle related factors like diet and physical activity level have changed in Norwegian children, as has already been noted. This reflects the fact that food availability has increased and the extensive consumption of energy-dense foods and soft drinks (38: ch. 7, 53). In combination with increased inactivity, e.g. due to screen activities, changing patterns of diet might impact upon children's growth and weight status (54, 55).

1.2.3 Perinatal factors

Obesity during pregnancy is associated with gestational diabetes. There is no clear evidence that exposure to gestational diabetes is associated with childhood obesity (51). However, an association between gestational diabetes and greater mean birth weight has been shown, whereas the association was significantly attenuated when adjusting for maternal pre-pregnancy BMI (56). Infants of women with gestational diabetes have higher percentage body fat compared to the infants of healthy mothers (57).

Breastfeeding is another perinatal factor, with substantial research undertaken in this field. However, whether breastfeeding prevents the development of overweight and obesity later in life is still debated (58, 59).

Both low- and high birth weight are associated with childhood overweight and obesity; size and growth (catch-up growth) during infancy are associated with increased risk of obesity and more central fat distribution among children and adults (60, 61). Findings from a study, based on data from the NCG point to early infancy as the first critical period for the onset of overweight at 8 years (62).

The proportion of macrosomic offsprings (≥4500 g) decreased between 2000 -2011 in Norway (figure 3) (63). Likewise, the mean birth weight increased during the 1990s but decreased during the 2000s and is now at a normal level (figure 4)(64). Children born in 2002 make up the 2010 NCG sample; the same year that mean birth weight and the proportion of children with high birth weight (≥4500 g) hit peak levels in Norway. Results from the three rounds of the NCG-study (2008, 2010 and 2012) were relatively stable. Nonetheless, the highest prevalence of overweight and obesity was reported among children born in 2002 (36). One may wonder if the proportion of children with high birth weight and the proportion of overweight and obese children at 8 years of age will continue to correlate in subsequent age cohorts. This can be explored by following systematic measuring of children.

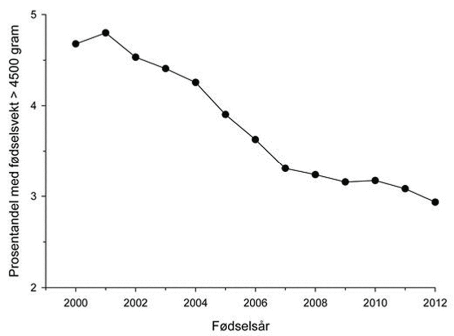

Figure 3: The proportion (%) of infants with birth weight ≥4500 g, 2000 to 2012.

Source: Norwegian Institute of Public Health, 2013, Andelen tunge fortsetter å gå ned [internet] (http://www.fhi.no/artikler/?id=106894).

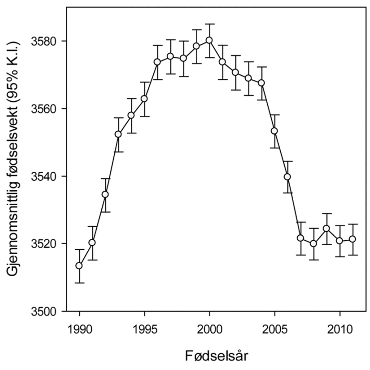

Figure 4: Mean birth weight (gram) in Norway, 1990 to 2011.

Source: Norwegian Institute of Public Health, Årstabeller for MFR for 2011, 2013.

1.2.4 Parental socio-economic position

Social stratification is of significance for health and the development of diseases. The term socio-economic position (SEP) is commonly used in health research (65). A number of indicators including occupation, income and education, are used, with each of these indicators measuring a different aspect of SEP. The ability to distinguish between factors that influence different groups in society varies and depends amongst other things on health outcome and the population being studied. Education is a frequently applied indicator in epidemiology and is used as a generic measure of SEP (65).

The association between SEP and child obesity varies across countries worldwide (66, 67). In developed countries there is largely an inverse relationship between SEP and adiposity (68), including Norway, based on self-reported data (29, 69) and objectively measured anthropometric data (30, 31). These findings are consistent with findings from Sweden, Denmark and Finland (70-72). Brundtland et al. compared the growth of children from varying social strata (areas with varying average income) in Oslo and found that prior to the war children from high-income areas were taller than children from lower strata. Until about 1955, children from the higher strata also weighed more, whereas in 1970 children from lower strata weighed more (18). Brundtland et al. reported that height differences between areas had nearly disappeared in 1970 in Oslo, while mean weight still was highest in low-income areas (18, 19). This information suggests that predictors, like SEP, are context- and time dependent. How various risk groups develop over time thus requires regular updates.

1.2.5 Urban-rural area of residence

Like the association between SEP and adiposity, the association between degree of urbanity and adiposity varies across countries. High SEP was reported to be associated with obesity in China and Russia, whilst obesity was more prevalent in urban areas of China and rural areas in Russia (66). Both in Norway and other developed countries, obesity is markedly more prevalent among adults from rural areas (73, 74). A recent Norwegian study of adults reported that obesity, over time, has become more prevalent in rural districts, with this only partly explained by educational inequalities between central and rural districts (75). It is well-known that parental obesity is a strong predictor of child- and adolescent obesity (76).

In almost all low- and middle income countries urban children are taller and heavier than children in rural areas (77), with the difference explained by the considerable advantage urban children have in term s of nutrition. Child and adolescent overweight and obesity measured in terms of geographical differences in developed countries have previously been reported in Sweden (71, 78-80), Finland (72, 81), Italy (82), the US (83-85), Canada (86-88) and Iceland (89). In these studies, overweight and obesity had greater prevalence in rural areas, except for one study from New Zealand reporting leaner rural children (90). A Norwegian study based on 2008 NCG data has published findings on urban-rural differences, indicating a greater proportion of overweight and obese children in rural areas. However, the study did not contain data on SEP or other socio-demographic variables at individual level (91).

1.2.6 Country background

Large changes in the socio-demographic composition, like increased immigration, in Norway and other Western countries over recent decades make it important to examine the effect this might have on childhood obesity. Previous studies have shown that immigrants to developed countries more rapidly develop obesity than the host population (26, 92-95). Immigrant families are exposed to cultural changes, including different food habits to that of the host population. Poor language skills might contribute to making the choice of healthy foods harder (96). The effect of acculturation was assessed in a Norwegian sample of adult immigrants living in Oslo. Acculturation was measured as language skills (proficiency in the Norwegian language), with those immigrants with better skills had more preferable BMI changes, whereas immigrants' time of residency did not have any effect on BMI changes (97). Large differences in adiposity between immigrant groups from developing countries have been reported among grown-ups (98) and adolescents (99) in Oslo, Norway.

1.2.7 Parental marital status

In recent decades the numbers of families where parents are either cohabiting or divorced have increased in developed countries. It is claimed that the risk of a cohabitation dissolving is between double to four times that of it leading to marriage (100). Family structure is an important predictor of child well-being. Family stress has a role in the development of both overweight and underweight among children (101). Størksen et al investigated the long-term effects of parental divorce on children at an average of 8 years after the divorce. They reported moderate but significantly higher levels of anxiety and depression and lower levels of well-being in adolescents who had experienced parental divorce compared to those who had not (102).

Previous studies have shown an association between family structure and overweight and obesity. Overweight and obesity were found to be more prevalent among children in single parent families and those with divorced parents (72, 103-107), whereas other studies did not find any association (30, 108, 109). Some such studies have methodological limitations; either small samples, self-reported data and/or parental marital status measured at birth, i.e. not at the time anthropometric measurements were taken (110-113).

1.2.8 Others

Certain CNS pathology (51), sleeping problems (114, 115) and diversity of gut microbes (116) are other possible risk factors for the development of childhood overweight and obesity.

1.3 Measures of overweight and obesity

Obesity is defined as "...a condition of abnormal or excessive fat accumulation in adipose tissue that presents a risk to health" (7, 117).; in that way is obesity linked to both excess fatness and risk.

Regarding the use of key terms in this thesis: The recommended terminology is used when prevalence estimates are presented, e.g. percentage of *overweight (including obesity)*, explained in 1.3.1. Referring to the phenomenon in general the term *overweight and obesity* is used. *Adiposity* is used as a generic term referring to both general overweight and obesity, and abdominal obesity. Occasionally, if referring specifically to e.g. *obesity* (BMI≥ 30kg/m^2), that specific term is used.

General overweight and obesity

Weight is the simplest measure of body size. To increase the correlation between weight and body fat, weight is adjusted for height (118). BMI, calculated as weight (kg) divided by the square of height (m^2), has been established as a valid but indirect measure of adipose tissue in epidemiological studies (119-121). BMI is cheap and easy to measure and reproduce. BMI measures the sum of both fat mass and fat-free mass, but gives no indication of the distribution of body fat. Although BMI has been found to fairly well indicate adult body fatness (122, 123), the use of BMI in children have more limitations. Childhood and adolescent BMI varies with age and gender, with an increase in BMI during growth explained mainly by increases in fat-free mass rather than the fat-component; the opposite of that which applies in adults (124). Both the International Obesity Task Force (IOTF) and WHO BMI-based systems (see 1.3.1) were evaluated using densitometry, and both were found to have a very high specificity (i.e. low proportion of non-overweight misclassified as overweight) but low sensitivity, especially among females adolescents (i.e. high proportion misclassified as normal weight) (125). A corresponding study was performed based on the Centers for Disease Control and Prevention's classification (CDC). This reported that the accuracy of BMI varied according to the degree of fatness; among children ≥95^{th} percentile (i.e. among relatively fat children) BMI was a specific indicator of excess body fat and moderately sensitive (126).

Abdominal obesity

WC is a complementary measure of body composition. Centralised body fat has health-implications and is associated with increased risk of cardiovascular and metabolic complications in children (127-132). The lack of population specific WC reference values has led to that WC has been used in conjunction with height (waist circumference divided by height). WHtR is commonly used measure.

Over the last few decades WC has increased in infants, children and adolescents to a greater extent than BMI (26, 133, 134). This indicates that the fat distribution has changed (or is changing) and suggests a steeper increase in abdominal fatness compared to height- and weight based adiposity measure (134, 135). Abdominal obesity can be assessed using WC-based measurements (128, 136-138), and is recommended as a means of both estimating the prevalence of abdominal obesity for epidemiological purposes and as a means of following these trends among children (7, 139).

1.3.1 Defining overweight and obesity among children

Using BMI and WC in the classification of childhood overweight and obesity is complicated by the numerous available systems, the existence of which hampers the comparison of epidemiological studies.

Classification systems are largely based on the distribution of adult BMI and therefore correlated to relevant adult risks (122). The adult cut-off points; BMI of 25 kg/m^2 for overweight and 30 kg/m^2 for obesity are related to risk of comorbidities and mortality (7). However, obesity-related morbidity is not as pronounced in children as it is among adults. There is still no consensus on whether a classification system for paediatric obesity should be linked to fatness rather than to BMI and the prediction of obesity-related diseases and/or health consequences (122). Measuring fat tissue is complicated in epidemiological studies.

The European Childhood Obesity Group (ECOG) has recently published recommendations for the use of classification systems and terms, with the intention of clarifying definitions, reduce confusion and allowing greater comparison between studies (140). The usage of international systems in national contexts - to ease international comparison - is controversial since maturation patterns differ between countries and thereby impact upon body composition (122).

General overweight and obesity

In the year 2000 the IOTF provided cut-off points for childhood BMI (2-18 years) based on representative cross-sectional data from six countries and linked to adult cut-offs corresponding to centiles that match 25 kg/m^2 and 30 kg/m^2 at 18 years of age (141). In this sense, cut-offs were constructed in reference to WHO health related cut-off for adult obesity. The impetus behind IOTF's cut-off values was based on the need for coherence between childhood and adult indices of obesity.

In 2007, the WHO developed BMI-for-age reference values for school-aged children and adolescents (5-19 years) (142), referring to standard deviation scores (SDS). In 2006, the WHO released growth standards for pre-school children; the WHO Child Growth Standards (0-5 years); based on samples of breastfed children from six countries worldwide (143). The CDC presented revised age- and sex-specific growth charts for the United States in 2000, which also serve as reference values (144).

Table 1 shows the various classification systems (IOTF, WHO and CDC) and different terminology, demonstrating the challenges involved when comparing estimates.

Table 1: Various classification systems (IOTF, WHO and CDC) and different terminology and cut-off values/references demonstrate the challenges involved when comparing estimates.

Classification system			
IOTF[a]			
Terminology	Overweight excluding obesity	Obesity	Overweight (including obesity)
Cut-off values	25≤ BMI < 30*	BMI ≥ 30*	BMI ≥ 25*
WHO[b]			
Terminology	Overweight excluding obesity	Obesity	Overweight (including obesity)
References	+1SDS≤ BMI < +2SDS**	BMI ≥ +2SDS**	BMI ≥ +1SDS**
CDC[c]			
Terminology	Overweight	Obesity	Overweight and obesity
References	85th ≤ BMI < 95th centile	BMI ≥ 95th centile	BMI ≥ 85th centile

*) BMI ≥25 corresponds to centiles that match BMI of 25 and 30 at the age of 18 years (adults). **) SDS (standard deviation scores) a) IOTF (International Obesity Task Force) b) WHO (World Health Organization) c) CDC (The Center for Disease Control and Prevention)

The figure below illustrates the diverging results of these classification systems, with three different definitions used to evaluate one data set (figure 5). The graph stems from the Portuguese WHO COSI-study (145).

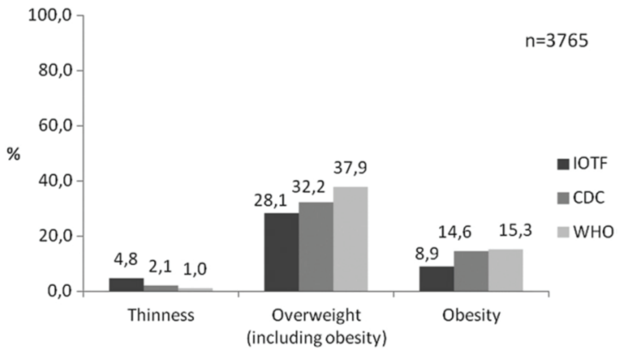

Figure 5: Portuguese children's nutritional status defined by International Obesity Task Force, Center for Disease Control and Prevention, and World Health Organization criteria. (Rito *et al* 2012, reproduced with permission.)

Abdominal obesity

As already mentioned there are no universal criteria or cut-offs for either WC or WHtR. Several countries, including Norway, have developed age- and gender-specific reference values for WC and WHtR (37, 146-150). WHtR≥0.5 has been suggested as a simple measure of abdominal obesity, though it has not been validated (131, 132). It is claimed that WHtR≥0.5 identifies youths with a higher likelihood of having cardio metabolic risks (129-131). The advantage of using a cut-point of ≥0.5 is that there is no need for population- and/or age- and gender-specific cut-off values. It also suggests an easily understood public-health message: “keep your waist circumference to less than half your height” (132).

2. Aims of the study

The main aim of the thesis was to identify groups of Norwegian children at increased risk of being overweight and obese.

The more specific aims were:

Paper I	To evaluate the validity of data collected by the School Health Service using uncalibrated instruments; whether instrument error will have an impact on the estimates of childhood overweight and obesity in population-based surveys.
Paper II	To investigate the urban-rural gradient of childhood overweight and obesity and whether it differs according to level of maternal education.
Paper III	To investigate the associations between parental marital status and general overweight and obesity, and abdominal obesity and whether these associations differ in terms of gender.

3. Materials and methods

The study data are from the nationally representative Norwegian Child Growth Study (NCG); a collaboration between the Norwegian Directorate of Health, the Norwegian Institute of Public Health and the School Health Service. NCG followed the protocol from the WHO European Childhood Obesity Surveillance Initiative (COSI) described in the introduction (1.1.2). Corresponding studies have been carried out in 25 European countries (151).

3.1 Study design, study population and sampling methodology

In the NCG, third graders were examined at the same schools in 2008, 2010 and 2012. This thesis is based on data from the 2008 (paper I) and 2010 surveys (paper II and III).

A nationally representative sample of 3474 children from 127 schools (in 2008) and 3166 children (1629 boys and 1537 girls) from 125 schools (in 2010) with complete anthropometric measurements, participated in the NCG. Mean age in 2010 was 8.3 years (SD=0.3 years).

To limit the sample size and yet still ensure national representativity a stratified two-stage sampling design was used (figure 6). The primary sampling unit was *county*. Ten (10) of nineteen (19) counties were selected (Akershus, Oslo, Vestfold, Vest-Agder, Rogaland, Hordaland, Møre og Romsdal, Sør-Tøndelag, Nordland and Troms) by simple random sampling among all four geographical strata (ie. the administrative Health Regions) in order to ensure nationwide coverage and the possibility of reporting on all parts of the country. The secondary sampling unit was *school*. Initially, 130 of 3920 public primary schools were selected randomly, and the sample was intended to be proportional to population size in each county. Schools with only one or two pupils in the relevant grade were excluded from the NCG, which in 2008 resulted in 127 schools participating. In 2010, another two schools were excluded due to their having too few third graders, resulting in the participation of 125 schools.

3.2 Data collection

Data collection was conducted in October and first week of November by the school health nurse/s at each school. Prior to data collection school nurses participated in a workshop in each county (2008) or region (2010 and 2012) where they were given training on how to perform the necessary measuring procedures and collect the necessary correction values, all according to a standardised protocol (appendix II).

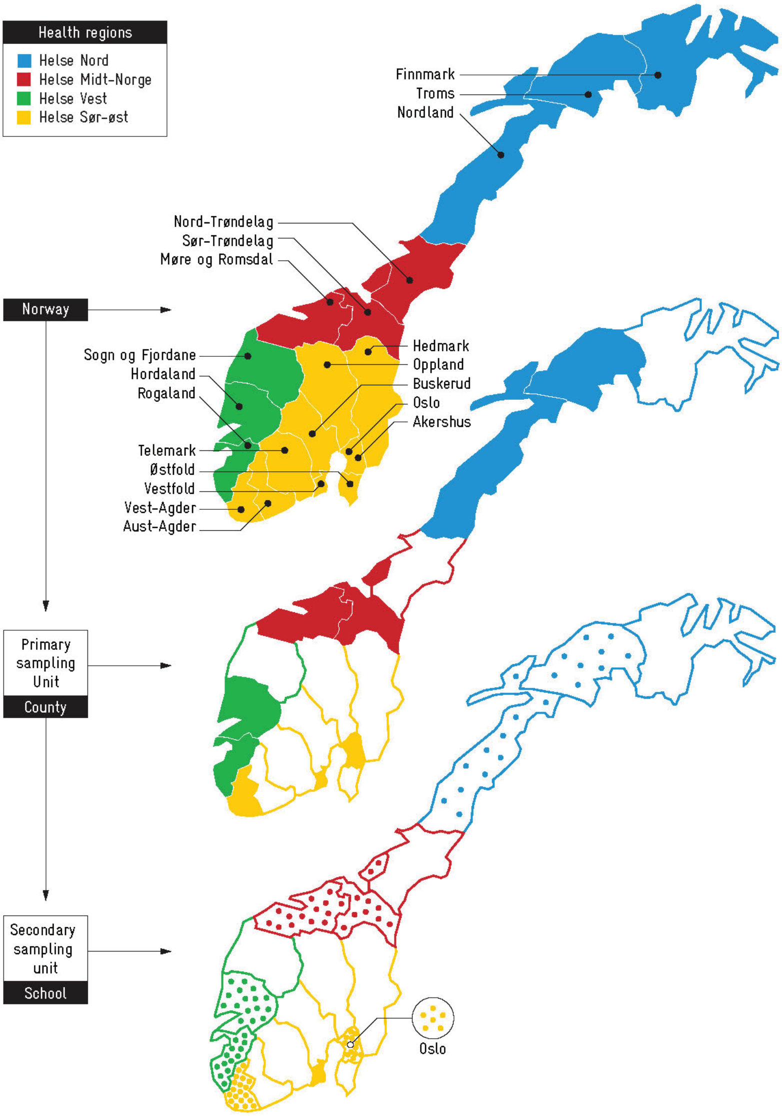

Figure 6: Two-stage sampling of children in the Norwegian Child Growth study. (Illustration by Martin Asbjørnsen.)

3.2.1 Anthropometric measures

Body weight and height were measured while the children were wearing light indoor clothing without shoes and were recorded to the nearest 0.1 kg and 0.1 cm respectively (152, 153). BMI was calculated as weight/height ^{x} height (kg/m^2) and children were classified as overweight or obese based on age- and gender specific cut-off values of BMI for children developed by the IOTF (141) and the WHO definitions for children aged 5-19 (142, 154). Additionally, the school nurse completed the ELEV-skjema (PUPIL-form, appendix III) and measures were corrected if the child wore items other than light indoor clothing: 100 grams were added for some additional light clothing or plus 500 grams for heavier clothing.

Waist circumference (WC) was measured to the nearest 0.1 cm with arms hanging relaxed along the body. WC was measured with a measuring tape midway between the lower rib margin and the iliac crest (153). Marks were made on the skin of each child with a felt-tip pen in order to ensure the correct level of measurement. Waist-to-height ratio (WHtR) was calculated as WC/height (cm/cm), with a ratio equal to or higher than 0.5 classified as waist-to-height ratio ≥ 0.5 (WHtR ≥ 0.5). Measurements were taken only once and were recorded on the ELEV-skjema (PUPIL form). Data entry was done manually. Height, weight and WC were entered twice, and any punching errors were then corrected.

Furthermore, correction values were collected at the same time as the anthropometric data of the children in 2008 and 2010 (procedure explained below). The intention was to obtain information on the accuracy of measurements, i.e. how close the measure was to its ***true*** value. Cases of inaccuracy were referred to as instrument error. Thus, the instrument error was equivalent to the correction value and corresponds to the difference between the *true* value and the uncorrected value measured by a (uncalibrated) instrument.

Each school received a reference weight and length which were about the weight and length of third graders; 28 kg and 120 cm. The procedures were thoroughly explained and illustrated in the Method booklet (appendix II) and in paper I, p. 2. On the basis of the corrections values reported in the SKOLE-skjema (School form, appendix IV) the anthropometric measures of the children were corrected post-hoc. Thus, the corrected measures corresponded (in theory) to measures taken by calibrated instruments, even though the instruments themselves were not calibrated.

Components of measurement error associated with measurement technique were not considered in this study.

3.3 Ethics and approvals

NCG was evaluated by the Regional Committee for Medical Research Ethics (reference nr: 2010/938a) and approved by the Norwegian Data Inspectorate (reference nr: 08/00709-4/IUR). Detailed information about the study and consent forms (appendix V) were sent to the parents or guardians via the school nurse beforehand. Written informed consent was obtained from a parent or legal guardians via the school nurse prior to participation in the study.

4. Summary of papers

Paper I

Impact of instrument error on the estimated prevalence of overweight and obesity in population-based surveys.

The fact that instrument error increases the variance of the distribution of BMI is the basis for this study. Combined with a defined cut-off value this may impact upon the estimated prevalence of overweight and obesity. To ensure high quality surveillance data, we wanted to assess the impact instrument error might have on prevalence estimates of overweight and obesity, due to uncalibrated scales and stadiometers.

Anthropometric measurements from a nationally representative sample (the 2008 NCG) were used. Each of the 127 participating schools received a reference weight and a reference length to determine the correction value. Correction value corresponds to instrument error and is the difference between the true value and the measured, uncorrected weight and height at local scales and stadiometers. Simulations were used to determine the expected implications of instrument errors. To systematically investigate this, the coefficient of variation (CV) of instrument error was used in the simulations and was increased successively. Simulations showed that the estimated prevalence of overweight and obesity increased systematically with the size of instrument error when the mean instrument error was zero. The estimated prevalence was 16.4% with no instrument error and was, on average, overestimated by 0.5 percentage points based on observed variance of instrument error from the NCG. Further, the estimated prevalence was 16.7% with 1% CV of instrument error, and increased to 17.8%, 19.5% and 21.6% with 2%, 3% and 4% CV of instrument error, respectively. In conclusion, failure to calibrate measuring instruments might lead to overestimation of the prevalence of overweight and obesity in population-based surveys.

Paper II

Adiposity among children in Norway by urbanity and maternal education: a nationally representative study.

In this cross-sectional study we wanted to investigate the urban-rural gradient in adiposity and whether the association differed by maternal education.

Height, weight and waist circumference (WC) were measured in 3166 eight-year-olds participating in the 2010 NCG. Risk estimates for overweight (including obesity) and abdominal obesity (WHtR≥0.5) were calculated by log-binomial regression. Mean BMI and WC and risk estimates of overweight (including obesity) and WHtR≥0.5 were inversely associated with both urbanity and maternal education. These associations were robust after mutual adjustment for each other. Furthermore, there was an indication of interaction between urbanity and maternal education, as trends of mean BMI and WC increased from urban to rural residence among children of low-educated mothers (p = 0.01 for both BMI and WC), whereas corresponding trends for children from higher educational backgrounds were non-significant (p > 0.30). However, formal tests of the interaction term urbanity by maternal education were non-significant (p-value for interaction= 0.29 for BMI and = 0.31 for WC). In conclusion, both children living rurally and children of low-educated mothers had higher mean BMI and WC than children living in more urban areas and children of mothers with higher levels of education.

Paper III

Parental marital status and childhood overweight and obesity: A nationally representative study.

On the basis of the 2010 NCG (see paper II) we aimed to examine whether parental marital status was associated with general overweight and obesity, and abdominal obesity among children. We also sought to explore whether the associations differed according to gender.

The main outcome measures were general overweight (including obesity) (BMI≥25kg/m2) using IOTF cut-offs and abdominal obesity (waist-to-height ratio≥0.5). Prevalence ratios, adjusted for possible confounders, were calculated by log-binomial regression. General overweight (including obesity) was 1.54 (95 % confidence interval (CI): 1.21-1.95) times more prevalent among children of divorced parents compared to children of married parents, and the corresponding prevalence ratio for abdominal obesity was 1.89 (95 % CI: 1.35-2.65). Formal tests of the interaction term parental marital status by gender were not statistically significant. However, in gender-specific analyses the association between parental marital status and adiposity measures was only statistically significant in boys (p=0.04 for general overweight and obesity, and p=0.01 for abdominal obesity). The estimates were robust against adjustment for maternal education, family country background and current area of residence. In conclusion; general overweight and obesity, and abdominal obesity were more prevalent among children of divorced parents, with the study providing valuable information by focusing on societal changes in order to identify vulnerable groups.

5. General discussion

5.1 Methodological considerations

The degree to which methodological issues might have influenced the above results is discussed in what follows.

5.1.1 Internal validity

There are two main types of error in epidemiological studies: random error and systematic error (or bias). Random errors are largely related to sample size and the variability of the sample. High variability due to small samples results in reduced precision of the estimates and thus influences the width of confidence intervals. Random error could be reduced towards zero if the sample size were infinitely large (155). Random errors in an observational study such as ours could also be random typing errors, e.g. when the nurses registered measurements or when data were entered into the database. However, these errors were minimized by entering the main variables (height, weight and WC) twice, whilst typing errors were corrected. Additionally, data were cleaned, in the sense that cases with missing or obviously erroneous height or weight were removed. A scatter plot of the anthropometric measures was used to identify potentially erroneous height and weight measures. In the second phase, which of the three variables was more likely to contain an error was assessed. If WC was the only likely error then the value rather than the entire record was deleted. If an error in weight or height was likely, then the entire record was deleted.

Geographical groups were stratified in terms of maternal education (figures 3 & 4 in paper II), which resulted in subgroups containing relatively few individuals, especially in rural areas. In addition, using gender stratified analyses when studying differences between parental marital status categories in paper III (figures 1 and 2) resulted in limited statistical power and imprecise estimates with wide confidence intervals.

Despite the fact that the NCG was carefully designed (confer 3.1), the potential for **selection bias** has to be addressed. First, the school nurses took the measurements. This was probably an advantage and might partly explain the high attendance rate of 89 % in 2010. The Regional Committee for Medical Research Ethics gave permission for the school nurses to remind the parents once about returning the consent form. The NCG-study requested the school nurses to register whether the parents/guardians did not want their child/ren to participate. Only 1 % of the parents were actively opposed to allowing their child to participate in the study. We have no information about the remaining 10 % and the reasons why they did not participate, although we can surmise that children are absent from school as a result of natural causes such as colds and other illnesses. Secondly, all children attending private and municipal schools were invited to participate, omitting only those private schools not accredited by *the Private Education Act* (and therefore without access to municipal School Health Service). Thirdly, as was described earlier (confer 3.1), sampling was designed so as to obtain samples proportional to population size based on an assumption of school size in each county. Significant deviations from proportionality were observed in the final sample and analyses were weighted in order to correct for significantly over- or under-represented geographical strata and counties, where analytical tools that took into account the two-stage sampling procedure were required. To sum up, given the high attendance rate, sampling methodology, appropriate analytic tools being used and including both public and private schools, selection bias is probably not a major concern in the NCG.

As described in 3.2.1, we envisaged the risk of **information bias** on the basis that the instruments (scales and stadiometers) used in the NCG were pre-existing at each school with no requirement for calibration or maintenance, which could potentially introduce bias at school-level. We therefore collected information on instrument error and corrected all measurements. Data on correction values were also used in paper I, which is further discussed later (confer 5.2 *Instrument error*). Moreover, information bias due to clothing was minimised by correcting for additional clothing, as described earlier in 3.2.1 and in paper II.

The **exposure variables** were obtained from the Norwegian population register and are considered high quality data; maternal education, area of residence and parental marital status. Immigrant education data might be less precise than for people educated in Norway due to delays in registration and self-reported data errors in some cases. The national education level of Norwegian mothers (women 30-40 years old) was reflected in our sample.

The total numbers of inhabitants in each municipality constituted the urbanity variable in paper II and III, as in several other Norwegian epidemiological studies (74, 156, 157). However, the validity of this variable can be questioned; to what degree does the population size of a municipality reflect urban-rural difference? Population size is a fairly crude measure and one cannot exclude that it may be inaccurate and not precise means of distinguishing between urban and rural characteristics. On the other hand, several studies have drawn similar conclusions to those we drew in paper II. The crude measure might lead to some misclassification of exposure and underestimation of real associations. A more precise definition of urbanity and an alternative measure could possibly have shown a stronger gradient.

Finally, in paper III, data on marital status were confined to a “snapshot” of current status, which implies that we did not have information on how long the parents had been married, or divorced. Nor was it clear whether the married couple with whom a child lived was made up of both its biological parents. Furthermore, the never-married category, including cohabiting, single and separated parents, was probably the most heterogeneous, containing both intact and dissolved relationships as well as single parents. The aim of the study was to investigate the association between parental marital status and child weight status. It was based on an assumption that marital conflict and/or dissolution might impact upon a child's weight status. Taking into account the low age of the children, the married parents were likely to be the biological parents, and thus the married category is most probably a valid measure. Likewise, the divorced category is unambiguous.

Confounding

A confounder is a risk factor that must be associated both with the outcome and the exposure variable. Confounding is common in observational epidemiological studies, with age and gender as common potential confounders.

All children included in this study were third graders and mean age was evenly distributed in the sub-groups in paper II and III, and varied a maximum of ten days between the groups. Age was therefore not considered a confounder in our study. In paper II, gender differences in adiposity were observed in the descriptive statistics. That was the rationale for adjusting for gender in further analyses. In paper III the analyses were stratified for gender.

In our studies we hypothesised that overweight/obesity would vary by area of residence, level of maternal education and parental marital status. To take into account potential confounders, DAGs (directed acyclic graphs) were drawn to investigate causal pathways. Despite few variables and simple DAGs, it could be challenging to decide whether a factor was a confounder or a mediator. Regarding paper II, maternal education could impact the association between area of residence and adiposity. On the other hand, it is equally natural to assume the impact is opposite (figure 7 and 8).

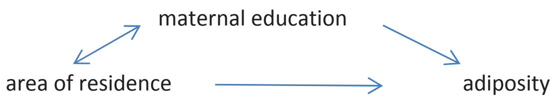

Figure 7: Maternal education impacts the association between area of residence and adiposity.

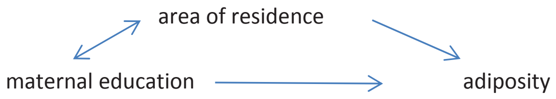

Figure 8: Area of residence impacts the association between maternal education and adiposity.

Whether education (or area of residence) should be considered a mediator or a confounder in the aforementioned example is not crucial, because the estimates were essentially unchanged when adjusting the factors mutually (confer table 3 in paper II). The same applied for the associations in paper III, where country background could be a potential confounding factor. Regardless, the association did essentially not change after adjusting for country background.

However, we cannot exclude that a measure that better captures the differences in the family's total SEP resources could help explain urban-rural differences in adiposity among children. On the other hand, our results show that education on its own explains differences in adiposity, as stated above. Secondly, analyses based on paternal education were also run with mainly the same results as those based on maternal education. However, we did not have data on family income. Since we had no information on whether the parents had a shared economy, neither maternal nor paternal income (separately) was considered a valid indicator in this study.

Reliability

All nurses that carried out measurements had attended an NCG-course and training (described in section 3.2). Measuring the children was recommended to be undertaken by two nurses (observers). In some cases nurses from two "NCG-schools" in the same municipality cooperated the day measurements were taken, or the school nurse and the senior municipal health nurse carried out the measurements together.

Considering the large number of observers in the study reliability ought to have been assessed, though due to limited resources this was not done. Previous studies have reported that weight and height are precise measures (158-160). The inter-observer reliability of WC is fairly low (159), while the intra- observer reliability has been reported to be highly reproducible (161).

5.2 Main findings

The cross-sectional design does not allow conclusions to be drawn about causal relationships. Whether any of the predictors are causally related is a complex matter, as are many other relations studied in health research

Socio demographic factors

Our study confirmed previous findings on the **socio-economic differences** in adiposity, where children of high-educated mothers had the lowest prevalence of adiposity (paper II). This is in accordance with previous studies in Norway (29, 30, 69, 162) and Europe (68, 71, 163). Whereas we found that the risk of being abdominally obese almost doubled among children with low-educated mothers compared to those with high-educated mothers, the risk of the same children being generally overweight and obese was only about 30 % higher (paper II).

Longitudinal changes of altered body composition have been reported in both Norwegian adults and children (26, 164). A study of 9 year olds from Oslo did not find changes in BMI between the study periods in 1999/2000 and 2005, while WC increased significantly. Interestingly, analysis of interaction (SEP by study period) was borderline significant in girls, which implies that mean WC tended to increase in girls from low-SEP groups compared to high-SEP-groups over a 5-year- period. Despite cross-sectional data, our findings are in line with this and may indicate ongoing changes – of the fat distribution related to socio-economic background - that should be further investigated in future studies.

It would have been desirable to have information on lifestyle variables in the NCG in order to further explore to what extent physical activity and diet can explain SEP differences in adiposity. This also applies to the other exposure variables urbanity and marital status. However, we did not collect data on lifestyle factors given that a high attendance rate was given priority in the NCG and parents were as such not expected to fill out time consuming questionnaires.

In a Norwegian nationwide sample, a clear social gradient in objectively measured physical activity in children was not found (33), which might be due to weaknesses in study design; self-reported data on parental social position and/or small samples size when stratified according to both age groups and gender. However, Swedish studies, based on self-reported data on physical activity have revealed that a greater proportion of children of less educated parents were inactive for more than 4 hours per day and participated to a lesser extent in organised sport (71, 165). Based on these findings, no conclusions can be drawn regarding the impact of lifestyle factors on SEP differences in adiposity. Nonetheless, there are indications that children of low-educated parents have a less healthy lifestyle compared to children with parents having a high educational background, which probably is a factor of significance in childhood adiposity.

Height growth may be of interest and have implications for the development of adiposity. We found that the gradient for height was the inverse of the gradient for adiposity and increased significantly from low- to high education category in accordance with previous studies of children (166-168) and adults (169, 170). High-educated mothers have been shown to give birth to taller boys and girls (166, 171).

Findings in paper II cannot confirm that socio-economic differences in height have been reduced or disappeared among more recently born children, as was reported of 1975s school children from Oslo (18, 19). This is noteworthy since differences in living conditions in Norway have improved considerably since Brundtland et al. reported height differences between low- and high income areas in Oslo in the 1940s (18). Cavelaars et al. investigated educational height differences among adults in Europe and speculated as to whether improvements in living conditions in lower socio-economic groups have been replaced by other unfavourable conditions such as maternal smoking and an unbalanced diet, e.g. easily available unhealthy food (170). This reasoning is similar to that exploring socio-economic differences in weight and height in Scottish children aged 4-10 between 1974 and 2004 (172). They found that overweight and obese children were taller, regardless of parental income group, which points towards the view that observed inequalities (higher prevalence of overweight and obesity in lower-income groups) were not due to short stature per se. However, the relative height growth in the low-income group was significantly lower compared to that of the high-income group, whereas z-weight was similar in the two groups. This indicates that the reported increase in overweight and obesity in the lower socio-economic group was largely due to the relative limitation of height growth. Their suggested explanation was increasing intake of inexpensive, easily available, energy-dense and low-nutrient food in lower socio-economic groups and is in line with the speculations of Cavelaars et al. above.

We do not know to what extent this pertains to Scandinavian children growing up in more equal societies. In Norway there are no longitudinal data that could reveal such inequalities in growth among children and adolescents.

Our study of **urban – rural differences** showed that children in rural areas had on average higher weight, BMI and WC, with a significant trend of increase in these measures from urban to semi-urban to rural areas (paper II). After adjustment for maternal education the outcomes were practically unchanged. This indicates that the geographical differences remain independent of maternal education. As described in paper II, formal tests of the interaction terms urbanity by maternal education were non-significant. However, when BMI and WC were plotted separately, according to maternal education, different patterns were suggested across urbanity (confer paper II, figure 3 and 4). Only children of mothers with primary education showed a significant trend of increasing BMI and WC from urban to rural areas, whereas the association was not statistically significant in children with secondary and tertiary educated mothers. These patterns should be confirmed in future studies.

It is not clear which indicators should be used to identify geographical inequalities – or urban-rural differences, as previously discussed in 5.1.1. Although the common purpose of previous studies mentioned in 1.2.5 was clear, i.e. to explore the urban-rural gradient of childhood adiposity, various indicators have been used (such as population size in a certain area, population density, parental questionnaire characterising the neighbourhood in addition to national classification systems). For that reason it might be surprising that all the studies found urban-rural differences. What characterises urban and rural areas and what mechanisms underlie the urban-rural differences being captured in such diverse indicators?

Sund et al. have suggested that geographical inequalities in health in Scandinavian countries are probably largely the result of a spatial aggregation of health inequalities that exist on an individual level (173). The development of theoretical models has resulted in an increasing interest in the possible health effects of group-level factors (174). Until recently (the 1990s), the presumed explanation for differences in health and disease in populations was thought to be the characteristics of individuals (compositional effect). However, studies at an individual level might have limitations because processes that take place at group or community level may be ignored (contextual effect) (175). Multi-level analysis enables studying disease causation which extends across macro- and individual levels, explaining in turn how group/community- and individual-level variables interact (174). There is some evidence that contextual effect has an influence on health-outcomes beyond the individual level (176-178).

By complementing our study with a SEP indicator on area-level, e.g. municipality characteristics like average income among local inhabitants, it would have allowed comparison with previous findings, where Heyerdahl et al. found that the effect of urbanity was attenuated after adjustment of area-level SEP (91). However, it was out of the scope of the current study to conduct multi-level analyses.

Data on physical activity and diet by urbanity are scarce, or at least of samples comparable to Norwegian school children. Self-reported data on physical activity and diet from a Swedish study indicated that rural children played more outside than urban children while they also were inactive to a greater extent and participated less in organised sport activities than urban children (71). Moreover, consumption of sugar-sweetened beverages among children in rural areas was higher, although not significantly so. Lifestyle factors do not seem able to explain the observed urban-rural differences. On the other hand, the validity self-reported data on diet and physical activity can be questioned; e.g. it is cognitively demanding for young children to assess whether, for example, playing with friends should count as physical activity (179, 180).

We need to explore further why overweight and obesity is more common rurally. To further develop indicators would improve the basis upon which conclusions about underlying mechanisms for urban-rural differences can be drawn. Additionally, data on physical activity would also have been helpful.

In paper III, studying **parental marital status**, we found that general overweight and obesity was more prevalent among children of divorced parents, consistent with previous studies of parental divorce from Greece (104), Australia (106) and the US (107). Similar studies have found that children whose parents lived separately had a higher risk of being overweight or obese, i.e. comparison of one-parent and two-parent families (72, 105, 111), yet another group of studies showed that the association was strongly attenuated and no longer statistically significant after adjusting for SEP (108, 110).

As described in 5.1.1 (*Confounding*) neither maternal education, area of residence or country background explained the difference in adiposity between children of married and divorced parents.

We also showed that children of divorced parents had increased prevalence of abdominal obesity. We are not aware of previous studies that have investigated the association between parental marital status and abdominal obesity. In stratified analyses we found that boys might be at especially high risk of being abdominal obese. However, as discussed in 5.1.1, the gender-specific analyses had reduced statistical power. The formal test of interaction (gender by marital status) of the continuous variable WC was borderline significant (p=0.06). A larger sample is needed in order to confirm these findings. This can be done by combining the samples of the NCGs in future research.

Our study aimed to investigate whether family disruption was associated with general- and abdominal obesity among children, based on the assumption that marital conflict and dissolution could impact upon children's health and well-being (181) and thus contribute to weight problems (101). However, due to the cross-sectional nature of our data we could not conclude that the higher prevalence of adiposity in children with divorced parents was caused by the divorce itself. The conceivable explanations for the observed differences have been further discussed in paper III. To expand upon the current limited understanding of the effect of family structure on adiposity longitudinal data, more detailed marital status information and the opportunity to trace the reciprocal marital status of biological parents are all needed (as problematized in section 5.1.1). This would enable future research to differentiate between families of intact and dissolved relationships regardless of form (marriage or cohabitation). A US study based on longitudinal data made it possible to look into time periods of increased risk of adiposity related to the moment of family disruption. They found a significantly increased risk of obesity two years in advance of the family disruption, and years after the disruption (107).

Instrument error

To ensure valid anthropometric measures we collected information about instrument errors at each school, described in 3.2.1. These data were also used in a methodological study (paper I). The background for this study was the discovery of a stadiometer at a school nurse office that had remained mounted on the wall while the floor-covering had been removed a few years earlier, resulting in biased height-measurements

In paper I, we assumed that instrument error would increase the variance, and we hypothesised that increased variance would lead to overestimation of the prevalence of overweight and obesity (confer figure 1 in paper I, p.2). The mean of the instrument error (correction value) was set to zero to enable us to assess the impact of increased variance. We found that instrument error systematically increased the estimated prevalence of overweight and obesity (analogous to underweight, at the other end of the distribution), based on simulation of the coefficient of variation of instrument error from the 2008 NCG. As described in paper I, the scales measured on average 0.14 kg too little and the stadiometers measured 0.07 cm too little. Findings in paper I have no further implications for paper II and III, as all weight and height measurements were corrected according to the corrections values collected in the 2010 NCG (confer 3.2.1).

5.2.4 External validity

In terms of paper I, the outlined principle of inaccurate instruments could be applied to measurement error in general, and specifically for weight and height measuring instruments, regardless of country.

The results of paper II and III are generalisable to the Norwegian 8 year old population. The development of child growth and the increase in adiposity might limit the temporal validity of the findings. Generalising the results of NCG outside of Norway should be done with caution. However, results are probably externally valid for an extended Scandinavian child population, based on the fact that the overall distribution of anthropometric values is similar among young children in Denmark, Sweden and Finland. The SEP gradient is corresponding in Scandinavian countries as is the pattern of family structure. However, deviating conditions regarding ethnicity and the extent of immigration may mitigate the extent to which the results are generalisable.

5.3 Ethical considerations

In Norway, the systematic measuring of height and weight in schools declined during the 1980's (19) and in 1998 systematic measurements were replaced by *measurements on medical indication only*. In the 2011 national guidelines, the Norwegian Directorate of Health again recommends routine measurements of height and weight among children by the School Health Services (182). Unlike in 1920, where the great concern was whether children were sufficiently nourished, the reason now is quite the opposite.

It is important to emphasise that obese individuals should not be seen as undesirable in any context. At the same time, obese people are subject to enormous social stigma and discrimination (41). To the best of our knowledge, there is no consensus on whether to consider childhood obesity a disease or not, because there is a lack of a clear and specific definition of *disease*. However, childhood obesity could have lifelong health consequences, such as type 2 diabetes and cardiovascular disease and is as such a big challenge from a public health perspective. As I have suggested earlier in this thesis, it is crucial that we broaden our understanding of how overweight and obesity are distributed in the population; in subgroups and in geographical regions etc. The measure of interest is on a population level, but in order to get these data we need information on individuals, optimally every single one.

Some groups in Norway oppose the measuring of school children's height and weight. It is claimed that a focus on the body and body weight by regular weighing and measuring contributes to stigmatisation (183). This resistance and a public opinion, though limited, against measuring school children might be a response to a decade long focus on body (weight) and obesity. The opposing groups wish to emphasise the rights of the individual – and do not necessarily see that in public health, the individual must be seen as a part of the whole population. This issue was carefully considered in the planning phase of the NCG-study and discussed with experienced school health nurses. One great advantage was that the measurements were undertaken by the local school nurse, a professional health worker skilled in communicating with and relating to children. To ensure privacy, the school nurse saw only one child at a time, with children not told the results of the measurements. There is no one simple solution here, but the point is that as citizens and societies we have shared and common responsibility regarding health threats. This principle may also apply in this context, since a lack of knowledge about children's growth patterns will have profound implications for preventive health work (184).

6. Conclusions and future directions

By studying predictors of overweight and obesity, we have found vulnerable subgroups in the Norwegian child population. General- and abdominal obesity were more prevalent among children living rurally compared to urban areas and children with divorced parents compared to children of married parents. Children of low-educated mothers were also at higher risk than children of high-educated mothers and especially those children living rurally. We also found educational height differences; children of low-educated mothers were on average lower. Furthermore, in a methodological study we found that failure to calibrate measuring instruments is likely to lead to increased variance of the BMI distribution, which in turn might impact the estimated prevalence of overweight and obesity in population-based surveys.

Prevention of overweight and obesity in the child-population (as well among adults) is challenging. It has been claimed that "Like cholera, obesity may be a problem that cannot be solved by individual persons but that requires community action." (185). The educational inequalities in adiposity and height that we have observed may be critical because the enduring socio-economic disparity in children will undoubtedly contribute to maintaining socio-economic differences in health. Structural measures aiming at giving the children equal preconditions for good health; ensuring that the good choices are easier to make for the families and for the children, are important. Preventive strategies should target risk groups as well as at the entire child-population so as to maximise health gain. A White Paper (St.meld. 34 2012 -2013) specifies that the municipalities are required to have an overview of population health, and emphasises their particular responsibility for child and adolescent health. Future practise should therefore accentuate a sustained effort of periodically monitoring comparable anthropometric measurements of representative samples of children and adolescents. Regardless of chosen policies, monitoring will enable effective evaluation of any interventions and surveillance of future developments.

Future research

Obtaining longitudinal data would help us to study the development of children's height and weight, which is significant in itself to reveal the development of socio-economic inequalities. It will provide information on how general- and abdominal obesity is distributed; over time and in subgroups. Moreover, longitudinal data will increase our understanding of how family structure might impact on the development of overweight and obesity. Further research should be aimed at increasing knowledge of why rural children are more overweight and obese and developing indicators to better understand the mechanisms behind the observed urban –rural differences. Geographic Information Systems (GIS) could be developed for this purpose; the physical environment of the community, e.g.

where the schools and their catchment areas are situated, could be analysed and the degree of urbanity be determined. Finally, to broaden the spectrum of indicators, at a minimum we should study how adiposity is distributed by ethnicity in a nationally representative sample.

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Appendix

I - Overview table

An overview of Norwegian studies - the prevalence of overweight and obesity, from 1995 onwards.

Studies not considered being representative other than regarding a very limited subpopulation or geographical area are excluded in this overview.

Ref. study	Authors	Age of subj. (n) boys/(n) girls	Population	Year measured	O[1]/ S[2]	OWOB boys	OWOB girls	OW boys	OW girls	OB boys	OB girls	Definition
(25)	Anderssen, SA et al	9 702/605	Norway	2005-06	O	15.6	19.4	12.8	14.7	2.8	4.7	IOTF
(25)	Anderssen, SA et al	15 514/478	Norway	2005-06	O	13.6	12.9	9.2	11.8	4.4	1.3	IOTF
(33)	Kolle, E et al	9 665/708	Norway	2011	O	16.7	20.5	11.6	17.3	5.1	3.2	IOTF
(33)	Kolle,E et al	15 504/456	Norway	2011	O	17.2	16.1	14.0	14.2	3.2	1.9	IOTF
(24)	Juliusson, PB et al	4-15 2086/2029	Bergen	2003-06	O	14.6	17.7	12.5	14.8	2.1	2.9	IOTF
(26)	Kolle, E et al	9 174/174	Oslo	1999-2000	O	11.5	13.8					IOTF
(26)	Kolle, E et al	9 247/193	Oslo	2005	O	17.0						IOTF
(27)	Klasson-Heggebø, L et al	9 211/196	Oslo	2000	O	mean BMI 17.0 (SD2.1)	mean BMI 17.1 (SD2.4)					-
(27)	Klasson-Heggebø, L et al	15 167/180	Oslo	2000	O	mean BMI 20.2 (SD2.4)	mean BMI 20.1 (SD3.2)					-
(28)	Andersen, LF et al	4th grade 328/336	Norway	2000	S	17.3	18.8			3.0	4.0	IOTF
(28)	Andersen, LF et al	8th grade	Norway	2000	S	11.5	11.5			2.5	1.1	IOTF
(29)	Groholt,EK et al	15-16	Norway	2000-04	S			14.8	8.8	2.9	1.9	IOTF
(30)	Júlíusson, PB et al	2-19 3280/3106	Bergen	2003-06	O	13.2	14.5			2.1	2.5	IOTF
(30)	Júlíusson, PB et al	6-11 (subpop) 1150/1177	Bergen	2003-06	O	15.7	18.4			3.6 (boys & girls)		IOTF
(31)	Bjelland, M et al	11 764/717	South Norway (HEIA)	2007	O	13.6	14.6			1.8	1.7	IOTF
(23)	Bjornelv, S et al	14-18 3307/3366	UngHUNT1	1995-97	O	17.5	16.9	14.1	13.9	3.4	3.0	IOTF
(23)	Bjornelv, S et al	15 (subpop) 756/775	UngHUNT1	1995-97	O	17.3	14.7	14.6	12.8	2.8	1.9	IOTF
(22)	Krokstad, S et al	13-16	UngHUNT3	2006-08	O	22.0	20.0	(19)*	16*	(6)*	4*	IOTF
(22)	Krokstad, S et al	16-19	UngHUNT3	2006-08	O	27.0	25.0	19*	20*	8*	5*	IOTF
(32)	Vilimas, K et al	8 3453	Oslo	2004	O	21.6	21.6	18.4	18.4	3.2	3.2	IOTF

1) O= objectively measured, 2) S=self-reported, *) the estimates are read from a bar graph and therefore somewhat uncertain

II - Metodebok for skolehelsetjenesten (Method booklet)

Barns vekst i Norge

Metodebok for skolehelsetjenesten

For å få pålitelige resultater fra undersøkelsen Barns vekst i Norge er det viktig at skolens vekt og høydemåler kontrolleres før målingene igangsettes, og at du følger standardiserte metoder for veiing og måling, slik som vist i denne metodeboken.

I DEL 1 i dette heftet finner du informasjon om hvordan skolens personvekt og høydemåler kontrolleres på en enkel måte. Dette må gjøres for at prosjektsekretariatet senere kan justere for eventuelle avvik på skolens vekt og høydemåler. Når skolens personvekt og høydemåler er kontrollert og resultatene ført inn i SKOLEskjemaet, kan du begynne med målingene.

I DEL 2 finner du prosedyrene for hvordan du går fram for korrekt måling av vekt, høyde og livvidde.

Lurer du på noe, ta kontakt med Folkehelseinstituttet.

Du finner kontaktinformasjon på siste side.

DEL 1

Slik kontrollerer du skolens vekt og høydemåler

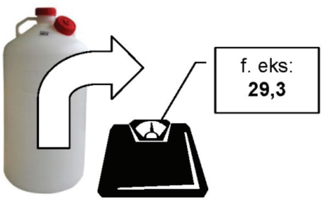
√ Kontroll av skolens personvekt

Alle skoler som deltar får tilsendt en beholder med et nummer på. Vannbeholderen, fylt med vann, er kontrollveid ved JUSTERVESENET og vekten er registrert av prosjektledelsen ved Folkehelseinstituttet.

Du skal *ikke* justere/endre innstilling på skolens vekt, men kun følge prosedyren som er beskrevet nedenfor før måling av elevene påbegynnes.

Slik gjør du:

- Påse at personvekten står på et hardt og flatt underlag.
- Fyll plastbeholderen med kaldt vann fra springen (hvis vannet er varmt vil plastbeholderen utvide seg – det skal unngås).
- Sjekk at eventuelle bulker er borte når beholderen er fylt med vann.
- Etterfyll beholderen med vann når beholderen er "bulkfri" – fyll helt til siste dråpe før det renner over. Skru på korken.
- Løft deretter opp plastbeholderen på vekten, se illustrasjon under.
- Noter nummeret på beholderen i SKOLEskjemaet.
- Les av hva beholderen fylt med vann veier og noter det på SKOLEskjemaet, se eksempel under.



Eksempel fra SKOLEskjemaet:

Noter hvor mye plastbeholderen fylt med vann veier på skolehelsetjenestens vekt:
(noter måleresultat i kilo med en desimal)
Vekt (kg) 29,3

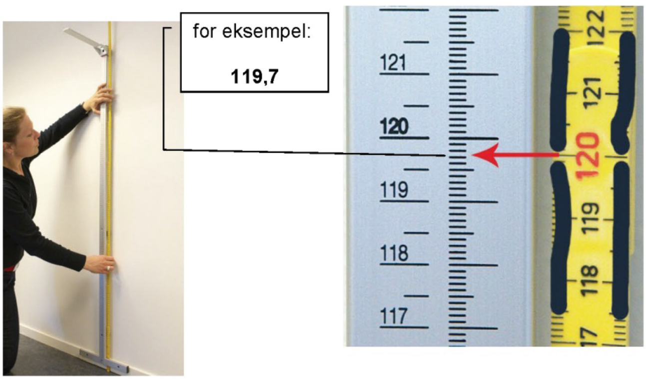
√ Kontroll av skolens høydemåler

Alle skoler som deltar får tilsendt en meterstokk. Kontrollmåling av skolens høydemåler gjøres for å kunne kontrollere for høydemålerens nøyaktighet.

Du skal *ikke* tilpasse/flytte på skolens høydemåler, men kun følge prosedyren som er beskrevet nedenfor før måling av elevene påbegynnes.

Slik gjør du:

- Plasser meterstokken like ved siden av skolens høydemåler. Pass på at meterstokken er rett - ikke bøyet eller buet - og "hviler" på gulvet.
- Les av hvor mye **120 cm** på **tilsendt målestokk** (gul på bildet) tilsvarer på **skolens høydemåler**. Noter på SKOLEskjemaet.



Eksempel fra SKOLEskjemaet:

Les av hvor mye ***120 cm*** *på* ***tilsendt meterstokk*** *(gul på bildet) tilsvarer på* ***skolens høydemåler****: (noter måleresultat i centimeter med* *<u>en</u>* *desimal)*

Høyde (cm) 1 1 9 , 7

3

DEL 2 - bruk ELEVskjemaet

Slik utfører du målingene

Når vekten og høydemåleren er standardisert i følge **DEL 1** i Metodeboken, kan du begynne med målingene.

Vær oppmerksom på at:

- Barna skal fortrinnsvis ha på seg lett tøy som t-skjorte og strømpebukse/stillongs eller lignende, ikke sokker.
- Barna skal ikke bli fortalt resultatet av målingene.
- Selvrapportert vekt, høyde eller livvidde godtas ikke.

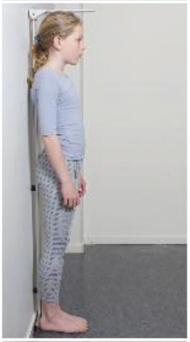
√ Slik veies barnet

1. Barnet bes om å stå helt stille på midten av vekten med føttene noe fra hverandre til vekten er registrert.

2. Noter barnets vekt med 0,1 kilograms nøyaktighet på ELEVskjemaet.

√ Slik måles barnets høyde

1. Barnets føtter skal være samlet - hælene skal ikke løftes fra gulvet og beina skal være strake.



2. Sjekk at skuldrene er i samme nivå samt at hælene, baksiden av leggene, setet og skulderbladene er inntil måleren/veggen. Armene skal henge langs sidene. Barnet bes om å "stå rett".

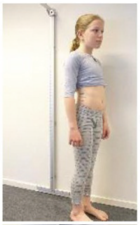
3. Barnets hode skal ha en posisjon slik at en linje fra øvre ørekanalåpning til et punkt tilsvarende benstrukturen av nedre øyehule (nedre orbitakant) er horisontal.

4. Hvis håret er tykt, legges et lett trykk på hodeplaten.

5. Målingen leses av i centimeter og noteres med nærmeste hele 0,1 centimeter på ELEVskjemaet.

√ Slik måles barnets livvidde

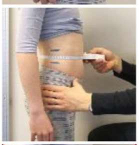
Husk at det tilsendte målebåndet benyttes til denne målingen. Rødt SECA-merke skal vende opp ved måling. Vær obs- les av målingen som bildet under viser.



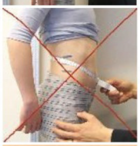
1. Barnet bes om å løsne opp bukse/skjørt, slik at klærne kan trekkes ned noe lavere enn øvre hoftekam. T-skjorte/trøye rulles opp i nivå med nedre ribbebue.

2. Be barnet om å stå avslappet med armene og hendene ned langs siden. Tyngden skal være likt fordelt på begge bein. Ikke kommenter hvordan barnet skal puste – det fører sannsynligvis til at barnet holder pusten.

3. For å finne riktig nivå for livviddemåling, palper først hofteregionen og lokaliser høyre hoftekam. Marker med en penn den øverste laterale kanten av høyre hoftekam. Palper den nedre del av ribbebuen lateralt og gjør et merke på huden. Sett deretter et markant merke midt imellom de to merkene.



4. Plasser deg foran barnet og plasser målebåndet horisontalt rundt livet i nivå med det mellomste merket. Målebåndet skal være fast rundt livet, uten at det strammes hardt.



Feil: her er ikke målebåndet horisontalt rundt livet.

5. Målet bør tas mot slutten av en normal ekspirasjon og leses av i centimeter og registreres med nærmeste hele 0,1 centimeter.

6

Innsending av måleresultater

Etter at målingene av elevene er sluttført, fyller du ut SKOLEskjemaet med de resterende opplysningene og sender dette sammen med alle ELEVskjemaene i vedlagte returkonvolutt.

Henvendelser

Hvis du har spørsmål, kan du kontakte:

- Anna Biehl, e-post: anna.biehl@fhi.no
  Nasjonalt folkehelseinstitutt
  tlf 21 07 82 74 / 41 55 33 06
- Ragnhild Hovengen, e-post: ragnhild.hovengen@fhi.no
  Nasjonalt folkehelseinstitutt
  tlf 21 07 82 04 / 97 16 48 40

Du finner også kopi av denne metodeboken og annen informasjon på studiens nettside: www.fhi.no/barnevekst

Resultatene fra målingene i 2010 skal etter planen være klare våren 2011.

Takk for innsatsen!

Postboks 4404 Nydalen
0403 Oslo
Tlf: 21077000
www.fhi.no/barnevekst

III - ELEV-skjema (Pupil-form)

Barns vekst i Norge

folkehelseinstituttet

ELEVskjema

(Fylles ut av helsesøster)

1. Elevkode 5531
2. Skole:
3. Fylke:

4. Elevens kjønn:

☐ Gutt

☐ Jente

5. Elevens fødselsdato: Dag / Måned / År

☐☐/☐☐/☐☐

6. Elevens for- og mellomnavn:..

   Elevens etternavn:...

7. Elevens adresse:

   Gateadresse: ....

   Postnummer:......................Sted:...

Mål
Noter mål i angitt enhet med en desimal:

8. Vekt (kg) ☐☐,☐

9. Høyde (cm) ☐☐☐,☐

10. Livvidde (cm) ☐☐,☐

11. Beskriv klærne barnet har på under målingene:
(velg kun ett alternativ)

☐ Lett tøy som t-skjorte og strømpebukse/stillongs eller lignende
☐ Tykkere tøy som genser og olabukse eller lignende
☐ Annet (spesifiser) ....

12. Tidspunkt for måling:
(velg ett passende alternativ)

Kl. 08-10 ☐
Kl. 10-12 ☐
Kl 12-14 ☐
Kl 14-16 ☐

13. Dato for måling: Dag / Måned / År

☐☐/☐☐/☐☐

Signer for at samtykkeerklæringen fra foreldre/foresatte er mottatt.

Helsesøsters signatur:...

IV - SKOLE-skjema (School form)

Barns vekst i Norge

folkehelseinstituttet

S K O L E s k j e m a

FØRSTE SIDEN AV SKOLESKJEMA FYLLES UT AV HELSESØSTER
FØR MÅLINGEN AV ELEVENE BEGYNNER

1. Skolekode ☐☐ ☐☐☐

2. Skole:

3. Fylke:

KONTROLL AV MÅLEINSTRUMENTER – se sidene 2 og 3 i Metodebok

4. Noter nummeret på tilsendt plastbeholder: ☐☐☐

5. Noter hvor mye plastbeholderen fylt med vann veier på skolehelsetjenestens vekt:
(noter måleresultat i kilo med en desimal)

Vekt (kg) ☐☐ , ☐

6. Hvor mye tilsvarer 120 cm på skolens høydemåler målt med FHIs tilsendte meterstokk?
(noter måleresultat i centimeter med en desimal)

Høyde (cm) ☐☐☐ , ☐

V- Samtykke (Consent form)

SAMTYKKE

Jeg har lest informasjonsskrivet og samtykker i at barnet mitt deltar i undersøkelsen BARNS VEKST I NORGE

Barnets navn:

____

Klasse:________ Skole:________________________________

Foresattes navn:

____

Dato:________Underskrift:____________________________

folkehelseinstituttet

Vennligst returner dette samtykket i vedlagt konvolutt til skolen (skolens helsesøster) ***innen 1 uke.***

Papers

I

Biehl et al. BMC Public Health 2013, 13:146
http://www.biomedcentral.com/1471-2458/13/146

BMC Public Health

RESEARCH ARTICLE Open Access

Impact of instrument error on the estimated prevalence of overweight and obesity in population-based surveys

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Abstract

Background: The basis for this study is the fact that instrument error increases the variance of the distribution of body mass index (BMI). Combined with a defined cut-off value this may impact upon the estimated proportion of overweight and obesity. It is important to ensure high quality surveillance data in order to follow trends of estimated prevalence of overweight and obesity. The purpose of the study was to assess the impact of instrument error, due to uncalibrated scales and stadiometers, on prevalence estimates of overweight and obesity.

Methods: Anthropometric measurements from a nationally representative sample were used; the Norwegian Child Growth study (NCG) of 3474 children. Each of the 127 participating schools received a reference weight and a reference length to determine the correction value. Correction value corresponds to instrument error and is the difference between the true value and the measured, uncorrected weight and height at local scales and stadiometers. Simulations were used to determine the expected implications of instrument errors. To systematically investigate this, the coefficient of variation (CV) of instrument error was used in the simulations and was increased successively.

Results: Simulations showed that the estimated prevalence of overweight and obesity increased systematically with the size of instrument error when the mean instrument error was zero. The estimated prevalence was 16.4% with no instrument error and was, on average, overestimated by 0.5 percentage points based on observed variance of instrument error from the NCG-study. Further, the estimated prevalence was 16.7% with 1% CV of instrument error, and increased to 17.8%, 19.5% and 21.6% with 2%, 3% and 4% CV of instrument error, respectively.

Conclusions: Failure to calibrate measuring instruments is likely to lead to overestimation of the prevalence of overweight and obesity in population-based surveys.

Keywords: Instrument error, Calibration, Anthropometry, Weights and measures, Obesity, Overweight, Epidemiology

Background

From a public health perspective there is a need for ongoing surveillance and monitoring of the prevalence of overweight and obesity in the population [1-3]. It is important to ensure that surveillance data is of a high quality such that one can follow trends over time and compare results within and among countries. Anthropometric measurements, such as weight and height, are relatively inexpensive and easy to collect in population studies, but the validity of these measurements must be critically evaluated [4-8]. In epidemiological research and surveillance programs, the body mass index (BMI) (kg/m^2) is widely used as a measure of adiposity. BMI cut-off values have been constructed to categorise individuals as underweight (BMI<18.5 kg/m^2) [9], normal weight (18.5 kg/m^2 ≤ BMI <25 kg/m^2), overweight (25 kg/m^2 ≤ BMI <30 kg/m^2) or obese (BMI ≥30 kg/m^2) [10]. Nevertheless, there is currently only a limited

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understanding of how using uncalibrated instruments impact upon BMI-based estimates of overweight and obesity. Only a few studies have considered how the inaccuracy of anthropometric measurements influences the interpretation of collected data [4,11]. For the present study, we have postulated that instrument error will not necessarily affect the mean height or mean weight, and thus mean BMI, but the variance in general will increase [7]. The height of a distribution curve is inversely proportional to the variance (SD) and instrument error will thus contribute to a flatter top to BMI distribution near the mean and more area in its tails [12] (Figure 1). Inaccurate height and/or weight measurements may therefore cause overestimation of the proportion above the cut-off value, i.e. the estimated prevalence of overweight and obesity.

Measurement error and instrument error

The terminology used to describe anthropometric measurement error is not consistent [4,13]. Four frequently used concepts are precision, reliability, accuracy and validity [14]. The major sources of error associated with weight and height measurements of children are the observer, the child being measured (hydration and bladder contents, clothing, etc.), and the instrument used [5]. The precision and reliability of measurements refers to the extent to which repeated measurements give the same value, whereas accuracy and validity refer to how close a measurement is to its "true" value and is related both to the measurement technique as well as the measuring instrument [4,15]. Since a true value cannot be determined, in practice a conventional "true" value is used. The *accuracy* of a measuring instrument is the "*ability to give responses close to a true value*" [16:p.41]. In the present paper we focus on the accuracy of measuring instruments, which, in cases of inaccuracy will be referred to as *instrument error*. Components of measurement error associated with measurement technique will therefore be ignored. There are many reasons for the inaccuracy of measuring instruments, including overuse without maintenance or recalibration, incorrect usage and general wear and tear as a result of frequent transportation.

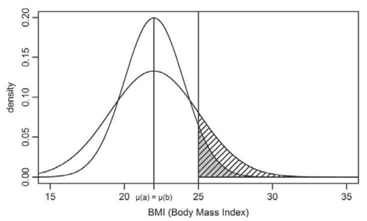

Figure 1 Two hypothetical normal distributions of BMI with equal means but different variances; increased variance gives a lower and broader shape compared to a distribution with less variance. Vertical line indicates cut-off value (BMI ≥ 25 kg/m^2). The dark shaded area corresponds to the prevalence of overweight and obesity for the distribution with less variance, and the light shaded area corresponds to additional prevalence due to increased variance.

Calibration vs. correction values

Measuring instruments should be calibrated according to a *standard* and adjusted in case of deviation [16]. Since population-based surveys often involve a large number of measurement sites, standardised calibration of all measuring instruments is an expensive and complicated procedure. As an alternative, the NCG-study developed a method where a *correction value* was determined for each instrument using a reference weight and a reference height. The correction value is equivalent to the instrument error and corresponds to the difference between the "true" value and the uncorrected value measured by an uncalibrated instrument. The term *reference* was used, since the method does not satisfy the requirements of a *standard* within metrology [16:p.46]. The procedure is described in detail below.

The main aim of the present study was to assess the degree to which instrument error, due to uncalibrated scales and stadiometers, impacts upon the overall estimated prevalence of overweight and obesity in population-based surveys. Growth data from a nationally representative sample and correction value data for all the instruments used in the study were utilised to illustrate the implications.

Methods

To illustrate how instrument error affects the prevalence of overweight, we generated datasets from real data on weight and height from a sample of 8 year old children, to which simulated data with various degrees of instrument error were added. For each simulation a new prevalence estimate was produced, and after several simulations the mean and variance of the prevalence estimate could be calculated. Finally, to get an idea of how the size of the instrument error affects the prevalence estimate we successively increased the instrument error and re-ran the simulations.

Study population

Anthropometric measurements were obtained in 2008 from a nationally representative sample of 3474 third grade pupils (~8 year olds) recruited in 127 primary schools as a part of *the Norwegian Child Growth Study (NCG)*. Participating schools were selected using a stratified two-stage sampling design following a protocol that was jointly developed by the WHO Regional Office for

Europe and the participating Member States of the World Health Organization European Childhood Obesity Surveillance Initiative.

Ethical approval

The NCG-study was evaluated by the Regional Committee for Medical Research Ethics and approved by the Norwegian Data Inspectorate. Parents and guardians were informed about the study by letter beforehand and written informed consent was obtained from a parent or legal guardian via the school nurse prior to the study.

Data collection

Prior to data collection all school nurses involved in the study received training in the standardised procedures of anthropometric measurement and the collection of correction values. Methods were explained and illustrated in a booklet specially developed for the NCG-study.

The measuring instruments used in this study were those already available on site, in that the types probably differed from one school to another. However, the usage and positioning of these instruments was standardised, e.g. scales had to be placed on a hard, horizontal floor.

Anthropometric measurements

Body weight and height were measured according to standard procedures [17] and recorded to the nearest 0.1 kg and 0.1 cm respectively. Body Mass Index (BMI) was calculated as weight/height^2 (kg/m^2). Children were categorised as either under and normal weight (BMI < 25 kg/m^2) and overweight or obese (BMI ≥ 25 kg/m^2) using one cut-off value [10].

Correction values

Correction values were collected in 2008 at the same time as anthropometric data collection. Each of the 127 schools received a reference weight and length that provided data from which to calculate the correction value for instruments at each school. The reference weights and lengths were within the range of the sample's anthropometric measurements, i.e. a weight close to 28 kg for the scales and a length of 120 cm for the stadiometers.

The anthropometric measurements of the children were corrected post-hoc. The corrected measurements thus correspond to measurements taken by calibrated instruments and are assumed to be free of instrument error, although the instruments themselves were not calibrated.

Scales

A 25-l plastic container, filled with cold water, was used as a reference weight. Initially the containers were brought to the Norwegian Metrology Service and each container was numbered (1–127), filled with cold tap water and weighed on a calibrated scale. The reference weight of each container – the "true" weight - was registered in a protocol. The containers were then distributed to the participating schools and the school nurses were instructed to fill up the container with cold tap water until the last drop trickled over, cap it, weigh it once according to the standardised method and register the weight. Finally, we calculated the correction value (instrument error) for all 127 scales to be the difference between the "true" weight of the container and the uncorrected weight of the corresponding container measured at the school scale by the school nurse.

In cases where the measurements of the children were carried out over two days, the procedure of weighing the plastic container was not required to be repeated as long the scales were not moved.

Stadiometer

A wooden folding rule approved to EU class III [18] was used as a reference length. The folding rule was stabilised and straight before reading. Using the standardised method the school nurse recorded the value of the school stadiometer that corresponded to 120.0 cm on the reference length (Figure 2). The folding rule was blacked out above and below 120 cm to avoid misunderstanding. The correction value (instrument error) was calculated as the difference between 120.0 cm and the registered measure of the stadiometer at each school.

Figure 2 Procedure to determine correction values in the NCG-study. As part of the procedure to determine correction values in the NCG-study, the value of the stadiometer at each school (left) that corresponded to 120.0 cm of the reference length (right) was recorded. In practice, the folding rule was blacked out above and below 120 cm to avoid misunderstanding.

Data analyses and simulation

To investigate the impact of instrument error on the estimated prevalence of overweight including obesity (BMI ≥25 kg/m^2) we simulated random samples of corrected height- and weight data derived from the NCG-study and correction values (instrument error) were added in each simulation (n=1000). The coefficient of variation (CV) is an expression for the magnitude of instrument error and is useful to compare the variability in samples involving different measurements (weight in kilograms and height in metres).

Two different models were applied to systematically investigate how instrument errors affected the prevalence of overweight and obesity. To reduce the level of complexity we assumed the CV for both the scales and stadiometers to be equal in the *first model*. The CV of the correction value (instrument error) was increased gradually by 0.5 percentage points for both instruments according to the formula:

$$\mathbf{CV}\ (\%) = \mathbf{100^x(SD/mean)},$$

where *SD* is the standard deviation of the correction value (instrument error) and *mean* is the mean of the corrected height and weight values respectively. The corresponding SD of the correction value (instrument error) for scales and stadiometers was deducted for each CV value and used in the simulation model. The mean of error terms was set to zero. BMI was then calculated for each value of CV and the estimated prevalence of overweight and obesity was assessed (Table 1). The *second model* was run with the actual size of correction value (instrument error) from the NCG-study with differentiated CVs for scales and stadiometers and the mean was still assumed to be zero (Table 1).

All simulations were programmed in STATA 11.

Results

Correction values

On average it was observed that the instruments in the NCG-study underestimated weight and height measurements. The correction values of scales ranged from −3.0 to +1.7 kg, mean (SD): −0.14 (0.64) and from −3.5 to +4.0 cm, mean (SD): −0.07 (1.11) for stadiometers. In the NCG-study the CV of instrument error of the scales and stadiometers was 2.1% and 0.9%, respectively. This indicates that the CV of instrument error was at least twice as large for scales compared to stadiometers.

Estimated prevalence

Simulations showed that the estimated prevalence of overweight and obesity changed systematically with increased instrument error (Figure 3). The estimated prevalence of overweight and obesity was 16.4% with no instrument error, corresponding to measurements taken by calibrated instruments, with the mean of error term set to zero. The mean of the estimated prevalence increased to 16.7% with 1% CV of instrument error, and to 17.8%, 19.5% and 21.6% with 2%, 3% and 4% CV of instrument error, respectively (Table 1).

Table 1 An overview of the two models presenting the coefficient of variation (CV%), mean and SD of instrument error and the corresponding estimated prevalence of overweight and obesity (BMI ≥ 25 kg/m^2) as mean, SD and the range (minimum-maximum values)

CV(%)	Instrument error				Simulations		
	Scales		Stadiometers		Runs (n)	Estimated prevalence of overweight and obesity (%)	
	Mean	SD	Mean	SD		Mean	SD (min-max)
Model I							
0	0	0	0	0	1000	16.4	0 (16.4 – 16.4)
0.5	0	0.15	0	0.66	1000	16.5	0.17 (15.9 – 17.1)
1.0	0	0.29	0	1.32	1000	16.7	0.24 (16.0 – 17.5)
1.5	0	0.44	0	1.98	1000	17.2	0.28 (16.3 – 18.0)
2.0	0	0.58	0	2.64	1000	17.8	0.35 (16.7 – 19.2)
2.5	0	0.73	0	3.30	1000	18.6	0.39 (17.2 – 19.6)
3.0	0	0.87	0	3.96	1000	19.5	0.41 (18.1 – 20.7)
3.5	0	1.02	0	4.62	1000	20.5	0.46 (19.1 – 22.1)
4.0	0	1.16	0	5.28	1000	21.6	0.51 (19.5 – 23.2)
Model II							
2.1*/0.9**	0	0.64	0	1.11	1000	16.9	0.25 (15.8 – 17.7)

* CV of instrument error (%) of scales from the NCG-study.
**CV of instrument error (%) of stadiometers from the NCG-study.

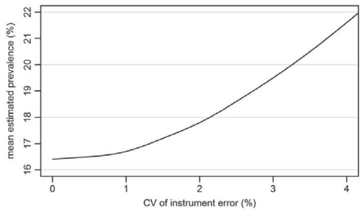

Figure 3 The mean estimated prevalence (%) of overweight and obesity (BMI ≥ 25 kg/m^2) in relation to the coefficient of variation (CV) of instrument error (%).

The prevalence was underestimated in a minority of the simulated samples. When the CV of instrument error was 1%, about 1 in 12 of the simulated samples underestimated the true prevalence. When the CV was 1.5% this happened only 1 in 200 of the simulated samples, and when the CV was 2% or greater no simulated samples underestimated the true prevalence.

In the *second model*, using the actual size of the CV of instrument error of the NCG-study, uncorrected estimates showed an average overestimation corresponding to 0.5 percentage points of the prevalence of overweight and obesity among 8 year-olds (Table 1).

Discussion

In this study we found that instrument error due to uncalibrated scales and stadiometers, combined with cut-off based classification systems, can lead to minor but systematic overestimation of the prevalence of overweight and obesity in a nationally representative sample.

To the best of our knowledge, this is the first study to show how increased variance of anthropometric measurements can affect outcome measures in obesity surveillance. Previous studies have considered the accuracy of anthropometric measurements, but did not evaluate the impact on the estimated prevalence of overweight including obesity (BMI ≥25 kg/m^2) [7]. It has been reported that scales in healthcare settings did not have higher accuracy than scales in fitness- or weight loss centres [19]. Furthermore, beam-balance scales are more accurate than scales with electronic mechanisms, whilst bathroom-type scales with a spring mechanism are least accurate [11]. These findings indicate that it is possible to increase accuracy by ensuring the school health service has good quality instruments.

Our findings are particularly relevant for population-based studies and surveillance programs that maximise the use of existing resources, such as instruments in the school health service. It is important to consider and balance accuracy with feasibility [20]. We thus developed a simple yet effective procedure for the NCG-study in order to obtain correction values for instruments at each school. This need was clearly demonstrated by the wide range of instrument error (4.7 kg and 7.5 cm) observed in this study from 127 scales and stadiometers. Valid data were collected with limited costs. We also found that, on average, instruments in the NCG-study slightly underestimated both weight (mean: –0.14 kg) and height (mean: –0.07 cm) measurements. However, this information was not used in the current analyses since the aim of this study was solely to assess the effect of instrument error variation. The average of the error terms was therefore set to zero in the simulations. If the mean error term was not set to zero, but rather set to the values observed in the NCG-study, the entire distribution would have shifted to the left due to the negative means, whilst the effect of "heavy tails" demonstrated in this study would have been equalised or toned down.

A possible limitation of the approach adopted in the NCG-study, i.e. adjusting for the correction value, is that it may only be valid for the specific point on the measuring-scale that corresponds to the reference weight and length value. To ensure the collection of the correction value on the appropriate part of the measuring-scale in weighing scales, a reference weight was chosen within the range of value of our target population. For stadiometers corrected at one point, measurements are likely to be correct along the whole measuring-scale.

According to the procedures, the plastic containers used to collect correction values were only measured once. Duplicate measurements would have increased the reliability, but optimisation and feasibility must be considered. Overly complicated procedures would undoubtedly increase the risk of dropout. In the present study, no schools dropped out. At the majority of schools, the data collection was completed within one day.

Only a single average cut-off value for overweight and obesity was used for the entire sample of 8–9 year old girls and boys in the simulations, and not age- and sex specific cut-off values as recommended by the IOTF [10]. This was done deliberately, in order to simplify the analyses. The expressed aim of the study was to explore the phenomenon of increased variance rather than to present correct estimates of the prevalence of overweight including obesity. For the same reason, the two-stage sampling methodology was not taken into account in the simulation analysis.

The rationale behind running the simulations according to two different models was to illustrate, in the first model, that an increasing instrument error will systematically impact upon the estimated proportion of overweight and obesity in surveys. The second model contained the actual CVs of instrument error for scales and stadiometers derived from the NCG-study and serves as a realistic example.

In the literature it is often stated that instruments are calibrated prior to data collection, without giving detailed calibration procedures. It has been claimed that once instruments are installed and calibrated, error due to the instruments is negligible [5]. Our findings suggest the contrary. Indeed, the impetus for this paper stems from the finding that old flooring had been removed from a school health office without adjustments to the wall-mounted stadiometer and with subsequent inaccurate height measurements. It shows that even when measuring instruments are calibrated upon acquisition and installment they can become uncalibrated, underlining the need for procedures for regular maintenance of anthropometric instruments. Generally, measuring instruments are bought calibrated, but due to lack of awareness, they may never be maintained or recalibrated after years of use.

Conclusions

To the best of our knowledge, this is the first study to demonstrate that instrument error will systematically increase the estimated prevalence of overweight and obesity. This study emphasises the need for regular maintenance or recalibration of instruments in order to reduce instrument error and to obtain more accurate estimates in populations-based surveys. Although the present analysis is limited to the use of inaccurate height and weight measuring instruments, the outlined principle is generic and can be applied to measurement error in general.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

RH had the original idea. AB and BHS did most of the statistical analyses and prepared the first draft. All authors participated in the discussion, interpretation of the results and contributed in writing the manuscript and had final approval of the submitted and published version.

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BMC Public Health

RESEARCH ARTICLE Open Access

Adiposity among children in Norway by urbanity and maternal education: a nationally representative study

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Abstract

Background: International research has demonstrated that rural residency is a risk factor for childhood adiposity. The main aim of this study was to investigate the urban-rural gradient in overweight and obesity and whether the association differed by maternal education.

Methods: Height, weight and waist circumference (WC) were measured in a nationally representative sample of 3166 Norwegian eight-year-olds in 2010. Anthropometric measures were stratified by area of residence (urbanity) and maternal education. Risk estimates for overweight (including obesity) and waist-to-height ratio ≥0.5 were calculated by log-binomial regression.

Results: Mean BMI and WC and risk estimates of overweight (including obesity) and waist-to-height ratio ≥0.5 were associated with both urbanity and maternal education. These associations were robust after mutual adjustment for each other. Furthermore, there was an indication of interaction between urbanity and maternal education, as trends of mean BMI and WC increased from urban to rural residence among children of low-educated mothers ($p = 0.01$ for both BMI and WC), whereas corresponding trends for children from higher educational background were non-significant ($p > 0.30$). However, formal tests of the interaction term urbanity by maternal education were non-significant (p-value for interaction was 0.29 for BMI and 0.31 for WC).

Conclusions: In this nationally representative study, children living rurally and children of low-educated mothers had higher mean BMI and waist circumference than children living in more urban areas and children of higher educated mothers.

Keywords: Epidemiology, Anthropometry, Waist circumference, Overweight, Obesity, Child, Socioeconomic position, Rural, Urbanity, Public health

Background

Obesity is one of the most important public health problems of our time [1]. In order to plan prevention strategies, develop and evaluate health promoting programmes and organise future health services, it is necessary to strengthen the knowledge base about the prevalence of adiposity and its distribution among children. It is well established that many aspects of health vary with socio-economic position (SEP) and across urban-rural residency [2]. International research has identified rural residence as a factor associated with childhood overweight and obesity [3-9], and the association between SEP and adiposity among children is predominantly inverse [10]. Correspondingly, previous Norwegian studies have found an association between parental SEP and childhood adiposity [11-14], while few studies have investigated possible implications of rural residency [13,14]. We still lack an understanding of which of these factors is most important for adiposity. Moreover, earlier studies were either based on self-reported data of weight, height and SEP or based on area level aggregates

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of SEP. The present study is the first Norwegian study based on measured height, weight and waist circumference (WC) in a nationally representative sample of children linked with register based information of maternal education as an indicator of SEP for each child. Given limited understanding of how childhood adiposity varies according to urbanity in relation to socio-economic position (SEP), the aim of this study was to investigate the urban-rural gradient in general and abdominal obesity and whether the association differed depending upon level of maternal education.

Methods

Data from the cross-sectional survey, the *Norwegian Child Growth Study* (NCG) was used. NCG followed the protocol of the World Health Organization European Childhood Obesity Surveillance Initiative (COSI) [15], which was jointly developed by the WHO Regional Office for Europe and the participating member states. NCG was approved by the Regional Committee for Medical Research Ethics and by the Norwegian Data Inspectorate. Consent forms and detailed information about the study were sent to parents or guardians beforehand. Written informed consent was obtained from a parent or legal guardian via the school nurse prior to the study.

Subjects

A nationally representative sample of 3166 third graders (1537 girls and 1629 boys), mean age 8.3 years (SD: 0.3 years), with complete anthropometric measure, participated in NCG 2010. To lower the cost and logistics burden and still ensure national representativity, a stratified two-stage sampling design was used. The primary sampling unit was *county*. Of all 19 Norwegian counties, 10 were selected (Akershus, Oslo, Vestfold, Vest-Agder, Rogaland, Hordaland, Møre og Romsdal, Sør-Trøndelag, Nordland og Troms) by simple random sampling among all five geographical strata (the administrative Health Region) in order to ensure a nationwide coverage and the possibility of reporting on all parts of the country. The secondary sampling unit was the *school*. The sample of schools was selected randomly and was intended to be proportional to population size in each county; a total of 125 state schools participated. The attendance rate was 89% of all included children.

Data collection

Measurements were performed by school nurses at participating schools during October 2010. Each of the scales and stadiometers used in this study were already present at each school, i.e. brand and type model probably differed from one school to another. One SECA measuring tape (SECA GmbH Hamburg, Germany) was distributed to each participating school. Prior to data collection, all school nurses were trained in the taking of anthropometric measures according to standardized procedures, which was explained and illustrated in a booklet specially developed for the NCG. As described elsewhere [16], this included a collection of *correction values*, which were determined for each instrument involved in the survey. The corrected measures thus corresponded to measures taken by calibrated instruments and were assumed to be free of instrument error. Procedures of how the instruments were positioned were standardized: Scales had to be positioned on a hard, horizontal floor and the wooden folding rule had to be stabilized and straight – not curved – in order to be used as a reference.

Anthropometric measurements

Body weight and height were measured with the children wearing *light indoor clothing* without shoes [17,18] and were recorded to the nearest 0.1 kg and 0.1 cm respectively. Measures were corrected if the child wore other than light indoor clothing: plus 100 grams for some additional light clothing or plus 500 grams for heavier clothing. Body Mass Index (BMI) was calculated as weight/height^2 (kg/m^2) and children were classified as overweight or obese based on age- and gender specific cut-off values of BMI for children developed by the International Obesity Task Force (IOTF) [19] and the WHO definitions for children aged 5-19 [20,21].

Waist circumference (WC) was measured to the nearest 0.1 cm with arms hanging relaxed along the body. WC was measured with a measuring tape midway between the lower rib margin and the iliac crest [18]. Marks were made on the skin of each child with a felt-tip pen in order to ensure the correct level of measurement. Waist-to-height ratio was calculated as waist circumference/height (cm/cm), with a ratio equal to or higher than 0.5 classified as waist-to-height ratio ≥ 0.5 (WHtR ≥ 0.5).

At data entry, height, weight and WC were entered twice, with any punching errors corrected.

Outcome variables

For descriptive purpose the continuous outcome variables included *weight (kg)*, *height (cm)*, *BMI* (kg/m^2), *WC (cm)* and *waist-to-height ratio.* The categorical outcome variables were *overweight* (25 kg/m^2 $\leq$ BMI <30 kg/m^2), *overweight (including obesity)* (BMI $\geq$ 25 kg/m^2), *obesity* (BMI $\geq$ 30 kg/m^2) and waist-to-height ratio ≥ 0.5 (*WHtR* $\geq$ *0.5)*. Risk estimates were presented as overweight (including obesity) according to IOTF, here referred to as general overweight and obesity, and waist-to-height ratio ≥ 0.5, here referred to as abdominal obesity. Adiposity is used occasionally in this paper as a general term and refers to both general overweight and obesity and abdominal obesity.

Explanatory variables

In addition to gender, the explanatory variables included area of residence and maternal education. Participants were divided into three groups recognised as *urbanity*, based on information on *area of residence* (municipality) provided by Statistics Norway: 1) urban (municipalities with more than 50 000 inhabitants), 2) semiurban (municipalities with 10 000 – 49 999 inhabitants) and 3) rural (municipalities with 9 999 or fewer inhabitants). *Maternal education* was measured at an individual level and was selected as the indicator of SEP [10]. Unique personal identification numbers, assigned to all Norwegian residents, were used to link data on parental educational attainment from the National Education Database. The data were compiled by Statistics Norway. Education was measured as the highest level of education attained according to the Norwegian NUS2000 standard. NUS2000 has recently been harmonised with International Standard Classification of Education (ISCED -97) [22,23]. In the present study we collapsed the seven levels of education to three main levels in order that the groups had sufficient numbers of individuals whilst at the same time reflecting the dispersion of education: 1) *tertiary education* refers to level 5-6 in ISCED -97 (first and second stage of tertiary education), 2) *secondary education* refers to level 3-4 in ISCED -97 (upper secondary and post-secondary non-tertiary) and 3) *primary education* refers to level 0-2 in ISCED -97 (primary and lower secondary). The proportion of children in each subgroup is presented in Table 1.

Statistical analyses

To investigate differences in childhood adiposity as measured by urbanity and maternal education a series of analyses were performed. First, mean and standard deviations (SD) were calculated for the continuous anthropometric measures of all the children, as well as separately for girls and boys. Then, crude and adjusted mean values for BMI, weight, height and WC by urbanity and education and a 95% confidence intervals (95% CI) were estimated using linear regression. Trends in anthropometric variables across education categories were tested by treating the education variable as continuous in the linear regression, whilst the beta coefficient was used as the trend estimate. A similar approach was adopted to test for urbanity. Secondly, crude prevalence above predefined cut-off points for both adiposity measures were calculated and 95% CI. Adjusted values were estimated using generalized linear model with binomial distribution and a log link function, expressed as relative risk (RR) and 95% CI. Thirdly, to allow BMI and WC to vary across level of education and urbanity simultaneously, interaction terms education by urbanity dummies were included in the regression models. The primary analysis (Table 2) was based on the entire sample (N = 3166), while the multiple analyses were restricted to respondents for whom there existed complete information pertaining to maternal educational attainment and urbanity (N = 2968).

Table 1 Number and proportion of children, n (%), distributed into subgroups of area of residence and maternal education

	Area of residence		
	Urban	**Semiurban**	**Rural**
Maternal education	**n = 1256**	**n = 1252**	**n = 460**
Tertiary n	665	573	183
(%)	(53)	(46)	(40)
Secondary n	387	470)	201
(%)	(31)	(37)	(44)
Primary n	204	209	76
(%)	(16)	(17)	(16)
TOTAL (%)	(100)	(100)	(100)

Since age was evenly distributed in the educational and residential sub-groups, and did not affect the results, age was not included in the models (linear regressions). Average age varied a maximum of ten days between the groups.

To properly take into account the complex two stage sampling procedure, all analyses were performed with the survey-prefix (svy) in STATA version 11. The STATA data files in the NCG-study have the sample design declared, including population sizes for each of the sampling levels. As previously described, the sample of schools was intended to be proportional to population size in each county, but in case of over- or under-representation in the final sample, analysis were weighted in order to avoid biased estimates. All differences were considered significant at p levels < 0.05.

Results

The overall prevalence of overweight (including obesity) ($BMI \geq 25$ kg/m^2) and obesity ($BMI \geq 30$ kg/m^2) according to IOTF was 19.0% and 4.0%, respectively (Table 2). The prevalence of overweight (including obesity) was significantly higher among girls ($p = 0.03$), whereas there was no significant gender difference in the prevalence of obesity. When using the WHO cut-off values the prevalence was 27.6% and 8.6% for overweight (including obesity) ($BMI \geq 25$ kg/m^2) and obesity ($BMI \geq 30$ kg/m^2), respectively. According to WHO, the prevalence of obesity was significantly higher among boys ($p = 0.02$), whereas there was no gender differences for overweight (including obesity) – which is the opposite of the result using the IOTF definition. In addition, there were no gender differences in mean weight and BMI, but mean height was significantly higher among boys ($p < 0.01$). The prevalence of $WHtR \geq 0.5$ was 8.9%, with no gender differences.

The proportions of children living in urban, semiurban and rural areas were 42%, 42% and 16%, respectively (Table 3). Nearly half of the children had a mother with

Table 2 Means (SD) of anthropometric measures and proportions (95% CI) and numbers of WHtR ≥ 0.5 (waist-to-height ratio ≥ 0.5) and weight classifications (by BMI as defined by IOTF and WHO), of all children and separately for girls and boys

	All children N = 3166		Girls N = 1537		Boys N = 1629		p-value*
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
Weight (kg)	29.5	5.6	29.3	5.5	29.6	5.7	0.21
Height (cm)	131.8	5.9	131.2	5.9	132.4	5.8	< 0.01
BMI (kg/m²)	16.9	2.4	16.9	2.3	16.8	2.4	0.41
Waist circumference (cm)	58.4	6.1	58.0	6.0	58.8	6.2	0.04
Waist-to-height ratio	0.44	0.04	0.44	0.04	0.44	0.04	0.36
							p-value*
	% (N)	**95% CI**	**% (N)**	**95% CI**	**% (N)**	**95% CI**	
WHtR ≥ 0.5	8.9 (288)	7.2 - 10.7	9.2 (139)	6.8 - 12.2	8.7 (149)	6.4 - 11.8	0.82
IOTF:							
Overweight	15.0 (467)	13.2 - 16.8	18.2 (272)	15.6 - 21.1	12.0 (195)	10.0 - 14.3	< 0.01
(25 ≤ BMI < 30)							
Overweight incl. obesity	19.0 (592)	16.7 - 21.4	21.6 (321)	18.1 - 25.6	16.5 (271)	14.0 - 19.4	0.03
(BMI ≥ 25)							
Obesity	4.0 (125)	3.0 - 5.1	3.5 (49)	2.3 - 5.1	4.6 (76)	3.4 - 6.1	0.18
(BMI ≥ 30)							
WHO:							
Overweight incl. obesity	27.6 (857)	24.8 - 30.6	27.7 (413)	24.0 - 31.8	27.6 (444)	24.1 - 31.3	0.94
(BMI ≥ 25)							
Obesity	8.6 (268)	7.7 - 10.3	6.7 (97)	5.0 - 8.9	10.4 (171)	8.2 - 13.1	0.02
(BMI ≥ 30)							

* p-value for gender differences.

tertiary education, 36% had a mother with secondary education and 16% had a mother with primary education.

Results from the unadjusted analyses showed that mean BMI and mean WC increased significantly from urban to rural area of residence (p-values for trend were 0.01 for BMI and < 0.01 for WC). Mean BMI and mean WC showed similar trends according to maternal education (p-value for trend was 0.03 for BMI and < 0.01 for WC), although the association was complex-inverse, where children of the highest educated mothers had the lowest mean values, and children of the middle educated mothers had higher mean values than children of the lowest educated mothers.

Mean weight increased significantly from urban to rural area of residence (p-value for trend = 0.01), whereas the trend was not significant across maternal educational attainment. Mean height showed the opposite pattern; with no trend across urban-rural residency but decreasing mean height with high to low maternal educational attainment (p < 0.01). Analyses adjusting for maternal education gave similar results (Table 3). The main analyses were also performed using paternal education, with only insignificant deviations from the results using maternal education (data not shown).

Compared to children living in urban areas those living in rural areas had a 1.5 fold (95% CI =1.2-1.9) higher risk of being overweight or obese according to IOTF cut-off values (BMI ≥ 25), and a 2.2 fold (95% CI =1.5-3.3) higher risk of having a WHtR ≥ 0.5 (Figure 1). Furthermore, compared to children of mothers with tertiary education, the relative risk of being overweight or obese and having a WHtR ≥ 0.5 was 1.3 (95% CI =1.0-1.6) and 1.8 (95% CI = 1.3-2.6), respectively for children of mothers with primary education (Figure 2).

Different urban-rural patterns were apparent when BMI (Figure 3) and WC (Figure 4) were plotted separately according to maternal education; notably children of mothers with primary education showed on average increasing BMI and WC from urban to rural areas of residence (p-values for trend were 0.01 for both BMI and WC). Corresponding trends for children from higher educational background were non-significant (p = 0.30-0.58). A formal test of the interaction terms area of residence by maternal education did not reach statistical significance (p-value for interaction was 0.29 for BMI and 0.31 for WC). Furthermore, in rural areas there were no statistically significant differences in mean values of BMI and WC between children of mothers with the

Table 3 Crude and adjusted BMI (body mass index), weight, height and WC (waist circumference), according to area of residence and maternal education, presented as means (95% CI)

		BMI (kg/m^2)		Weight (kg)		Height (cm)		WC (cm)	
Area of residence	**N (%)**	**Crude**	**Adjusted[a]**	**Crude**	**Adjusted[a]**	**Crude**	**Adjusted[a]**	**Crude**	**Adjusted[a]**
		Mean (95% CI)	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**
Urban	1256	**16.7**	**16.7**	**29.2**	**29.3**	**132.0**	**132.0**	**57.9**	**58.0**
	(42)	(16.5-16.9)	(16.5-16.9)	(28.9-29.5)	(29.0-29.6)	(131.6-132.4)	(131.6-132.3)	(57.4-58.5)	(57.5-58.5)
Semiurban	1252	**16.9**	**16.9**	**29.5**	**29.5**	**131.6**	**131.6**	**58.6**	**58.6**
	(42)	(16.6-17.2)	(16.6-17.2)	(28.9-30.0)	(29.0-30.0)	(131.2-132.0)	(131.2-132.0)	(58.0-59.3)	(58.0-59.3)
Rural	460	**17.2**	**17.1**	**30.1**	**30.1**	**132.0**	**132.1**	**59.2**	**59.1**
	(16)	(16.9-17.4)	(16.9-17.4)	(29.6-30.6)	(29.6-30.5)	(131.3-132.8)	(131.4-132.8)	(58.6-59.9)	(58.6-59.7)
p-value*		0.01	0.03	0.01	0.02	0.65	0.87	< 0.01	0.01
Maternal education	**N (%)**	**Crude**	**Adjusted[b]**	**Crude**	**Adjusted[b]**	**Crude**	**Adjusted[b]**	**Crude**	**Adjusted[b]**
		Mean (95% CI)	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**	**Mean (95% CI)**
Tertiary	1421	**16.7**	**16.7**	**29.2**	**29.2**	**132.0**	**132.1**	**57.8**	**57.9**
	(48)	(16.5-16.8)	(16.5-16.8)	(28.9-29.5)	(28.9-29.6)	(131.7-132.4)	(131.8-132.4)	(57.4-58.3)	(57.5-58.4)
Secondary	1058	**17.1**	**17.1**	**29.9**	**29.8**	**131.8**	**131.8**	**59.1**	**59.0**
	(36)	(16.8-17.3)	(16.8-17.3)	(29.4-30.3)	(29.3-30.3)	(131.3-132.3)	(131.3-132.3)	(58.6-59.6)	(58.5-59.5)
Primary	489	**16.9**	**16.9**	**29.4**	**29.3**	**131.3**	**131.3**	**58.6**	**58.6**
	(16)	(16.6-17.2)	(16.7-17.2)	(28.8-29.9)	(28.8-29.9)	(130.8-131.8)	(130.8-131.8)	(57.9-59.3)	(58.0-59.2)
p-value*		0.03	0.03	0.20	0.28	< 0.01	< 0.01	< 0.01	0.01

[a]) adjusted for maternal education and gender, [b]) adjusted for area of residence and gender, *) p-value for test for trend.

highest and lowest education level ($p = 0.19$ and $p = 0.20$ respectively).

Discussion

In this first Norwegian study of measured anthropometric data of a nationally representative sample linked with register based information of maternal education, we found an urban-rural gradient in childhood adiposity. In addition, adiposity increased from high to low maternal education level. The trends of anthropometric measures (BMI and WC) across area of residence differed depending upon the level of maternal education. Whereas children of low-educated mothers living in rural areas had a particularly high mean BMI and WC, the educational differences in mean BMI and WC among children living in urban or semiurban areas were less prominent.

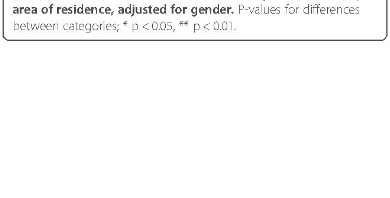

Figure 1 Relative risk (RR) and 95% CI of overweight (including obesity) (IOTF) and WHtR ≥ 0.5 (waist-to-height ratio ≥ 0.5) by area of residence, adjusted for gender. P-values for differences between categories; * $p < 0.05$, ** $p < 0.01$.

The results in this study have confirmed earlier finding of the association between parental SEP and childhood adiposity [3,11-13,24]. The finding of a complex-inverse association, implying that the prevalence of adiposity is lowest amongst the children of the most educated mothers and highest in the middle compared with the lowest educated mothers, is also in accordance with the results in a 2008 systematic review [10]. In addition, our findings of a socio-economic gradient in height are well-known from other studies, both among adults [25,26] and children [27,28].

It is also well established that health may vary across geographic locations [29]. In recent years an association between overweight and obesity among children and residency in rural areas has been reported [3-9]. The characteristic for rural areas vary greatly and should not be seen as homogeneous; rural setting in the US differs for instance from rural setting in Scandinavian countries.

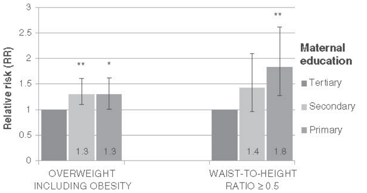

Figure 2 Relative risk (RR) and 95% CI of overweight (including obesity) (IOTF) and WHtR ≥ 0.5 (waist-to-height ratio ≥ 0.5) by maternal education level, adjusted for gender. P-values for differences between categories; * $p < 0.05$, ** $p < 0.01$.

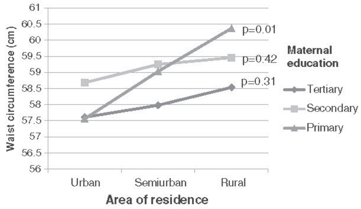

Figure 4 Mean waist circumference (cm) per maternal education level (tertiary, secondary and primary) by area of residence, adjusted for gender. P-values for trend within each educational group.

Despite this, the findings in our study confirm an urban-rural gradient.

Further, the present study has shown that level of maternal education does not explain geographical differences. This contrasts to other Scandinavian studies which have shown that geographical differences were attenuated when adjusting for education at area-level [9,14]. It is reasonable, however, to assume that adjusting for data on individual level as we did, provides results with greater validity than adjusting for the average attained education for all individuals within a municipality.

Interestingly, despite the adjusted analyses did not change the estimates noticeably (education did not explain the geographical differences and vice versa), only children with primary educated mothers showed a significant trend of increasing mean values of BMI and WC from urban to semiurban and to rural area of residence. The educational subgroups in rural areas were rather small (contained from 76 to 201 children), which might explain why the difference in mean values of BMI and WC between the highest and lowest education level in rural areas were not statistically significant. To the best to our knowledge no previous study has reported such a pattern.

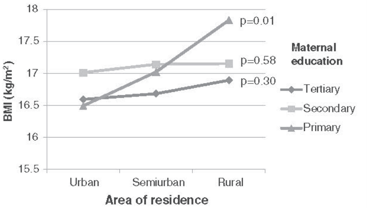

Figure 3 Mean BMI (kg/m^2) per maternal education level (tertiary, secondary and primary) by area of residence, adjusted for gender. P-values for trend within each educational group.

This study has a number of notable strengths and limitations. First and foremost, to our knowledge this is the first nationally representative sample with measured anthropometric data linked with individual level register based data on education. In addition, the attendance rate was high (89%). On the other hand, it might not be coincidental who was absent from school the day measurements were taken and we cannot therefore exclude the possibility that a higher proportion of the non-participating children were overweight or that lower social groups may have been overrepresented among the non-participants. The sampling methodology ensured a nationally representative sample of Norwegian third graders where all invited schools participated in the survey. Further, the proportion of mothers with primary education was in accordance with the average level in Norway (females 35-49 years). Moreover, the proportion of low-educated mothers was similar (16-17%) irrespective of area of residence. Summed up, given the high attendance rate, sampling methodology and similar attendance levels in urban and rural areas, it is reasonable to believe that selection bias should not be considered a problem in our study.

Another strength is that the anthropometric data were systematically collected and objectively measured. Furthermore, objectively measured WC of a national sample may be of particular value as a measure of body composition, since it is of interest how the fat is distributed [30]. Changes in body composition over the latest decades have been investigated and it has been found that trends in WC and skinfold thickness have exceeded trends in BMI [11,31]. WC is a better predictor for central fatness [31-33] and is therefore recommended to be used as a complementary measure in clinical and epidemiological settings [34,35]. The reference point of WHtR ≥ 0.5 has no true validity in children, but it is suggested as a cut-off that could be used in a public health context as a simple measure of abdominal obesity [36]. Maffeis et al found a high level of sensitivity and specificity of WHtR ≥ 0.5 as a cut-off and negligible differences among three different age-groups of children, which support age independence of 0.5 cut-off of WHtR [37]. However, further studies are needed to validate WC as well as WHtR cut-offs in children [36].

The explanatory variable *area of residence* - describing the degree of urbanity - was derived from population size information in each municipality. It is a rather rough measure. For instance, if two schools are located in the same municipality, they were categorized equally, even if the surroundings and level of urbanity of the two schools differed substantially.

Education is attained relatively early in life and is often more stable during young adulthood compared to occupation and income [38]. Education is also strongly associated with health and health related behaviour [39,40]. In addition, maternal education has been found to be the strongest single SEP predictor of childhood obesity [10]. Data on maternal education was derived from the National Education Database, which is preferable to self-reported data or information of average education at an area level. The variable *household income* was not available, which is a limitation of the study. Data on parents' individual income (register based information) was available. However, social security payments in Norway are not classified as income, and the variable *income* would therefore not provide correct information on available economical recourses in the family and is not included in the analyses. Information bias was further addressed by correcting anthropometric data for instrument errors [16]. By using "uncalibrated" measures, the associations were not substantially changed. Moreover, the weight of clothes that deviated from the standard of "light indoor clothing" was corrected. In addition, data were double entered, ensuring that punching errors were a minor problem. To achieve a nationally representative sample and to take into account the complex sampling design, weighting was conducted to correct for deviations from the proportionality of population size in each geographical strata.

The assumed explanation for geographical differences in health has been that areas differ because they are composed of different groups of people with different characteristics [29]; compositional explanation of health inequalities. However, other studies have, like the current one, reported that SEP – or behavioural risk factors like physical activity and diet - do not account for urban-rural differences in the prevalence of overweight and obesity [4,6]. This indicates that the cause of geographical differences is still uncertain. In recent years, researchers have argued that the effect of neighbourhood may impact upon individual- level health outcomes [29]; the contextual explanation. Multilevel analysis, to investigate area effects on health after accounting for individual-level factors, could have contributed to an improved understanding of these mechanisms, i.e. the impact of individual characteristics (compositional) and of neighborhood (contextual) on health outcomes like adiposity. The sample in the present study was, however, too small to allow such analyses.

Norway is an egalitarian welfare state with high maternal education level. However, there is a trend of increasing level of education in several countries [41]. The mechanisms that we have found might thus also apply to other countries, independent of the distribution of education.

Conclusions

In this nationally representative study, children living rurally and children of low-educated mothers had higher mean BMI and waist circumference than children living in more urban areas and children of higher educated mothers.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

RH was responsible for conception of the Norwegian Child Growth Study, and AB was involved in the planning and in the data collection. AB and HM were responsible for the conception of this paper. AB and BHS analysed the data and AB drafted the manuscript. All authors interpreted the data, participated in critical revisions of the paper and approved the final submitted version.

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III

Parental marital status and childhood overweight and obesity: A nationally representative study.

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Abstract

Background

Socio-demographic changes in Norway and other western industrialised countries, including family structure and an increasing proportion of cohabiting and divorced parents, might affect the prevalence of childhood overweight and obesity. We aimed to examine whether parental marital status was associated with general- and abdominal obesity among children. We also sought to explore whether the associations differed by gender.

Methods

Height, weight and waist circumference were measured in 3166 third graders (mean age 8.3years) in the nationally representative Norwegian Child Growth-study of 2010. The main outcome measures were general overweight (including obesity) (BMI$\geq$25kg/m^2) using IOTF cut-offs and abdominal obesity (waist-to-height ratio$\geq$0.5) by gender and parental marital status. Prevalence ratios, adjusted for possible confounders, were calculated by log-binomial regression.

Results

General overweight (including obesity) was 1.54 (95 % confidence interval (CI): 1.21-1.95) times more prevalent among children of divorced parents compared to children of married parents, and the corresponding prevalence ratio for abdominal obesity was 1.89 (95 % CI: 1.35-2.65). Formal tests of the interaction term parental marital status by gender were not statistically significant. However, in gender-specific analyses the association between parental marital status and adiposity measures was only statistically significant in boys (p=0.04 for general overweight (including obesity) and p=0.01 for abdominal obesity). The estimates were robust against adjustment for maternal education, family country background and current area of residence.

Conclusion

General- and abdominal obesity were more prevalent among children of divorced parents. This study provides valuable information by focusing on societal changes in order to identify vulnerable groups.

Strengths and limitations of the study

- This study is representative of the Norwegian population of 8 year-old children.
- Anthropometric data were objectively measured; additionally accompanied by register-based data of parental marital status, maternal education and family country background.
- Data on parental marital status was a "snapshot" of current status with no further information of how long the parents had been married, cohabiting or divorced.
- There were no data on physical activity or diet, which could have contributed to further elucidate the differences.

Introduction

Childhood obesity has major public health implications.(1) The factors accounting for the burden of overweight and obesity are not yet fully understood.(2) Family structure has undergone major changes over the last few decades, the number of divorces has remained at a high level in Norway since 1980.(3) About 25% of children live either the entirety or some part of their childhood with only one of their biological parents or grow up living in two different homes.(4) Marital conflict and dissolution impact upon the well-being of children and may have implications for the future health status of children.(5, 6) Recent studies have reported an association between family structure and childhood overweight and obesity, suggesting that living with either only one parent or divorced parents increases the risk of childhood overweight and obesity.(7-9)

The fact that in recent decades there have been large socio-demographic changes in Norway and in Western countries generally, with an increasing proportion of cohabiting and divorced parents, makes it important to examine the impact these changes have had on childhood overweight and obesity. An additional concern is that over the past few decades waist circumference has exceeded trends in body mass index (BMI) in both child- and adult populations.(10-12) This is important because a more central distribution of fat, measured as waist circumference, is associated with metabolic complications.(13, 14) The current study supplements this literature providing insight into the association between family structure and the prevalence of both general and abdominal obesity.

Using data from a nationally representative study, our primary objective was to examine the association between parental marital status and general overweight and obesity in addition to abdominal obesity among Norwegian third graders (8-9 years old). In addition, we explored whether there were gender differences within these associations, and whether the main associations were independent of maternal education, family country background and area of residence.

Methods

Cross-sectional data from the Norwegian Child Growth Study (NCG) were used.(15) NCG followed the protocol of the WHO Childhood Obesity Surveillance Initiative (COSI),(16) which has previously been described in detail.(17, 18)

Subjects

A nationally representative sample of 3166 third graders (1537 girls and 1629 boys) participated in the 2010 NCG study; mean age 8.3 (SD: 0.3) years. To ensure a national representative sample, a stratified two-stage sampling design was used. The attendance rate was 89 % of all invited children. Data on parental marital status were available for 3137 of the children (99%), whilst additional data on maternal education was available for 2968 of the children (94%).

Data collection

Measurements were performed by trained school nurses at participating schools during October 2010. Each of the scales and stadiometers used in this study were already present at each school, i.e. brand and type model probably differed from one school to another. One SECA measuring tape (SECA GmbH Hamburg, Germany) was distributed to each participating school. All school nurses were trained in anthropometric measures according to standardised procedures, which were explained and illustrated in a booklet specially developed for the NCG. Correction values were collected for each instrument involved in the survey and the measures of each child were corrected.(17, 18)

Anthropometric measurements

Body weight and height were measured with the children wearing light indoor clothing and without shoes, and were recorded to the nearest 0.1 kg and 0.1 cm respectively.(19) Measures were corrected if the child wore items other than light indoor clothing: plus 100 grams for some additional light clothing or plus 500 grams for heavier clothing. BMI was calculated as weight/height^2 (kg/m^2) and children were classified as overweight (including obesity) based on age- and gender specific cut-off values for BMI for children as developed by the International Obesity Task Force (IOTF) (20) and the WHO definitions for children aged 5-19.(21) Waist circumference (WC) was measured to the nearest 0.1 cm with arms hanging relaxed along the body with a measuring tape midway between the lower rib margin and the iliac crest.(19) Waist-to-height ratio (WHtR) was calculated as waist circumference/height (cm/cm). At data entry, height, weight and WC were entered twice, with any punching errors corrected.

Outcome variables

The continuous outcome variables included weight, height, WC, BMI and WHtR. The main outcomes were the categorical variables overweight (including obesity) (BMI≥25 kg/m^2) referred to as *general overweight and obesity* and waist-to-height ratio ≥ 0.5 (WHtR≥0.5) referred to as *abdominal obesity*. *Adiposity* is used occasionally and refers to both general overweight and obesity, and abdominal obesity.

Explanatory variables

Data on parental marital status were obtained from the National Population Registry and compiled by Statistics Norway. Data were linked using the unique 11-digit personal identification code assigned to all Norwegian residents. Parental marital status was categorised into three groups: married; never-married (including cohabiting, single and separated parents); divorced.(22)

Data on highest attained maternal education was obtained from the National Education Database and categorised according to the Norwegian Standard Classification of Education (NUS2000) into three levels: tertiary; secondary; primary (18).

Family country background was classified in three groups: Norwegian/Scandinavian; Non-Western; Western (other than Norwegian/Scandinavian). Area of residence was classified as: urban; semi-urban; rural.(18)

Statistical analyses

Mean and standard deviation for the continuous variables were reported for all children, and gender stratified. Crude prevalence of general overweight and obesity, and abdominal obesity were calculated with 95% confidence intervals (95% CI). Comparisons of difference in anthropometric characteristics between subgroups were performed by F-test for continuous variables and Pearson chi-square test for categorical variables. As a recommended alternative for logistic regression in cross-sectional studies,(23) we used generalised linear models (log-binomial regression) with a logarithmic link function to calculate prevalence ratio (PR) and with an identity link function to calculate prevalence differences. It is especially when the outcome is common (> 10 %) that odds ratio overestimates the PR. The effect of parental marital status on adiposity in boys and girls was tested in the regression models by the inclusion of the interaction terms parental marital status by gender. Statistical analyses were performed using STATA 12 and with survey-prefix command (svy) to take into account the complex two stage sampling procedure. A p-value <0.05 was considered statistically significant.

Ethics

NCG was approved by the Regional Committee for Medical Research Ethics and by the Norwegian Data Inspectorate. Consent forms and detailed information about the study were sent to parents/guardians beforehand. Written informed consent was obtained from a parent/legal guardian via the school nurse prior to the study.

Results

As previously reported, the prevalence of general overweight (including obesity) according to IOTF definitions was 19.0 % and according to WHO definitions the prevalence was 28.6 %, whilst 8.9 % had abdominal obesity. Overall, general overweight (including obesity) was significantly more prevalent among girls compared to boys (p-value for difference=0.03), whereas there was no gender difference for abdominal obesity (p-value=0.82).(18)

In gender collapsed analyses all the mean values of the anthropometric measures were significantly higher for children of divorced parents compared to children of married parents, except for height (table 1). In gender specific analyses, however, these differences were generally larger for boys than girls, and reached statistical significance only among boys; weight (p=0.04) and WC (p=0.03). The same pattern was found in terms of the categorical variables; in gender specific analyses the difference between children of married and divorced parents was only significantly different among boys (table 2).

Children of divorced parents had a 54% higher prevalence (95% CI 21% - 95%) of general overweight (including obesity) and 89% higher prevalence (95% CI 35% - 165%) of abdominal obesity compared to children of married parents (table 2), whereas children of never-married parents had a similar prevalence to children of married parents. Adjustment for maternal education and gender only slightly attenuated the associations, which indicate that maternal education and gender did not explain the association between parental marital status and childhood overweight and obesity. Similarly, the estimates were essentially unchanged after controlling for socio-demographic factors such as family's country background and their area of residence (data not shown). The crude anthropometric measures by parental marital status were essentially equal in the full sample (N=3137) and in the reduced sample with non-missing maternal education (N=2968), indicating that the reduced sample is representative of the full sample.

Gender stratified analyses, adjusting for maternal education, showed that boys with divorced parents had a 63% higher prevalence (95 % CI 11% -139%) of general overweight (including obesity) compared to boys of married parents (table 2), with the absolute difference being 9.9 percentage points. Correspondingly, the prevalence of abdominal obesity was 104% higher (95 % CI 23% - 237%) among boys with divorced parents compared to boys of married parents (table 2), and the absolute difference was 7.4 percentage points. The same pattern was seen among girls, but the associations were less pronounced and not statistically significant. The differences between marital status categories and gender are illustrated in figures 1 and 2, suggesting that boys of divorced parents were particularly prone to abdominal obesity. However, formal tests of the interaction term parental marital status and gender was only borderline significant for WC (p=0.06), and not significant for BMI (p=0.26), WHtR (p=0.13), general overweight (including obesity) (p=0.36) and abdominal obesity (p=0.27).

Table 1: Anthropometric characteristics by parental marital status, presented as mean and standard deviation (SD), for all children and boys and girls separately.

	Married	**Never-married**		**Divorced**	
	mean (SD)	**mean (SD)**		**mean (SD)**	
ALL CHILDREN	n=2004	n=903		n=230	
			p-value [a]		**p-value** [b]
Height (cm)	131.8 (6.0)	131.7 (5.6)	0.48	132.5 (6.4)	0.39
Weight (kg)	29.4 (5.7)	29.4 (5.2)	0.76	30.8 (6.5)	0.02
BMI (kg/m2)	16.8 (2.4)	16.9 (2.2)	0.96	17.4 (2.8)	0.03
Waist (cm)	58.3 (6.1)	58.4 (5.7)	0.48	60.3 (7.6)	<0.01
WHtR	0.44 (0.04)	0.44 (0.04)	0.48	0.46 (0.05)	0.02
BOYS	n=1017	n=470		n=121	
			p-value [a]		**p-value** [b]
Height (cm)	132.4 (5.9)	131.9 (5.6)	0.16	133.8 (6.3)	0.12
Weight (kg)	29.6 (5.8)	29.2 (5.1)	0.17	31.7 (6.8)	0.04
BMI (kg/m2)	16.8 (2.5)	16.7 (2.2)	0.59	17.6 (2.9)	0.12
Waist (cm)	58.8 (6.2)	58.4 (5.5)	0.18	61.4 (8.0)	0.03
WHtR	0.44 (0.04)	0.44 (0.04)	0.49	0.46 (0.05)	0.08
GIRLS	n=987	n=433		n=109	
			p-value [a]		**p-value** [b]
Height (cm)	131.1 (6.0)	131.4 (5.5)	0.71	131.1 (6.1)	0.75
Weight (kg)	29.1 (5.6)	29.5 (5.3)	0.56	29.9 (6.2)	0.47
BMI (kg/m2)	16.8 (2.3)	17.0 (2.2)	0.51	17.3 (2.6)	0.37
Waist (cm)	57.7 (5.9)	58.5 (5.8)	0.21	59.2 (6.9)	0.19
WHtR	0.44 (0.04)	0.44 (0.04)	0.17	0.45 (0.05)	0.17

[a]) p-value for differences between Married and Never-married, [b]) p-value for differences between Married and Divorced

Table 2: General overweight and obesity (BMI ≥ 25 kg/m^2) according to IOTF and abdominal obesity (waist-to-height ratio ≥0.5), presented as prevalence (%) and prevalence ratio (95 % CI) by marital status, crude and adjusted, for all children and separately for boys and girls.

			CRUDE			ADJUSTED	
		n=	Prevalence (%)	PR	(95 % CI)	PR	(95 % CI)
			GENERAL OVERWEIGHT AND OBESITY				
	All children (N=3137)		19.0				
PARENTAL MARITAL STATUS							
	Married	2004	18.2	1.00	Ref.	1.00	Ref.
	Never-married	903	18.8	1.03	(0.85 -1.25)	1.03 [a]	(0.84 - 1.26)
	Divorced	230	28.0	1.54	(1.21 -1.95)	1.46 [a]	(1.16 - 1.84)
	p-value		<0.01 [c]	0.01 [d]		0.02 [d]	
PARENTAL MARITAL STATUS							
GENDER SPESIFIC							
BOYS	Married	1017	16.2	1.00	Ref.	1.00	Ref.
	Never-married	470	14.6	0.90	(0.66 - 1.22)	0.94 [b]	(0.69 - 1.28)
	Divorced	121	27.5	1.69	(1.18 - 2.44)	1.63 [b]	(1.11 - 2.39)
	p-value		0.02 [c]	0.04 [d]		0.05 [d]	
GIRLS	Married	987	20.3	1.00	Ref.	1.00	Ref.
	Never-married	433	23.1	1.14	(0.87 - 1.50)	1.10 [b]	(0.82 - 1.47)
	Divorced	109	28.5	1.41	(0.97 - 2.04)	1.34 [b]	(0.91 - 1.98)
	p-value		0.16 [c]	0.19 [d]		0.32 [d]	
			ABDOMINAL OBESITY				
	All children (N=3137)		8.9				
PARENTAL MARITAL STATUS							
	Married	2004	8.5	1.00	Ref.	1.00	Ref.
	Never-married	903	8.2	0.97	(0.71 -1.32)	0.97 [a]	(0.69 - 1.36)
	Divorced	230	16.1	1.89	(1.35 -2.65)	1.76 [a]	(1.26 - 2.45)
	p-value		<0.01 [c]	0.01 [d]		0.02 [d]	
PARENTAL MARITAL STATUS							
GENDER SPESIFIC							
BOYS	Married	1017	8.5	1.00	Ref.	1.00	Ref.
	Never-married	470	6.7	0.79	(0.54 - 1.15)	0.85 [b]	(0.58 - 1.24)
	Divorced	121	19.1	2.24	(1.41 - 3.56)	2.04 [b]	(1.23 - 3.37)
	p-value		<0.001 [c]	0.01 [d]		0.03 [d]	
GIRLS	Married	987	8.5	1.00	Ref.	1.00	Ref.
	Never-married	433	9.8	1.16	(0.69 - 1.95)	1.07 [b]	(0.60 - 1.92)
	Divorced	109	12.8	1.51	(0.78 - 2.95)	1.48 [b]	(0.77 - 2.86)
	p-value		0.42 [c]	0.45 [d]		0.47 [d]	

[a]) adjusted for maternal education and gender, [b]) adjusted for maternal education, [c]) Chi-square test and [d]) test for overall p-value for differences between categories

Figure 1: Crude prevalence ratio (PR) of general overweight and obesity by parental marital status separately for boys and girls, where boys with married parents are the reference category, presented with 95% confidence intervals (95% CI).

Figure 2: Crude prevalence ratio (PR) of abdominal obesity by parental marital status separately for boys and girls, where boys with married parents are the reference category, presented with 95% confidence intervals (95% CI).

Discussion

In this nationally representative study we found that general overweight and obesity, and abdominal obesity were more prevalent among children of divorced parents compared with children of married parents. Our findings were robust to adjustments for maternal education, family country background and current area of residence. Although formal tests of the interaction terms parental marital status by gender were not statistically significant, gender stratified analyses showed that the prevalence of general- and abdominal obesity was significantly higher only amongst boys of divorced parents, compared to boys with married parents.

The study has several limitations which ought to be considered when interpreting its findings. First, data on parental marital status were limited to a "snapshot" of current status. For example, we had no information as to how long parents had been divorced. Further, the never-married category was heterogeneous and contained a diversity of family constellations, such as intact cohabiting relationships and dissolved relationships. More detailed information would have been beneficial to the study. Secondly, an obvious limitation is that our cross-sectional design provided no basis for studying causality; whether the development of overweight and obesity was initiated before the divorce or whether the impact on the children's weight status was primarily attributed to marital conflict or the divorce. Thirdly, one cannot exclude the possibility that a higher proportion of overweight children were absent from school on the day measurements were taken and were therefore overrepresented among non-participants, which in turn could imply that children of divorced parents were underrepresented in NCG, as previously stated.(24) If so, the associations shown in this study could be underestimated. But, given that the children were recruited into the NCG by the school health service, selection bias is most likely not a big issue in our study. Finally, the explanatory variables are few in the current study, with no information on e.g. physical activity level or dietary behaviour among the children, meaning that we cannot further explore our findings. On the other hand, high attendance rate was given high priority in NCG. In order to avoid non-participation parents were thus not requested to fill in time-consuming questionnaires. Few explanatory variables could therefore be considered an advantage for the current study. Another obvious strength is that, to the best of our knowledge, this is the first study with objectively measured and systematically collected anthropometric data of a nationally representative sample, and is accompanied by register-based data on parental marital status, parents' level of education, area of residence and country background for each child. Moreover, the NCG study has a high attendance rate (89 %).

Our finding that parental divorce is associated with childhood overweight and obesity is consistent with previous studies.(7-9) Few other studies have studied gender-differences, but one Australian study found an opposite gender-pattern, though the gender specific associations were not statistically significant.(9) A Norwegian study concluded that single parent families were not significantly associated with overweight and obesity among children aged 2-19 years.(25) The divergent findings most probably reflect a lack of agreement in terms of categorisation.The dichotomisation of marital status does not tell whether a single-parent family is the result of divorce, separation or death, or indeed whether a two-parent family are cohabiting or married. Accordingly, it does not form a solid basis for examining whether changing family structures or "divorce-stress" during childhood may affect weight-status among children. Other studies have also contained methodological limitations and were either based on small samples, self-reported data, and/or marital status was reported at birth.(26-29) Likewise, a review considering risk factors for childhood overweight and obesity found conflicting evidence for maternal marital status.(30) Only three studies were included, all of which measured marital status at birth.

Further, we found that children of never-married parents shared similar adiposity traits with children of married parents. The similarity most likely reflects the heterogeneity of the never-married-category, as mentioned in the limitation section above. This category could still be interesting to investigate further; a four times higher risk of dissolution of relationship has been shown for cohabiting couples as opposed to married couples,(31) and the proportion of cohabitations compared to marriages has increased steadily since 1980.(4)

The excess risk of adiposity among those with divorced parents remained after adjusting for maternal education, despite the fact that maternal education is the strongest single socio-economic predictor of childhood obesity,(32) and divorced parents are more likely to have lower educational level, as reported by a Norwegian study.(33)

One can speculate as to whether the changing structure of daily life has a large affect upon the children of divorced parents (living with only one parent or spending half their time with the mother and/or the father). The loss of various resources, like the absence of one of the parents or the loss of a parental figure, usually the father, can explain the negative implications of divorce.(6, 34, 35) A practical consequence might be less time for domestic tasks such as cooking and reliance on more convenient, ready-to-eat foods. As processed foods tend to be higher in fat and calories and lower in nutritional value(7) the result is an altered, less healthy diet. The household income and support from any non-custodial parent or the welfare state is often lower than in corresponding non-disrupted families.(36) Consequently, fewer economic resources may be available for divorced parents, which might lead to cheaper and less healthy choices. Other mechanisms affecting children's weight status through divorce (or dissolved relationship) could be related to emotional stress. Disruption in the parent-child relationship, continuing conflict between former spouses or other negative events like moving and the need to establishing new networks could induce emotional stress.(34, 35, 37) It has been shown that adolescents with substantial distress symptoms doubled among those with divorced parents.(37) Such emotional stress may impact upon eating behaviour and physical activity level and thus explain the development and maintenance of childhood overweight and obesity.(7, 38, 39)

The higher prevalence of overweight and obesity among children of divorced parents may also be due to selection. Health, socioeconomic resources, psychological characteristics, values and preferences affect the chance of marrying and remaining married, and has previously been found to account for some of the differences between children of divorced and married parents.(34, 40)

In the present study, children of *separated* parents were categorised together with children of *never-married* parents. From a perspective regarding selection as the main explanation, it could be argued that children of separated parents are miscategorised, since these parents will in the future most likely divorce, and are as such akin to divorced parents. Children of separated parents have most likely already been exposed to parental conflicts. However, children of separated parents have probably had less exposure to conflict and emotional stress compared to children of divorced parents. Because overweight and obesity take time to develop, we consider it is relevant to differentiate between the children of divorced and separated parents.

In this nationally representative study of third graders, we found that general overweight and obesity, and abdominal obesity were more prevalent among children of divorced parents compared to children of married parents. The association remained after adjusting for maternal education, family country background and area of residence. Formal tests of interaction terms parental marital status by gender were not statistically significant. However, our data suggest that boys of divorced parents seem to be particularly prone to abdominal obesity. By focusing on actual societal changes, this study adds valuable background information about potentially vulnerable groups at risk of developing adiposity.

Ethics approval: NCG was approved by the Regional Committee for Medical Research Ethics and by the Norwegian Data Inspectorate.

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