Surveillance of childhood obesity in Sweden

Focus on lifestyles and socioeconomic conditions

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Ineko

To my brother and sister
Lennart & Lisa

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ABSTRACT

Background and aim: There is a general lack of childhood obesity surveillance systems throughout Europe, including Sweden. Such systems are needed to develop policies, evaluate interventions and track secular changes in weight status. The general aim of this thesis was to describe the national and regional prevalence of overweight and obesity in Swedish 7-9-year-old children, as the initial step to establish a national childhood obesity surveillance system. Attention was given to socioeconomic factors at individual and area levels. Further aims were to analyze secular trends and longitudinal changes in weight status and lifestyle in a regional sample while considering area socioeconomic status (SES) and individual socioeconomic position (SEP).

Methods: Anthropometric measurements and lifestyle data were collected in 2008, 2010 and 2013. Weight status was classified according to International Obesity Task Force (IOTF), Cole 2007 and the World Health Organization growth standard (WHO). Schools were sampled in order to be representative for Sweden and all measurement methods were standardized. Two studies were based on the 2008 nationally representative sample of 7-9-year-old schoolchildren (n=4538) and investigated the associations between children's weight status and SES, urbanization and parental and child lifestyle variables. In two further studies, cross-sectional (n=3492) and longitudinal (n=678) trends in children's weight status and lifestyle in the region of West Sweden were investigated.

Results: The national prevalence of overweight was 16.6% including 3.0% obese; thinness was observed in 7.5%, according to IOTF/Cole 2007. Overweight was more common in rural areas, partly explained by the lower educational level in those areas. Parental weight status was strongly associated with child overweight and obesity. Overall more favorable lifestyle characteristics were observed in urban areas and for children of highly educated mothers. In West Sweden, trends in weight status between 2008 and 2013 were generally stable except for an increase in thinness in girls. Further, widening of the socioeconomic gap in obesity in girls occurred, due to non-significant decreases in areas with high education and increases in areas with low education. When applying the WHO-reference, prevalence of overweight was higher, due to lower cut-offs, while thinness was almost non-existent. Similar socioeconomic gradients but no trends in weight status were observed according to the WHO-reference.

Conclusion: Since obesity in the parents was the strongest risk factor for excess weight in children, targeting entire families in interventions should be a priority in management of the childhood obesity epidemic. Furthermore, strategies to reduce socioeconomic disparities in obesity are urgently needed. It may prove difficult to identify families at risk, therefore, targeting high risk areas, such as rural areas and areas with low SES, may be more effective. Further, in order to plan and evaluate public health strategies and policies there is a need for surveillance at the national level.

Keywords: surveillance, child, obesity, thinness, urban, rural, socioeconomic status, sedentary, sugar-sweetened beverages, lifestyle, COSI

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SAMMANFATTNING PÅ SVENSKA

Bakgrund och syfte: Nationellt representativ information om skolbarns viktstatus saknas i Sverige och i många andra europeiska länder. Avhandlingens övergripande syfte var att beskriva den nationella och regionala förekomsten av övervikt och fetma hos Svenska 7-9 åriga barn med fokus på socioekonomiska faktorer på individ- och områdesnivå. Vidare syften var att observera tvärsnitts- och longitudinella trender i viktstatus och livsstilsfaktorer och hur dessa påverkas av socioekonomisk status (SES) i området och individuell socioekonomisk position (SEP).

Metod: Antropometrisk data och information om livsstil samlades in vid tre tillfällen: 2008, 2010 och 2013. Viktstatus klassificerades enligt International Obesity Task Force. Skolorna valdes ut för att representera barn i årkurs ett i Sverige och alla mätmetoder var standardiserade. Två studier baserades på det nationella urvalet av 7-9 åringar (n=4538) från 2008, och undersökte associationer mellan barns viktstatus och SES, urbaniseringsgrad och barns och föräldrars livsstilsfaktorer. Två ytterligare studier undersökte trender i viktstatus och livsstilsfaktorer i Västra Götaland, dels mellan upprepade tvärsnitt (n=3492) och dels longitudinella mätningar i en mindre grupp (n=678).

Resultat: Den nationella förekomsten av övervikt var 16,6 % inklusive 3 % med fetma, 7,5 % hade undervikt. Övervikt förekom oftare i glesbebyggda områden, vilket till stor del kunde förklaras av lägre utbildningsnivå i de områdena. Föräldrars viktstatus var starkt korrelerat med barnets övervikt och fetma. Barn med högutbildade mödrar och de som bodde i tättbebyggda områden hade generellt sett mer hälsosamma vanor. I Västra Götaland var trenden i viktstatus generellt sett stabil men med ökande förekomst av undervikt hos flickor. Vidare ökade den socioekonomiska skillnaden i fetma hos flickor genom att förekomsten minskade ickesignifikant i områden med hög utbildningsnivå och ökade i områden med låg utbildningsnivå.

Slutsats: Eftersom fetma hos föräldrarna var den starkaste riskfaktorn för övervikt och fetma hos barnen, bör man prioritera att nå hela familjen för att hantera epidemin i barnfetma. Det är dessutom viktigt att hitta fungerande strategier för att minska de socioekonomiska skillnaderna. Eftersom det kan vara svårt att identifiera de familjer med störts risk kan det vara effektivt att rikta insatserna till områden med hög förekomst av övervikt och fetma, så som glesbyggda områden och områden med hög andel lågutbildade. Slutligen finns det ett stort behov av kartläggning av barnfetma på nationell nivå för att planera och utvärdera folkhälsoåtgärder och politiska beslut.

LIST OF PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

i. Sjöberg A, Moraeus L, Yngve A, Poortvliet E, Al-Ansari U, Lissner L. Overweight and obesity in a representative sample of schoolchildren – exploring the urban-rural gradient in Sweden. *Obesity Reviews 2011 May;12(5):305-14.*

ii. Moraeus L, Lissner L, Yngve A, Poortvliet E, Al-Ansari U, Sjöberg A. Multi-level influences on childhood obesity in Sweden: societal factors, parental determinants and child's lifestyle. *International Journal of Obesity (Lond). 2012 Jul;36(7):969-76.*

iii. Moraeus L, Lissner L, Sjöberg A. Widening socioeconomic gap in obesity among Swedish girls from 2008 to 2013, despite overall stability in prevalence. *In press Acta Paediatrica 2014.*

iv. Moraeus L, Lissner L, Olsson L, Sjöberg A. Age and time effects on children’s lifestyle and overweight Sweden. *In manuscript.*

CONTENT

ABBREVIATIONS

ASB	Artificially-sweetened beverages
BMI	Body Mass Index
COSI	Childhood Obesity Surveillance Initiative
FFQ	Food Frequency Questionnaire
FQ	Family Questionnaire
IOTF	International Obesity Task Force
OB	Obesity
OW	Overweight (including obesity)
PA	Physical Activity
PIA	Physical Inactivity
SD	Standard Deviation
SEP	Socioeconomic position
SES	Socioeconomic status
SSB	Sugar-sweetened beverages
WHO	World Health Organization

DEFINITIONS IN SHORT

Overweight	Based on two different international references, the IOTF (Cole et al. 2000) and WHO (WHO 2007) and corresponds to an adult BMI of ≥25 kg/m^2. Thus, throughout this thesis overweight includes obesity.
Obesity	Based on two different international references, the IOTF and WHO and corresponds to an adult BMI of ≥30 kg/m^2.
Thinness	Based on two different international references, Cole 2007 (Cole et al. 2007) and WHO and corresponds to an adult BMI of <18.5 kg/m^2.
Urbanization	Three levels of urbanization defined on two ways in this thesis, firstly based in a European definition (Eurostat 2003):
Urban	*Densely populated areas including at least 50,000 inhabitants in contiguous local living areas with more than 500 inhabitants per square kilometer.*
Semi-urban	*Contiguous local living areas with more than 100 inhabitants per square kilometer, and either 50,000 inhabitants or more for the contiguous living area, or adjacent to an urban area.*
Rural	*Thinly populated areas belonging neither to urban nor semi-urban areas.*
	Second, based on the standard classification on Swedish municipalities (SKL 2005):
Metro/suburb	*Metropolitan and suburban municipalities.*

Larger	*Larger cities and municipalities with >25,000 inhabitants.*
Other	*Commuter- and smaller municipalities.*
Low area education/SES	Municipality with 18-30% of adult population with university education.
Medium area education/SES	Municipality with 31-43% with university education.
High area education/SES	Municipality with 48-70% with university education.
Parental education/SEP	Retrieved from family questionnaire. Maternal and paternal education were both included in paper II while only maternal was used in paper IV. The following definitions were applied:
Low parental education/SEP	*Defined as ≤9 years of education in Paper II and ≤12 years in paper IV.*
Medium parental education/SEP	*Defined as between 9 and 12 years of education in Paper II and is included in low education in paper IV.*
High parental education/SEP	*Defined as >12 years of education in Paper II and IV.*

1 INTRODUCTION

For the individual child, obesity has consequences on several levels. The stigmatization of obese people in society can lead to bullying in school, low self-esteem, and body image dissatisfaction (Hesketh et al. 2004, Wardle et al. 2005). Further, physiological consequences can include orthopedic complications, sleep disturbances, and hormone imbalance (Abrams et al. 2011). Diabetes mellitus type 2, earlier found primarily in adults, is now manifesting itself in children and young adults, even though still seldom found in Swedish children (Berhan et al. 2014). Overweight or obese children are also at great risk not only of maintaining their excess weight into adulthood but also for cardio-metabolic morbidity later in life (Singh et al. 2008, Reilly et al. 2011). Early prevention is crucial, as substantiated by a longitudinal study on Swedish children, which showed that about 80% of those with overweight in preschool still had the problem as teenagers (Angbratt et al. 2011).

Obesity is a global problem, with the greatest increase in low- and middle-income countries where the double burden of disease – a high prevalence of underweight parallel to a high prevalence of obesity – is common. In high-income countries, the increase in obesity may be slowing down, but substantial differences within countries exist, often with a higher prevalence of obesity in those with less-advantaged socioeconomic conditions (Knai et al. 2012).

The rapid increase in obesity prevalence has caused the World Health Organization (WHO) to describe the disease as an epidemic (WHO 2000). In adults, the obesity prevalence has doubled since the 1980s (WHO 2014). The exact magnitude of childhood obesity is, however, not entirely known due to the lack of representative data worldwide. In an attempt to estimate the prevalence of overweight in Europe, Lobstein and colleagues compiled data from 21 countries (Lobstein et al. 2003). A large variation was observed with higher prevalence of overweight in southern European countries. This compilation consisted of national as well as regional data, and both measured and self-reported weights and heights.

In Sweden, representative data on weight status is available for male conscripts at 18 years up until the late 1990s. The data show that during the last three decades of the twentieth century, both overweight and obesity increased gradually. Obesity prevalence was almost nonexistent (0.9%) in the earlier cohort measured in 1971 and had increased to 3.2% in the cohort measured in 1995 (Rasmussen et al. 1999). For children, there is no nationally representative measured data available, but regional studies can give us an estimate of trends. Similar to young men, obesity in 10-year-old children measured in the schools' health services in the city of Gothenburg, increased from less than 1% to 2.9% between 1984 and 2000 (Mårild et al. 2004). In the municipality of Umeå in Northern Sweden, the prevalence of overweight doubled between 1986 and 2001, from 11.5% to 22.2%, in 6-11-year-old children (Petersen et al. 2003). In the early part of this century it seems as though the increase in obesity may be levelling off in older (Sjöberg et al. 2008, Sundblom et al. 2008) and younger (Bergström et al. 2009) Swedish children. However, this data is also based on regional samples. Further, the obesity prevalence is found to be higher in children with less advantaged socioeconomic conditions, and trends often differ when observing high and low SES groups separately (Sjöberg et al. 2008, Sundblom et al. 2008). Even given that the observed levelling off is similar throughout the country, the rapid increase over the last 40 years is alarming. The goal should be to reverse the epidemic and to obtain a prevalence of childhood overweight and obesity similar to the one observed in the 1980s, that is, below 1% obesity and 10% overweight. Achieving this goal calls for public health intervention as well as surveillance of weight status in nationally representative samples of children.

1.1 Frameworks for understanding childhood obesity

For the vast majority, excess weight gain occurs when energy intake exceeds energy expenditure. However, the complexity of obesity etiology in adults as well as in children is well-known and consequently makes it quite difficult to treat the disease. Although individual characteristics play a significant role, it is widely believed that a multilevel approach is essential when explaining and dealing with childhood obesity. Individuals are still an important part of the problem and the solution, but understanding that choices are not always conscious but influenced by environmental and cultural factors is essential. Since prejudice against obese children is common, also among peers, (Hansson et al. 2009) this multifactorial and environmental approach may avoid stigmatization of obesity.

Numerous models have been developed to obtain an overview of how the different factors interact with each other to influence body weight. The models have in common that they put individual characteristics and behaviors in different environmental contexts. One very extensive ecological framework was developed by the UK Government's Foresight Programme in 2007, in an attempt to tackle the rising levels of obesity in adults and children (Vandenbroeck et al. 2007). Their obesity system map centers on energy balance with 108 determinants and over 300 interconnecting arrows to demonstrate positive or negative relationships between these factors. The factors are grouped into seven main themes: physiology, individual activity, physical activity environment, food consumption, food production, individual psychology, and social psychology. Most of the themes can be applied on several levels – individual, family, and society – for example food consumption can relate to the individual or as an average for a population. This map successfully demonstrates the complexity and interdependence of variables associated with obesity and illustrates that a systems approach to combating the disease is essential.

The International Obesity Task Force has created what they call a causal web, which illustrates how the obesity prevalence in a population is influenced by determinants on different levels. From the international (global markets, media) and national/regional (transport, education) arenas, to the more local community (public transport, agriculture) and in school/home (leisure activity, school food) and finally the individual (energy expenditure, food intake) (Kumanyika 2001). The causal web is somewhat more comprehensible than the Foresight obesity system map but neither is specifically aimed at childhood obesity. In 2001, Davison and Birch used Ecological Systems Theory to develop a framework of child obesity predictors (Davison et al. 2001). The framework is built around child weight status with three levels of determinants circled around it. The inner circle consists of child risk factors and characteristics, which is surrounded by family characteristics and parenting styles, in turn surrounded by community, demographic, and societal characteristics. Child risk factors – dietary intake, sedentary behavior, and physical activity – are moderated by children's characteristics – gender and age – and each risk factor is influenced by factors in the surrounding circles. As new research fields are explored, the system maps and frameworks will have to be updated. Davison's and Birch' framework was modified in 2011 by Reed and colleagues who added rurality to the outer circle (Reed et al. 2011).

1.2 Surveillance of childhood obesity

Monitoring the prevalence of overweight and obesity as well as lifestyle factors that are associated with obesity in children enables evaluation of interventions and policy changes, which outcomes would otherwise only be speculative. In order for governments and stakeholders to develop policies and strategies aimed at dealing with public health problems, surveillance systems need to be installed. The surveillance system is not described as being a part of the ecological frameworks but can and should be used to monitor the different components of the framework and use the information to track trends in weight status, related lifestyle factors, and formulate policy (Branca et al. 2007, Wilkinson et al. 2007, Longjohn et al. 2010). It is also essential to monitor effects of intervention, especially in various socioeconomic groups, which may respond differently to intervention (Beauchamp et al. 2014).

Many countries lack national surveillance of childhood obesity. In the USA, the National Health and Nutrition Examination Survey (NHANES) is a well-established program of studies which has been ongoing since the early 1960s (CDC 2014). Physical examinations and interviews on health-related and dietary topics are performed in the respondents' home. Even though the quality of this data is considered to be very good, some argue that a surveillance system specifically aimed at childhood obesity is needed (Longjohn et al. 2010). Several states in the USA have aimed to implement such a system but so far only Arkansas has a functioning structure (Longjohn et al. 2010). In Alberta, Canada, the Child Health Ecological Surveillance System was developed in collaboration between health authority and researchers (Plotnikoff et al. 2010). It was to be used as a regional prototype to gather information and develop strategies to intervene on childhood obesity both on individual and environmental levels. The aim was to include information from multiple institutions and organizations such as daycare/school, municipal government and health services but also the fast food and fitness industries. In 2010 a feasibility study was conducted and although it was concluded that important stakeholders expressed a will to act, the surveillance system was determined as difficult to implement due to differing formats of electronic data, privacy legislation, a lack of relevant information, and limited resources (Plotnikoff et al. 2010).

In preparation for the WHO European Ministerial Conference on Counteracting Obesity in 2006, the WHO Regional Office for Europe produced a report on overweight and obesity prevalence, derived from published or unpublished data from population-based samples. The report concluded that only 20 countries out of the 53 European member states had representative measured data on children while another five countries including Sweden could provide self-reported data (Branca et al. 2007). Relying on self-reported data is not ideal in a surveillance system due to potential underreporting of the prevalence of overweight as well as skewed representation of subgroups (Nyholm et al. 2007, Ljungvall et al. 2013). The WHO Regional Office for Europe thus initiated a new program for surveillance of overweight and obesity in schoolchildren, the WHO European Childhood Obesity Surveillance Initiative, COSI (WHO 2011). The first data collection took place in 2008 and 13 countries participated. Weight and height were collected in a standardized fashion and countries could also choose to include other anthropometric measurement such as waist circumference. The intention of the pan-European surveillance system was not to replace existing national surveillance but to integrate the uniform methodology and support countries in creating sustainable monitoring. In most countries that participated in the first round of COSI, health authorities were in charge of implementation of the initiative. In Sweden however, there was limited political interest to integrate COSI into existing systems. Instead, research groups were asked to carry out the data collection.

In Sweden, there is a long tradition of measuring children's weight and height in the school health service. The data is used on an individual basis mainly to track children's growth and health (Socialstyrelsen 2014). In addition, the data has been used for regional and local surveillance of weight status (Mårild et al. 2004, Sjöberg et al. 2008, Lager et al. 2009). There is however a lack of, or differing, electronic report systems across the country, and measurement equipment as well as methods may vary. The possibilities of creating a national database have been investigated but so far some issues remain. Children's personal integrity needs to be protected while individual characteristics such as socioeconomic position are important determinants to record. So far, the Swedish Data Inspection Board has opposed such a database (Bjermo et al. 2014). The Swedish participation in COSI forms the first nationally representative sample with measured data of 7-9-year-olds in Sweden and the baseline for future comparisons.

Wilkinson and colleagues propose that an obesity surveillance system should consist of three levels of data (Wilkinson et al. 2007):

- Prevalence indicators: height, weight, and variables relevant for weight classification are collected. Other anthropometry measures can also be used.
- Predictor indicators: socio-demographic data such as deprivation indicators and origin.
- Intervention indicators: factors that can be intervened upon should be monitored; these can include habitual dietary intake and physical activity levels.

Backgrounds to the indicators, some of which are beyond the scope of this thesis are presented here.

1.2.1 Prevalence indicators

Classifying weight status in children

In surveillance systems there is need for standardization of anthropometric measurements and in the collection of related variables of importance. The most common measurement when assessing weight status in children is the body mass index (BMI). BMI does not distinguish whether weight is associated with muscle or fat while other methods such as measuring skinfolds could estimate body fat more accurately. However, such measurements are not feasible in large samples because of time constraints and high interoperator variability (Caroli et al. 2007). Measuring weight and height is non-invasive for the child and is time- and cost effective. BMI has also been established to accurately identify children with adverse cardio-metabolic risk profiles (Reilly et al. 2011). Since children's weight status cannot be based solely on weight and height but also relates to gender and age, these factors need to be included in data collection and choosing an appropriate age group for surveillance is important. Adiposity rebound and puberty are periods in children's growth when obesity development is frequent. To avoid measuring children during these periods, it has been suggested that age group 7-9 should be suitable (Caroli et al. 2007).

There are several methods for weight classification based on children's BMI which is defined as weight in kilograms divided by the square of the height in meters (kg/m^2). For clinical use children's age- and gender-adjusted BMI should be compared to national reference data (Reilly et al. 2011). For surveillance purpose however, an international reference that allows prevalence to be compared between countries is recommended (Rolland-Cachera 2011). The International Obesity Task Force reference (IOTF-reference) and the World Health Organization 2007 growth standard (WHO-reference) are two such references that are commonly used for weight classification. Cole and colleagues developed the IOTF reference based on six large nationally representative cross-sectional growth studies (Cole et al. 2000). Using sophisticated statistical methodology they created centile curves that passed through the BMI cut-offs for adult overweight and obesity classification, 25 kg/m^2 and 30 kg/m^2 respectively, at age 18 years. The averaged curves were then used to create age and gender-specific cut-offs from 2-18 years. In a later stage, the data was complemented with cut-offs that correspond to adult thinness, at BMI below 18.5 kg/m^2 (Cole et al. 2007). In order to express BMI as centiles or SD score, these datasets have recently been recalculated (Cole et al. 2012). The calculations resulted in only minor changes to the cut-offs, and virtually no difference in prevalence of overweight or obesity. Thinness was slightly more affected but only the more severe grades of thinness in younger age groups (Cole et al. 2012). The WHO standard was constructed from a combination of two samples. For ages 0-5 years, healthy children who were breastfed for at least six months and came from socioeconomic conditions that were favorable for healthy growth were included (WHO 2007). The US National Center for Health Statistics (NCHS) 1977 reference was then merged with the WHO 0-5 growth standard. From this, height- and BMI-for-age z-scores were created for children up to age 19 and weight-for-age z-score for children up to 12 years. Weight status can be classified from the BMI-for-age z-score. Overweight corresponds to >1 SD, obesity to >2 SD and thinness to <2 SD (WHO 2007).

Another anthropometric measure that is relatively time- and cost-effective is waist circumference. This measure has also been associated with cardio-metabolic risks in children and contrary to BMI it gives an indication of amount of abdominal fat (Bell et al. 2013). However, the functionality of this method is compromised by the lack of definition for high waist circumference in children. One method that has been proposed is dividing waist circumference by height (waist-height ratio) where ratios exceeding 0.5 are classified as high and suggesting increased risk for central obesity (McCarthy et al. 2006). Another limitation is that the measurement is not as straightforward as height and weight. Different sites for measurement yield different results and there is no agreement on which method to use – at the umbilical, at the narrowest waist or between the lowest rib and the iliac crest as suggested by the WHO (Wang et al. 2003). The measurement is also more demanding for children and examiners as it depends on breathing, whether the child is relaxed or not, and something as simple as the child being ticklish and having difficulty keeping still.

1.2.2 Prediction indicators

Area and individual level socioeconomic factors

There has been awareness of socioeconomic differences in childhood obesity for several decades (Stunkard et al. 1972). For the purpose of this thesis socioeconomic position (SEP) refers to individual socioeconomic circumstances while aggregated socioeconomic information at an area level is referred to as socioeconomic status (SES). In high-income countries, most studies find that children in families with low socioeconomic position (SEP) are at greater risk for obesity, while the opposite scenario is often observed in low- and medium-income countries (WHO 2000). Individual SEP can be measured through different indicators; education level, occupation status, and/or income are often used (Galobardes et al. 2006). Similar SEP gradients are usually observed regardless of which indicator is used. Information about SEP indicators can be self-reported by parents or sometimes obtained through national registers (Koupil et al. 2008).

For several reasons it can be difficult to obtain information about individual markers for socioeconomic position. There may be ethical obstacles or difficulty receiving high enough response rates in a questionnaire-based survey. Children from families with low SEP are often underrepresented in surveys in the first place and adding further limiting factors such as questionnaires may skew the results even more (Regber et al. 2013). Assigning children an area marker for socioeconomic status is often used as an alternative and has been found to work as a proxy for individual SEP (Janssen et al. 2006, Voorhees et al. 2009). In a national surveillance system it is important to include as many children as possible and thus area-level markers for SES may be preferable if access to individual information is restricted. Choosing the size of area of proxy may influence any associations between the proxy and the health outcome. Some argue that smaller areas should be used (Soobader et al. 2001), while others have found that areas of different sizes yield similar results (Geronimus et al. 1998).

Place of residence

Geographical location has been shown to influence health. In Sweden, health and ill health in adults are unevenly distributed across the country with higher prevalence of ischemic heart disease and general morbidity in less-urbanized areas (Melinder 2003). Obesity in conscripts has been found to be more prevalent in rural areas (Neovius et al. 2008). Across Europe, the same pattern has been found in children in Norway (Biehl et al. 2013), Italy (Binkin et al. 2010), Portugal (Rito et al. 2012), and Greece (Tambalis et al. 2013). Yet other countries such as Albania report a higher prevalence of obesity in urban areas (Hyska et al. 2014).

Origin

An individual’s country of origin or ethnicity has often been used as a background variable in public health research but difference in terminology as well as methods of collecting the data is common (Comstock et al. 2004). However, terminology differs between studies. In a recent study of 11-year-olds from seven European countries, children with at least one parent born abroad were found to be at higher risk for overweight in all but one country (Brug, et al. 2012). In Greece, where about 30% of children were classified as non-native, no elevated risk was observed. A Swedish study found that children in a community with a high proportion of immigrants and refugees tended to have a low perception of their ability to affect their own health compared to children in a rather ethnically homogenous community (Magnusson et al. 2011). Authors speculate that this may reflect a less sheltered life in children whose parents have experienced violent conflicts as one-fourth of the population in the area was potential refugees. Another Swedish study included adult immigrants from Turkey, Iran, and Poland and compared self-reported health between the groups in an interview-based survey (Wiking et al. 2004). Origin other than Swedish was related to poor self-reported health, more so in Iranian and Turkish immigrants, where immigration was generally political and war-related, than Polish where immigration was mostly family- related. The associations were mediated by discrimination, education level, and poor acculturation.

1.2.3 Intervention indicators

In addition to anthropometric data it is also important to collect information on indicators of child risk factors for developing obesity. These are modifiable factors that can be included in an intervention. Monitoring secular changes in lifestyle factors can yield valuable information used when planning interventions or when developing public health policy.

Physical activity and dietary intake or habits are notoriously difficult to measure, especially on a larger scale where objective measurements such as accelerometers, heart rate monitors, and biomarkers are unfeasible. There is also a risk that study subjects behave differently when they know they are being monitored (Must et al. 2005). For surveillance purposes representative samples are needed and cost- and time-effective methods are essential. Thus we rely on questionnaire-based methods to estimate physical activity, inactivity, and diet (Branca et al. 2007). Questionnaires are less demanding for subjects but are not without limitations. Response rates in general are decreasing (Galea et al. 2007) and results are at risk of being biased by the fact that parents of obese children are less likely to participate (Regber et al. 2013). Parents of low SEP and with limited understanding of the language in question are also often underrepresented (Regber et al. 2013).

Physical activity and inactivity

The relationship between physical activity and weight status is not entirely straightforward. Some studies using objective measurements of physical activity find an inversed relationship with obesity while others find no association or even a positive association (Dencker et al. 2008). Cross-sectional studies risk being biased by reversed causation, i.e. increased physical activity in obese children as a means to treat the condition. On the other hand, a child with adiposity could be less likely to be physically active due to bullying, or discomfort during exercise, making it further difficult to draw conclusions on causality (Puhl et al. 2013). However, an increased physical activity level is shown to be a good defense against weight gain (Must et al. 2005) as well as having several other health benefits (Janssen et al. 2010).

Physical inactivity or sedentary behavior is not only the absence of physical activity. During the day a child could have time to engage in vigorous physical activity and still be inactive for several hours. In recent years, physical inactivity has been independently linked to several adverse health effects in children, including excess weight and lower physical fitness (Tremblay et al. 2011). Similar to physical activity, inactivity can be measured objectively with accelerometers, but is often assessed through questionnaires in large national samples. Television (TV) watching and computer usage, summarized as screen time, is often used as an estimate of children's general physical inactivity, and high levels of screen time have been positively associated with child adiposity (Ekelund et al. 2006, Lissner et al. 2012).

Dietary intake

The relationship between dietary factors and obesity is difficult to assess due to methodological issues described earlier. Some relationships have however been documented. Consumption of sugar-sweetened beverages has been determined to be positively associated with child obesity in two recent reviews (Malik et al. 2013, Te Morenga et al. 2013). It is nevertheless unlikely that overconsumption of one particular food would cause excess weight in most people. A combination of food choices, taste preferences, access to diverse foods, and many other factors influence the diet (Scaglioni et al. 2011, Beets et al. 2014). In children, food that is offered in school and parental influence are also relevant (Scaglioni et al. 2008). Dietary patterns have recently been studied in relation to obesity. One European study including children from eight countries suggests that adhering to a diet high in vegetables, fruit, and whole meal was associated with a lower risk of becoming overweight after two years of follow up (Pala et al. 2013).

Parental determinants

High parental BMI has been established as a risk factor for child overweight and obesity in several studies (Mårild et al. 2004, Lamberti et al. 2011). Parental weight and height is generally self-reported, which may bias results due to underreporting of high weight (Nyholm et al. 2007). However, it is unfeasible to measure the parents in a large national survey. Genetics does play a role in the relationship but the rapid increase in obesity prevalence indicates that the influence is limited (Swinburn et al. 2011). Since parents and children share most levels illustrated in the ecological frameworks – government policies, community, and home environment – it is probable that they develop similar dietary and physical activity habits. Parenting style has also been associated with child overweight (Rhee et al. 2006) as well as the parental weigh status and parents' perception of the child's weight status (Francis et al. 2001).

2 AIM

The general aim of this thesis is to explore weight status and lifestyle in national and regional samples of Swedish school children during the obesity epidemic, in relation to societal and individual factors.

Specific aims:

- Assess the national prevalence of overweight, obesity and thinness in children in 1^{st} and 2^{nd} grade in Sweden as the initial step of establishing a national surveillance system.

- Map lifestyle habits of children and parents and how these relate to child weight status.

- Explore how national and regional weight status and lifestyle differ by area and individual socioeconomic factors as well as living area.

- Explore how weight status and lifestyle factors change over time – between cohorts and longitudinally – in West Sweden, and how these changes are related to socioeconomic factors.

3 METHODS

This thesis is based on three repeated cross-sectional surveys, as well as a longitudinal study in a subsample of children (Table 1, Figure 1). The first survey was nationally representative and the Swedish contribution to the WHO European Childhood Obesity Surveillance Initiative, henceforth referred to as COSI (WHO 2011). The following two data collection points, in 2010 and 2013, received only local funding and were thus conducted in one region in Sweden. All methods were harmonized with the other 12 countries participating in COSI in 2008, with only slight adaptation to Swedish conditions.

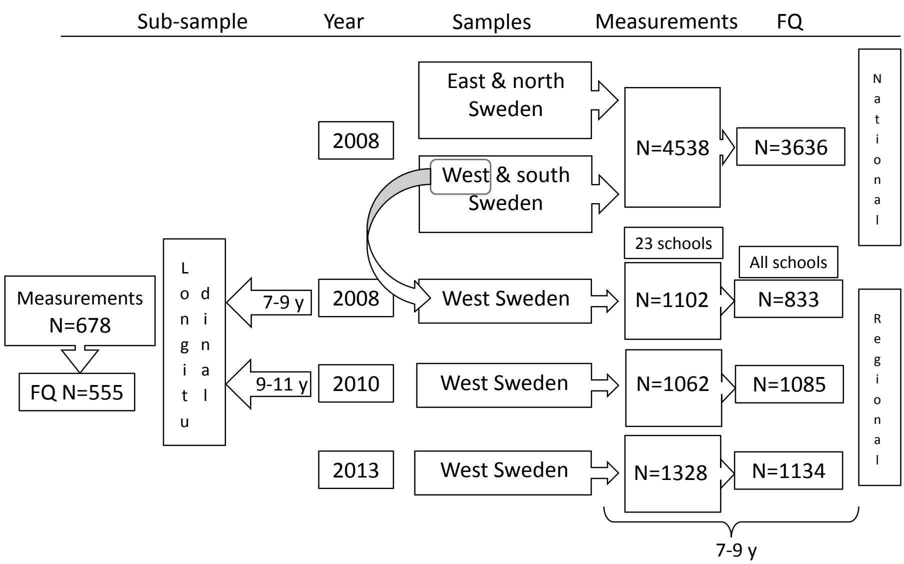

Figure 1. Included samples and number of children in the national and regional cross sectional studies as well as the regional longitudinal study.
FQ: family questionnaire, y: year, N: number

3.1 Sampling

In 2008 the national school registry included a total of 3,064 primary schools. Out of these, 220 schools were randomly selected by Statistics Sweden to be nationally representative for children in grades 1-2 (aged 7-9 years). Schools were sampled according to whether the school was public or private and which type of municipality they were situated in. The Swedish standard classification of municipalities was used: suburban, sparsely populated, commuter, metropolitan, large cities, manufacturing, and three categories of other municipalities; smaller with <12,500 inhabitants, medium sized with 12,500–25,000 inhabitants, and larger with >25,000 inhabitants (SKL 2005). Small schools with less than ten pupils were excluded from the selection. All 220 schools were invited to participate and 94 schools accepted. Dropout at the school level was evenly spread with regard to geography, type of municipality, public/private administration, and area education level when compared with the selected schools. According to class lists, 5,326 children in grades 1-2 were available in 2008 and thus included in the national study.

Out of the 220 invited schools, 36 were situated in the county of Västra Götaland (in this thesis referred to as West Sweden) and 25 of those were included in the national survey. In 2010 and 2013, the survey was repeated only in West Sweden (Figure 1). Children in grades 1-2 in all schools were invited and 29 schools in 2010 and 31 schools in 2013 accepted the invitation. Total number of invited children was 5,114. Twenty-three schools in West Sweden were included all three years, totaling 4,009. Figure 1 illustrates those included in the national and regional samples as well as numbers of measured children and children with completed family questionnaires.

In 2010 children from school grades 3-4 (aged 9-11 years) were also invited in those schools that had participated in 2008 (Table 1, Figure 1). Children whose parents consented to their children's anthropometric measurements being followed over time were identified and 678 children were included in longitudinal analyses. All three years, measurements were performed from last week of March to first week of June. In 2010, measurements in one school were postponed to October.

Table 1. Available and participating children, description of indicators under surveillance as well as methodology in the papers included in this thesis.

Paper	Paper I	Paper II	Paper III	Paper IV
Sample Available/ participating	National N=5,326/ 5,538	National N=5,326/ 3,636	Regional N=4,009/ 3,492	Regional N=5,114/ 3,052; 678[1]
Method	Cross sectional	Cross sectional	Repeated cross sectional	Repeated cross sectional/ longitudinal
Prevalence indicator	IOTF/Cole 2007[2], WHO, waist-height ratio	IOTF/Cole 2007[2], WHO	IOTF/Cole 2007[2], WHO	IOTF/Cole 2007[2]
Socioeconomic proxy	Area education, urbanization	Area and individual education, urbanization	Area education	Individual education
Parental determinants		PA, weight status, origin, breastfeeding		
Dietary factors		SSB, ASB, breakfast		SSB, fruit
Physical activity /inactivity		Sports participation, outside play, screen time, reading		Sports participation, screen time, reading

[1]Refers to longitudinal sample, children were identified based on parental consent.
[2]IOTF: International Obesity Task Force/Cole 2007 references (Cole et al. 2000, 2007).
[3]World Health Organization 2007 reference (WHO 2007).
N: number, PA: physical activity, SSB: sugar-sweetened beverages, ASB: artificially-sweetened beverages.

3.2 Ethical considerations

The methods used in the studies were non-invasive and posed no risk to the child. However even at this young age, body composition can be a sensitive matter and requires attentive, trained staff. In 2008 the study protocol was reviewed by Regional Ethical Review Boards in both Stockholm and Gothenburg. Ethical approval was granted for all parts of Sweden by the review board in Stockholm (No. 2008/309-31/5) while it was deemed unnecessary by the review board in Gothenburg (No. 070-08). An updated study protocol was reviewed and approved by the review board in Gothenburg for the regional study in 2013 (No. 761-12). In 2008 and 2013, opt-out consent was used in all schools, meaning that parents who did not want their child to participate were invited to contact the researchers. In 2010, five schools decided to use active consent, that is, parents gave written consent before measurements. In 2010 the participation rates of schools with active consent ranged from 48-69% and in schools which opt-out consent from 84-100%. Trends between 2008 and 2013, in the 23 schools included all years, were analyzed with and without the schools that used active consent. No differences in trends were observed and thus results including all 23 schools were presented.

3.3 Anthropometry

In 2008 responsibility for measurements was divided between University of Gothenburg (west and south Sweden) and Karolinska Institutet (north and east Sweden). Measurement teams trained together and used the same portable equipment, which was brought to each school. In 2010 and 2013, the University of Gothenburg performed the studies. Measurements followed the same protocol all three years and were conducted during school hours, mainly before lunch. Children were measured in a separate room and all clothing worn during measurements was registered. “Gym clothes” were worn by on average 95% of children and generally consisted of gym shorts or underwear and a t-shirt. Height was measured to the nearest 0.1 centimeters (cm) using SECA 214 portable stadiometers and weight was measured to the nearest 0.1 kilograms (kg) using SECA 862 digital weighing scales. The precision of the manufacturer-calibrated scales was monitored over the data collection period and it was found that these scales were stable and that no change in quality of measurements occurred. Waist circumference was measured in 2008 and 2010 using non-elastic measurement tapes to the nearest 0.1 cm, on the horizontal position midway between the lowest rib and the iliac crest, directly on the skin.

To classify weight status, two international definitions were used. The IOTF-reference was used to define overweight and obesity (Cole et al. 2000) and Cole 2007 was used to define thinness (Cole et al. 2007). These two references were based on the same international data samples and are here referred to as IOTF/Cole 2007. We also used the WHO-reference to define thinness, overweight, and obesity (WHO 2007). In this thesis, overweight includes obesity and children between corresponding adult BMI of 25-29.9 are classified as pre-obese. The BMI cut-offs are gender- and age-specific, IOTF/Cole 2007 by nearest half-year and WHO by month. Based on the WHO standard, BMI, height, and weight z-scores were also calculated. Waist-height ratio was calculated by dividing the waist circumference by height. A waist-height ratio above 0.5 was classified as high (McCarthy et al 2006).

3.4 Questionnaire

The family questionnaire (FQ) contained questions on children's physical activity and inactivity, diet, and parental background, and was developed for COSI by the Regional office for WHO Europe. It was translated from English by the Swedish research groups and slightly modified to accommodate Swedish conditions. The FQs were distributed to the children by teachers on the day of measurement and taken home for parents to fill out. In 2008 and 2010, closed envelopes containing the questionnaire were collected by the teachers and sent to the researchers. However, in 2013 the parents mailed the questionnaires directly to the researchers as requested by the ethical review board that year.

3.4.1 Diet

The FQ included a non-quantitative food frequency questionnaire (FFQ) consisting of 17 items in 2008 and 19 in 2010 and 2013. Food groups included were fruits and vegetables, dairy products, beverages (milk, juice, SSB and ASB), meat, fish, different snacks (cakes, chocolate, nuts) and foods such as pizza and hamburgers. The parents were asked to describe their child's usual intake and in 2008 respondents could choose from 4 response categories: never, 1-3 days/week, 4-7 days/week or every day. After evaluation of the first data collection the decision was made to increase the categories to 8 in the following two surveys: never, 1-3 days/month, 1 day/week, 2-3 days/week, 4-6 days/week, once every day, twice every day, and 3 times a day or more (Figure 2). This was due to feedback from the respondents that it was difficult to choose one of only four categories. There is for instance, a substantial gap between never and 1-3 days per week. We were however able to dichotomize variables similarly all three years. This thesis examines consumption of sugar-sweetened beverages (SSB), artificially sweetened beverages (ASB) and fruit. In analyses, consumption of SSB and ASB were dichotomized into 3 times/week or less and 4 days/week or more.

2008	Rarely or never		1-3 days per week		4-6 days per week	1 time per day		
2010 and 2013	Rarely or never	1-3 days per month	1 day per week	2-3 days per week	4-6 days per week	1 time per day	2 times per day	3 or more times per day
Soft drinks containing sugar	☐	☐	☐	☐	☐	☐	☐	☐
Diet or “light” soft drinks	☐	☐	☐	☐	☐	☐	☐	☐

Figure 2. Example from the food frequency questionnaire. Four categories were used in 2008 and eight were used in 2010 and 2013.

3.4.2 Physical activity and inactivity

Four questions concerned physical activity: whether the child was a member of a sports club, how many days per week they participated in sports, how many hours per day they played outside, and type of transportation to and from school (car/bus/walk/bike). This thesis focuses on sports participation (yes/no) and days of sports participation (more or less than 4 days per week). Inactivity was measured by three questions: how many hours per day their child spent on reading/homework, watching TV/video, and engaging in computer games. The questions were divided into weekdays and weekends and consisted of the following frequencies: never, <1 hour/day, 1 hour/day, 2 hours/day, 3 hours/day or more. Approximate hours per day were calculated for each variable. The three variables concerning physical inactivity were used to estimate total inactivity per day by adding up hours per day. A separate variable was created for screen time by combining TV and computer time. Parents also reported whether their child had a TV/computer in the bedroom.

3.4.3 Parental characteristics

In order to assess whether parents were physically active, the Swedish research team added a question that was not included in the original WHO COSI questionnaire. Questions about parental weight status and origin were also added. Parents reported whether they usually exercised at least two times per week (yes/no). In 2010 and 2013 a question about daily exercise (at least 30 minutes) was added. They also reported highest educational attainment and type of occupation. Weight and height were reported and weight status was calculated. Mother's and father's weight classes were combined into parental weight status where children were classified into having two normal-weight parents, one normal weight and one pre-obese, one normal weight and one obese, two pre-obese, one pre-obese and one obese or two obese parents. Child and parental country of birth were reported and whether parents were born in a Nordic country or not was used in analyses. In addition, breast-feeding (ever) was recorded.

3.5 Socioeconomic and area classifications

3.5.1 Area level

To be able to classify all children according to socioeconomic conditions, a proxy for socioeconomic position was developed based on school area. The mean percentage of adults (25-44 years old) with university education was gathered from municipalities where a school was situated. For the three metropolitan areas (Stockholm, Gothenburg, and Malmoe), information from each district was applied. Three educational levels were estimated; low area education (18-30% of adult population with university education), medium area education (31-43% with university education) and high area education (48-70% with university education) (Papers I and III).

For the regional surveys, unemployment rates were collected from The Public Health Agency of Sweden at municipality level or districts in the city of Gothenburg (Public Health Agency 2014). The unemployment rate at municipality level at year of measurement was assigned to each school (Paper III).

Children were classified according to the type of municipality in which their school was located using the Swedish standard classification of municipalities as described earlier. Degree of urbanization in the municipalities where the schools were situated was classified based on a European classification (Eurostat 2003) into urban, semi-urban, and rural (Papers I and II). For comparison with Swedish studies an alternative classification based on type of municipality was developed: metropolitan and suburban municipalities ("metro/suburb"); larger cities and municipalities with >25000 inhabitants ("larger"); commuter- and smaller municipalities ("other") (Sjöberg et al. 2014).

3.5.2 Individual level

Education level was collected from the FQ and classified into three levels, for the national sample; primary school (low), high school (medium) or university (high) (Paper II). In the regional samples, two levels of education were used, university education or not (high/low) (Paper IV). In longitudinal analyses information from baseline was primarily used to define maternal education, which was present in 659 children (in 97 children maternal education was collected from the second questionnaire in 2010).

Status of employment was reported in the FQ as a) public employment, b) private employment, c) self-employed, d) student, e) homemaker, f) unemployed, g) retired g) other. Employment status was dichotomized into employed (category a-c), and not employed (category d-g) and used as background information in Paper IV.

3.6 Statistical analyses

Schools are likely to reflect their social demographic and thus children in one school may be more similar to each other than to children from different schools and cannot be considered to be independent samples. Therefore each school was assigned a school code, which was included as random intercept in all models. Similar analyses with the GENLIN procedure for generalized regression analyses in SPSS were used in all four papers. The procedure was modified to suit analyses with dichotomous and continuous variables as well as comparisons between cross-sectional and longitudinal measurements. All differences were considered significant at P-levels <0.05 if nothing else is stated.

In Paper I weight status and continuous anthropometric values were compared between girls and boys. Weight status was also analyzed according to urbanization and area education level. Interaction terms with gender and urbanization were included in the analyses to test for modification by gender.

Gender specific analyses were performed when the interaction term was significant.

In Paper II, univariable analyses were performed with overweight and obesity as dependent variables and each of the lifestyle variables, SES, SEP and urbanization as independent variables. Associations were considered significant at P-level <0.1. All variables were dichotomized. Significant variables were then included in multivariable analyses with overweight and obesity as dependent variables. We tested for effect modification by gender in the risk estimates by including an interaction term in the model, and performed gender-specific analysis when the interaction was significant at a P-value of <0.05.

In Papers III and IV multilevel regression was used to analyze trends between 2008 and 2013 in weight status and lifestyle variables. Interaction terms were included in the analyses to examine effect modification by gender (Papers III-IV), SES (Paper III) and SEP (Paper IV). Cross sectional trends in lifestyle variables were adjusted for weight status as overweight/not overweight. In Paper 3, sensitivity analyses was performed by conducting analyses including and excluding children measured with active parental consent. No differences in the result were observed and these children were therefore included. In paper IV, Cohen's Kappa was used to estimate agreement between weight status in 2008 and 2010 in children measured longitudinally.

4 RESULTS

In the national survey 4,538 children were measured, corresponding to 86% of children available according to class lists (Paper I, Figure 1). Two additional surveys were conducted in West Sweden in 2010 and 2013. The regional portion of the national survey consisted of 1,142 children (n=535 girls, n=607 boys). In 2010, 1,448 children (n=744 girls, n=704 boys) were measured and 1,868 children in 2013 (n=906 girls, n=962 boys). However, to be able to compare children's weight status between the surveys we included the 23 schools that had accepted participation all years. The participation rates were 85% in 2008, 83% in 2010 and increased to 91% in 2013 (Paper III, Table 1). Conversely, when analyzing changes in lifestyle, the ambition was to include as many children as possible. Thus children with measurements as well as FQs from all schools were included in Paper IV (Figure 1). In the longitudinal sample, measured both in 2008 and 2010, 678 children were identified for comparison based on parental consent.

4.1 West Sweden compared to Sweden

All types of municipalities except those classified as sparsely populated were represented in the regional samples in West Sweden. Only just over one percent of children in the national sample attended a school in a sparsely populated municipality (Paper II). Comparing prevalence of overweight, obesity, and thinness among children in the regional sample and the rest of children in the national sample in 2008, no differences were observed (Table 2).

Table 2. Subsample in West Sweden compared to the rest of the national sample in 2008.

	Total	VGR	
	3356	1182	p[1]
Overweight	547 (16.3)	207 (17.5)	0.3
Obesity	97 (2.9)	37 (3.1)	0.7
Thinness	262 (7.8)	76 (6.4)	0.1

[1]*P-value calculated with independent samples t-test.*

The results can be categorized in four main themes, as illustrated in Figure 3. The child's weight status, classified from the prevalence indicators, is the center of the figure. The predictor indicators are the area factors (SES, urbanization) and parental characteristics (SEP, origin) while intervention factors are child- and parental characteristics. All ovals represent variables analyzed in relation to child weight status and arrows represent positive/ negative relationships. Double arrows indicate multiple influence e.g. SES influences all variables in "child lifestyle"; all "parental" variables influence child OW/OB. Double lines around a variable indicates association with child OW/OB in the multivariable analyses. Positive associations with overweight and/or obesity were: parental weight status, consumption of ASB, non-Nordic parental origin, less urbanized areas, low SES and low SEP. Finally, block arrows show significant trends between 2008 and 2013 in the group indicated.

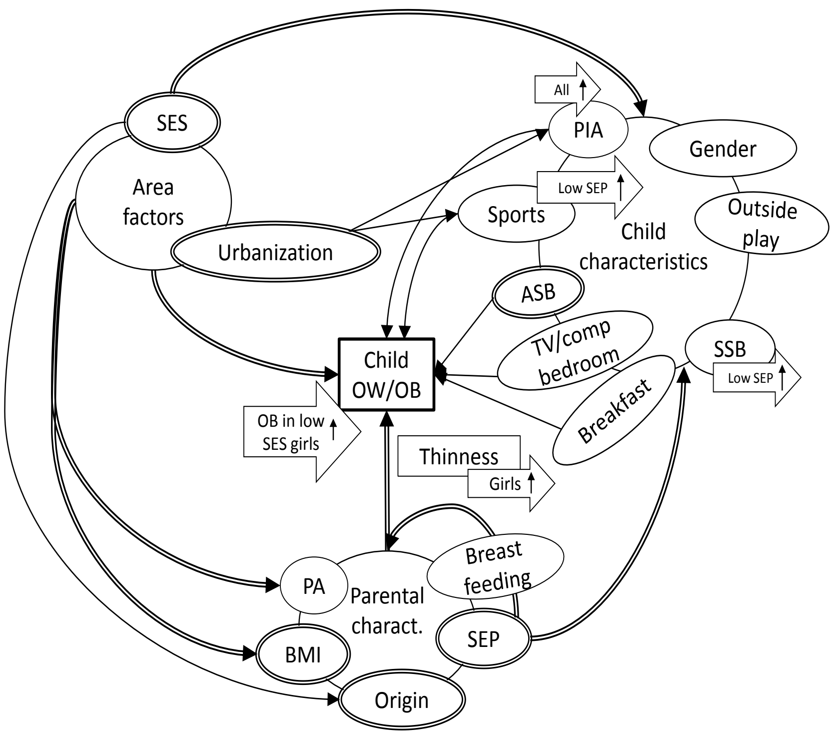

Figure 3. Summary of results in this thesis. Arrows indicate association between variables. PA: physical activity, PIA: physical inactivity, SSB: sugar-sweetened beverages, ASB: artificially-sweetened beverages, SES: socioeconomic status, SEP: socioeconomic position, OW: overweight, OB: obesity.

4.2 Weight status in the national and regional samples

In the national sample around one-sixth of 7-9-year-olds were overweight including around 3% obese by IOTF definitions. Eight percent had high waist-height ratio and almost 8% were classified as thin, mainly the less severe grade (Paper I, Table 1). In the national sample, children in areas with low education level and low maternal education were more often overweight or obese. This socioeconomic gradient was consistent over the years in West Sweden and in girls, obesity increased non-significantly in those with low maternal education, thus widening the socioeconomic gap. Thinness increased in girls with high and medium SEP and overall between cohorts (Paper III, Tables 2 and 3). Weight status in children in West Sweden was otherwise stable between cohorts and in those measured longitudinally.

Overweight and obesity was more prevalent in rural areas compared to urban and in smaller municipalities as well as commuter municipalities (Paper I). These geographical gradients were largely explained by the education level in the area (Figure 4a), except for obesity in boys, where it remained significant. No urban-rural gradient was observed for obesity in girls. The gradients in overweight and obesity were similar when applying the alternative definition for urbanization, but the gradient in obesity was observed in both boys and girls and was attenuated when adjusting for area education level (Figure 4b).

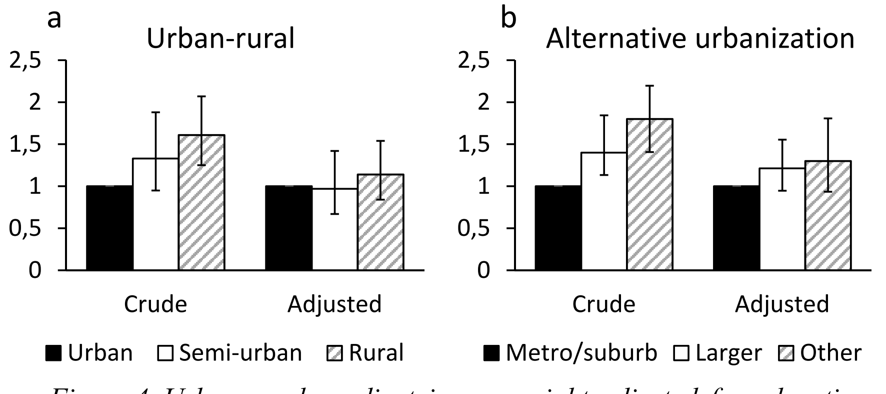

Figure 4. Urban-rural gradient in overweight adjusted for education level in the area. Urbanization was classified in two ways. Urban, semi-urban and rural areas were classified based on a European Union definition of urbanization (Eurostat 2003). Metro/suburb, larger and other were derived from The Swedish standard classification of municipalities (SKL 2005).

When applying the WHO-reference, prevalence of overweight and obesity was higher than when applying the IOTF-reference (Paper II, III). For thinness on the other hand, the prevalence was almost non-existent when using the more restrictive WHO cut-offs. None of the trends described earlier could be detected with the WHO cut-offs. The socioeconomic differences were however present regardless of which reference was applied.

In 2010, 129 children in grades 1-2 were measured using active consent. According to the IOTF-reference, no child with obesity was observed among the children in schools with active consent while 3.8% of children in the opt-out schools were obese, p=0.02. The overall trends in weight status were similar whether the schools using active consent were included or not (Paper III).

4.3 Lifestyle in the national and regional samples

In the national sample 80% of children (n=3,636) returned their FQ. In West Sweden, the response rate was somewhat lower, 73% in 2008, 75% in 2010, and only 61% in 2013.

4.3.1 Consumption of sugar-sweetened beverages

Only just over 1% of children consumed SSB every day in the national sample, and about 9% consumed it 4-7 days per/week (Paper II). Since the number of frequencies in the FFQ was considered to be too few in 2008, the question was altered in the following surveys (Figure 2). The reported consumption in the regional surveys is illustrated in Figure 5. Similarly to children the national sample, most children in West Sweden consumed SSB less than 4 days/week (Figure 5). The consumption was lower in children with high parental education and in areas with high education level (Paper II). In the regional longitudinal sample, SSB consumption 4-7 days/week increased in children with low maternal education from 6.5% to 16% while it was stable in children with high maternal education at about 8%. Between cohorts, consumption 4-7 days/week decreased in children with high maternal education and was stable in those with low maternal education (Paper IV).

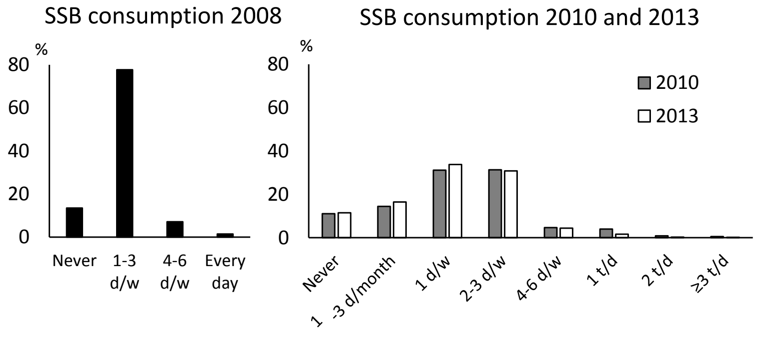

Figure 5. Consumption of SSB in the regional samples in West Sweden 2008, 2010 and 2013.
SSB: sugar-sweetened beverages, d/w: day(s) per week, t/d: time(s) per day.

4.3.2 Physical activity

About 77% of children were members of a sports club both in the national and regional samples and this was consistent over time. In the national sample, children with high parental and area education as well as boys were more often reported to be members than children with low parental and area education and girls (Paper II). These groups, as well as children in urban areas, were also reported to practice their sports more days per week. A reversed gradient was observed in outside play with higher levels in children in low SES areas and rural areas (Paper II). Between cohorts in West Sweden, the physical activity gradient between high and low maternal education levels disappeared due to a rise in exercise days in children with low maternal education (Paper IV). High sports participation (4-7 days/week) was associated with less obesity although the association did not remain in the fully adjusted model (Paper II).

4.3.3 Physical inactivity

Almost all children were inactive more than 2 hours/day in the national sample and about 80% engaged in screen activities more than 2 hours. About 15% were inactive more than 4 hours/day, which was associated with child overweight and obesity in univariable but not multivariable analysis. High level of inactivity as well as having a TV or computer in the bedroom was more frequent in children with low parental and area education (Paper II). In the regional samples the SEP gradient in high physical activity was consistent with an increase in all groups both cross-sectionally and longitudinally (Paper IV).

4.3.4 Parental characteristics

Parents' weight status followed the same patterns as the children's; prevalence of overweight and obesity was lower in urban areas and in individuals and areas with high education. Overall, 31% of mothers and 58% of fathers were overweight including obese. When combining parental weight status there was a dose response relationship with child overweight and obesity. About 40% of children with two obese parents were overweight compared to 7% of children with two normal-weight parents. The combined variable had the strongest association with child overweight and obesity in the multivariable analyses.

In the national sample, 63% of mothers and 55% of fathers reported exercising two times per week or more (Paper II). Regular exercise among fathers was associated with less overweight in children in univariable but not multivariable analyses. The majority of children in the national sample, 95%, were born in Sweden and about half of those not born in Sweden were born in another European country. Having at least one parent born in a non-Nordic country was positively associated with obesity in girls in the multivariable analysis. Almost all children were breastfed at some point and this variable was not associated to overweight or obesity in children (Paper II).

4.3.5 Grouping of risk factors

In the longitudinal sample measured in 2008 and 2010, we examined the influence of risk behaviors – consumption of SSB 4-7 days/week, being inactive more than 4 hours/day and no sports participation. It was not common to have all three of these behaviors, and only 25 children had two of these behaviors in 2008 (Table 3). Having one of the risk behaviors in 2008 was related to pre-obesity (p=0.004), overweight (p=0.02) and high waist-height ratio (p=0.02) in 2010, but this was not observed in the group with two risk behaviors.

Table 3. Risk behavior in 2008 related to weight status in 2010 in 487 children.

	Risk behavior 2008		
	No risk n=321	1 risk behavior n=141	2 risk behaviors n=25
Weight classification in 2010[2]	%	%	%
Thinness	6.3	9.4	4.0
Pre-obese	7.9	18.0[1]	8.0
Overweight	9.1	18.7[1]	12.0
Obese	1.3	0.7	4.0
Waist-height ratio >0.5	5.7	11.5[1]	12.0

[1]*Significantly different from reference (no risk) with p-value <0.05, p-value calculated with multilevel regression model.*

[2] *Weight classifications based on International Obesity Task Force reference (IOTF) and Cole 2007 et al. for thinness (Cole et al. 2000, 2007).*

4.4 Individual and area classifications

To be able to include all children in analyses we chose to use education level in the area as a proxy for parental education level. When comparing how well individuals were classified according to area education level, some discrepancies were found. In the national sample, around 45% were classified correctly, e.g. both high individual education and high area education. Another 45% were classified into an adjacent category, e.g. high individual education into medium area education. Only about 10% were thus classified into an opposite category. Fathers were classified somewhat more correctly than mothers, 50% correctly and 5% into opposite category. On the other hand, more information from mothers than fathers was obtained though the questionnaire. Only 7% of mothers and 10% of fathers reported primary school as their highest attained education.

5 DISCUSSION

The main finding in this thesis was that in a nationally representative sample of Swedish 7-9-year olds, about one sixth of the children were overweight, and 3% obese. A higher prevalence of overweight and overall less favorable lifestyle characteristics were found in families with a low education level and in less urbanized areas. The prevalence of overweight was stable in the large region of West Sweden, but socioeconomic differences remained and some evidence of increasing inequalities in obesity among girls was observed.

These results will be discussed in relation to other Swedish, European and global findings. A general discussion reflecting on the area-level and individual contexts as well as the importance of public health surveillance will follow. First, some methodological aspects will be addressed.

5.1 Methodological considerations

One issue regarding epidemiological studies is participation rates (Galea et al. 2007). To be able to draw conclusions about the population, a sufficiently large sample with reasonably high participation rates is needed. Some drop out is inevitable, and so long as the drop out is random and not systematic, the sample may still be representative. Our largest drop out was at the school level, where only 94 out of 220 schools accepted invitation in 2008 (Paper I). The main reasons for declining were time constraints and prior commitments. The drop out was geographically even, and the included schools were considered representative according to area education level and type of municipality. Participation rates at the child level were high, and the majority of nonparticipating children were sick or absent during the measurement day. Our results from the national survey were thus representative for Swedish children aged 7-9 years when it came to weight status. The participation rates in the regional samples were also high and can be considered representative for the large region of West Sweden (Paper III).

Participation rate is often lowered when using questionnaire-based methods, and the representativeness has to be evaluated accordingly. In our samples, the prevalence of overweight and obesity was higher in children who did not return their questionnaire compared to those who did. This could cause bias in observed associations. Further, the classification of socioeconomic indicators was available for all children only at the area level. Individual classification was questionnaire-based, thus yielding lower participation. In our sample, about half of those classified as highly educated on an individual level were also classified as highly educated at the area level. Only about 10% were classified completely opposite. Further, similar gradients in overweight and obesity were observed when using area and individual classification, indicating that aggregated area information may be sufficient in the absence of individual data. Using questionnaire-based data may also bias results, since response rates declined in the last survey.

One limiting factor in the studies where the family questionnaire was used was the lack of validation of the questions. We did, however, find similar associations between several lifestyle factors and weight status and socioeconomic factors, as others have found (Stea et al. 2012, Beck et al. 2013). Therefore, the methods may be considered adequate for estimating trends in the regional samples. The information was not detailed enough to assess intake of nutrients or amount of energy expenditure, but it could function as a marker for healthy/less healthy diet or physical activity/inactivity behavior.

Methodological differences between the three measurement points in West Sweden could influence our results. In 2010, children in some schools were measured after active parental consent was given. However, this was only the case for a small number of children, and excluding them from our analyses did not alter the results.

5.2 Results discussion

5.2.1 Weight status

Compared to other countries that participated in COSI, the prevalence of overweight in our national sample was similar to some European countries such as Norway, where 19% of children were overweight according to IOTF, compared to our 17% (Biehl et al. 2013). Our prevalence of obesity, 3%, was lower than southern European countries such as Italy, where 12% were obese (Binkin et al. 2010). The results from COSI confirm the north-south gradient in overweight across Europe, earlier identified by Lobstein and colleagues (Lobstein et al. 2003, Binkin et al. 2010, Kunesova et al. 2011, Biehl et al. 2013, Wijnhoven et al. 2013, Heinien et al. 2014). The Swedish national results are somewhat lower than those found in 10-year-olds in four Swedish municipalities, where the prevalence of overweight was 22% (Lager et al. 2009). In the IDEFICS study, a European-wide study of 2-9-year-old children, the Swedish part was situated in some suburban municipalities outside the city of Gothenburg. The prevalence they found in the age group of 7-8-year-olds – 10.3% in boys and 12.5% in girls – is similar to the one we observed in suburban municipalities in the national sample, which was 11.4% in total (G Tognon, personal communication, August 20, 2014).

Wijnhoven and colleagues have recently published the results from the second round of COSI (Wijnhoven et al. 2014). They conclude that a decrease in the prevalence of overweight could be observed in countries with the highest prevalence, such as Italy and Portugal. Conversely, some countries with a low prevalence, e.g. Norway and Latvia, experienced an increase. These changes occurred over only two years, and additional data points would add valuable information on these trends. So far, three rounds of data have been collected in the COSI project over five years, and the results from all three rounds are available for some of the countries. In Italy, the prevalence of obesity decreased slightly when adding the third data point (Spinelli et al. 2013). In Norway, where an increase in overweight was observed over two years, the prevalence was comparable to the first survey year (Norwegian Directorate of Health 2009). In Ireland, the prevalence of overweight decreased overall (Heinien et al. 2014). One Swedish review included regional studies from six municipalities (Lissner et al. 2010). They concluded that no increasing trend could be observed and that in girls in the city of Gothenburg, the prevalence of overweight decreased between 2000 and 2004. Our regional trends support the theory that the obesity epidemic seems to be slowing down when observing aggregated data.

However, changes can occur in subgroups, and in the regional sample we observed a significant increase of thinness in high and medium SES girls. There was also an increased socioeconomic gradient in obesity in girls, even though the trends in each SES group were non-significant. The Irish COSI study drew a similar conclusion: classifying schools by area deprivation, they did not observe declining overweight in deprived areas (Heinien et al. 2014). In England, the inequalities in obesity was observed to increase between 1997/8 and 2006/7 in a study including 4-10-year old children (Stamatakis et al. 2010). Parental SEP was classified by household income and a combination of income and occupation.

In addition to the socioeconomic gradient in overweight and obesity, we also observed that children in less urban areas were at higher risk for excess weight. This urban-rural gradient was observed regardless of which of the two classification methods was used. Results from different studies show heterogeneity across Europe. The Norwegian (Biehl et al. 2013) and Italian (Binkin et al. 2010) COSI studies also observed higher proportions of overweight children in less urban areas, although in Norway only in children with low maternal education. A recent study in Albania observed an opposite gradient (Hyska et al. 2014), consistent with countries undergoing an economic transition (Wang et al. 2002). In our study, the differences could largely be explained by education level in the given areas, even if the association between semi-urban areas and obesity in boys remained significant. When simultaneously including area education and maternal education level as well as other lifestyle variables in analyses, the geographic area was still related to obesity in boys. Differing classifications of urbanization may explain discrepancies between the Swedish and Norwegian studies. In the Norwegian COSI, the higher levels of overweight in rural areas were only observed in children with low maternal education (Biehl et al. 2013). Biehl and colleagues were able to obtain information on maternal education for all mothers via registers. The fact that we could not reach this level of representativeness may explain why we observed an urban-rural gradient in children with high as well as low maternal education (Sjöberg et al. 2014). If we could also obtain register-based information on individual education level our observations may be similar to those by Biehl and colleagues.

To enable comparisons between countries, it is recommended to present prevalence of weight status both according to the IOTF/Cole 2007-reference and the WHO-reference (Rolland-Cachera 2011). Applying the WHO-reference often yields higher prevalence of overweight and obesity and lower prevalence of thinness in the age group of 7-9 years (Rito et al. 2012, Wijnhoven et al. 2013). The trends in thinness and obesity in girls according to the IOTF-reference were not observed in our study when applying the WHO-reference. For obesity, this could reflect increasing SES differences in cases of more severe obesity, since the IOTF cut-offs are higher and thus more restrictive. Conversely, for thinness the lower WHO cut-offs should catch those with more severe thinness. This indicates that the increase we observed in girls using the IOFT-reference could be occurring in the lower distribution of normal weight. Since thinness increased in children with high SEP while obesity decreased non-significantly, there may be a downward shift in the BMI distribution. In a study in Gothenburg, thinness was found to increase in girls in a low SES area (Magnusson et al. 2011). When planning public health interventions aimed at reducing overweight, it is thus important to also consider increasing levels of thinness.

5.2.2 Lifestyle and parental determinants

Our results add to the picture that overweight and obesity in children are influenced by both individual and environmental factors. We found that children's weight status was strongly associated with their parents' weight status. This has also been found by others and is not surprising, since children and parents share both genes and environment (Mårild et al. 2004, Monasta et al. 2010, Lamberti et al. 2011). Girls with at least one parent born in a non-Nordic country were also at higher risk for obesity. Another Swedish repeated cross-sectional study including 15-16-year-old adolescents used the same definition of parental origin as we did, observing higher risk for overweight in children of non-Nordic origin in 2000 but not in 1994 (Sjöberg et al. 2011). Khanolkar and colleagues compared assessed risk in 4-5-year-olds according to maternal birth country. They used a more specified classification of origin than we did, finding that children with mothers born in Iran, Turkey and countries in North Africa and South America had an elevated risk compared to those with Swedish mothers (Khanolkar et al. 2013). Finnish maternal origin, on the other hand, was a protective factor. Even though origin is often found to be a risk marker for obesity, it is important to consider underlying factors. As concluded by Wiking and colleagues in a Swedish study, discrimination and education level were factors influencing adult immigrants' poorer self-reported health (Wiking et al. 2004).

There is evidence that children with high consumption of sugar-sweetened beverages (SSB) less often meet dietary recommendations concerning important nutrients (Ballew et al. 2000). Consumption of SSB could thus be seen as a marker for a less healthy diet in general. Even though we did not find an association between consumption of SSB and child overweight and obesity, two recent reviews have concluded that there is a positive association (Malik et al. 2013, Te Morenga et al. 2013). Our method of assessing dietary intake may not have captured the children's habitual consumption, or perhaps the relatively low consumption in Swedish children contributes to a low variation among children. However, we did observe that children in areas and families with lower socioeconomic position more often consumed SSB, which is consistent with findings in Norway (Stea et al. 2012), the USA (Beck et al. 2013) and Sweden (Magnusson et al. 2011). We were also able to detect secular and longitudinal changes in West Sweden, with more favorable patterns in children with high maternal education. There has been plenty of attention on sugar and SSB consumption in Swedish media during the last years (Sundblom et al. 2010). The Nordic Nutrition Recommendations, for instance, recommend limiting intake of added sugar (NNR 2012). The fact that there was no decrease and even a longitudinal increase of SSB consumption in groups with low SEP may indicate that these groups are less likely to assimilate health messages than groups with high SEP, a phenomenon which has been observed by others (Furuya et al. 2013). Higher health literacy has also been linked to lower intake of SSB in adults (Zoellner et al. 2011). Further, it may be less socially desirable to report a high sugar intake in some groups, and foods considered less healthy have been found to be underreported (Lafay et al. 2000). In our study on the national sample, we found that consumption of artificially-sweetened beverages (ASB) 4-7 days/week was associated with obesity in girls. As discussed in Paper II, this may relate that families with a perceived weight problem in children or parents consume ASB as a means of weight control. These factors add to the difficulty in measuring diet correctly and interpreting the potentially biased results.

There are no recommendations from Swedish health authorities for limiting sedentary behavior, only a general recommendation that prolonged sedentary behavior should be avoided (Folkhälsomyndigheten 2011). Other countries have gone a step further, such as the Canadian Society for Exercise Physiology and the Australian Government of health and ageing, which recommend limiting recreational screen time to less than two hours a day (CSEP 2012, Australian Department of Health 2014). They also recommend that children should take breaks and move around during long periods of sitting. Almost all children (95%) in our national samples engaged in sedentary behavior more than 2 hours/day, with 14% engaging in such behavior more than 4 hours/day. Several studies have found that sedentary behavior is an independent risk marker for adverse health effects, even in children who participate in moderate to vigorous physical activity (Ekelund et al. 2006, Chaput et al. 2013, Mitchell et al. 2013). We observed an increase of sedentary behavior in all groups of children in the regional samples, both between cohorts and longitudinally, and with a consistently higher level in children of low, compared to high, SEP. Physical inactivity has been associated with obesity in our and other studies (Tremblay et al. 2011), and the increase could thus consolidate the social inequalities in obesity. On the other hand, the number of days spent on sports participation increased between cohorts in children with low SEP in our study. In the longitudinal sample, days spent on sports participation increased in both high and low SEP groups and in boys as well as girls. This is consistent with a Swedish study which examined life style trends over a period of two years (Elinder et al. 2014). They observed an increase in three different age groups, including children in grade 2. A gender difference was also found, with boys spending more time on sports activities than girls, a difference which we observed in the cross-sectional measurements but not in the longitudinal sample. Reviews have found that increasing physical activity and decreasing sedentary behavior may prevent weight gain or reduce weight (Must et al. 2005, Biddle et al. 2014). However, these reviews also concluded that studies on this matter are limited due to short follow-up, imprecise measurements and differing definitions of physical activity and inactivity. Taken together, it seems that the age group in our study, 7-9 years, is an age where both physical activity and sedentary behavior increases. Given the higher levels of sedentary behavior in children with low SEP, this group may benefit from interventions targeting limited screen time, in combination with promotion of physical activity.

Even though some behaviors have been found to be independently associated with child obesity, a child's lifestyle encompasses many behaviors. The ecological models of obesity (Davison et al. 2001, Kumanyika 2001, Vandenbroeck et al. 2007) remind us that behaviors are influenced by global, national and local circumstances and structures. Studying how behaviors interact with each other may provide useful information when it comes to policy making and intervention planning. One review including studies from the USA explored weight status and dietary habits in relation to participation in organized sports (Nelson et al. 2011). Some studies found a positive relationship between sports participation and weight status while others found no relationship. Children that participated in sports consumed fruit and vegetables more often but also more fast food and consumed more calories overall than those not participating in sports. Authors speculate that easy access to food at the sports facilities add to the higher intake of the unhealthy foods (Nelson et al. 2011). A Dutch study including 13-year-old adolescents found that SSB consumption was positively related to both TV and computer use (Kremers et al. 2007). Strength of screen habits and consumption habits were measured using a validated index, and both behaviors were found to be habitual. The strength of habit of each behavior was also strongly correlated; indicating that one behavior automatically triggered the other. This is supported by findings in the European-wide IDEFICS study (Lissner et al. 2012). They observed that a high-risk TV behavior was positively associated with consumption of SSB, regardless of the children's taste preference. That is, even when a child did not have a preference for sweet tastes, they consumed more SSB if they had a high-risk TV behavior. The relationship between screen time and SSB consumption could possibly be related to exposure to food commercials (Borzekowski et al. 2001, Olafsdottir et al. 2013). In Sweden, commercials aimed at children less than 12 years of age are banned, but this law does not apply to TV channels broadcasting from abroad (Konsumentverket 2013). Children could thus be subjected to advertisement while watching TV and may also be influenced by commercials aimed at older children or adults.

Even when clustering of adverse health behaviors are observed, inconsistent findings are reported with regard to overweight. One large study, including 9-

11-year-olds from nine European countries, studied patterns of physical activity and screen time in relation to children's weight status, reported by their parents (te Velde et al. 2007). They found that in girls, screen time behavior (hours watched and watching TV during dinner) was more important in relation to overweight status than physical activity. In boys, a pattern of low physical activity and high sedentary behavior was associated with overweight (te Velde et al. 2007). A smaller British study inlcuding 10-11-year-olds used accelerometers to assess activity levels (Jago et al. 2010). They identified three patterns of physical activity and sedentary time and did not find any difference in BMI between the three patterns. In our longitudinal sample, we found that it was rare for children to have a clustering of adverse health behaviors, but having only one out of three behaviors – high SSB consumption, high inactivity or no sports participation – in 2008 was related to overweight and high waist-height ratio at follow up in the longitudinal sample. However, we did not observe any adverse effect with two or more risk factors, possibly because our sample size was too small. The conflicting results may also reflect the different methods of assessing children's behaviors. When planning public health intervention it seems to be important to carefully consider clustering of health behaviors. Changing one behavior may influence another behavior in a positive or negative direction, such as with increasing fast food intake in relation to organized sports (Nelson et al. 2011).

5.3 General discussion

5.3.1 The area and the individual

We found that several of children's lifestyle factors under surveillance, as well as adiposity, differed depending on the location of the school. Estimating education level in this way may misclassify children, as the municipality can be a relatively large area. An alternative would be to classify child residence according to postal code, which is a smaller geographical area than municipality. However, it is not certain that aggregated information from smaller areas correspond better to individual socioeconomic factors than information from larger geographical areas (Geronimus et al. 1998).

Using individual data may add information about socioeconomic position but it is limited by differential non-participation in less affluent areas, as observed in our studies. Further, decisions made based on ethical considerations that require active consent may have influenced our participation rates across the three measurement points. If ethical committees become even stricter, it may prove very difficult to obtain representative individual data.

For surveillance purposes it may be enough to use area-level socioeconomic proxies, but in order to draw conclusions about the reasons for the differing lifestyle habits and choices and the uneven distribution of several diseases including obesity across geographical areas, we must explore individual factors. However, the area may not only be used for aggregation of socioeconomic factors but can also influence children's and parents' lives in several ways. The built environment has been subject to much research in recent years. Papas and colleagues conducted a review of 20 studies that explored the relationships between the built environment and obesity (Papas et al. 2007). Studies with adults and children were included, and 17 of the studies found a positive relationship between some aspect of the built environment and obesity. The environmental factors under study varied, with the majority examining aspects of opportunities for physical activity. Only four explored availability of food sources, such as fast food outlets and grocery stores, while another two studies included both measures of access to physical activity and food sources (Papas et al. 2007). Of the two studies with this double focus, one found no relationship between proximity to playgrounds, fast food outlets or neighborhood crime and risk of overweight in 3-4-year-old children. The other found an inverse association between an increasing number of fitness centers and BMI in women but no associations to dietary factors such as the number of fast food outlets and other restaurants (Papas et al. 2007). Another review from 2009 focused on studies that examined the influence of the built environment on disadvantaged groups (Lovasi et al. 2009). They found that increased access to exercise facilities and supermarkets, as well as increasing neighborhood safety, may reduce inequalities in obesity.

The Swedish Neighborhood and Physical Activity (SNAP) study has examined walkability in 32 neighborhoods in the capital city of Stockholm (Sundquist et al. 2011). Walkability examines the aspects of the built environment that enable physical activity, such as active transport, and includes aspects such as connectivity of streets and residential density. For example, a high level of street connectivity can be measured through density of intersections, with a higher density providing a more direct path between destinations. In SNAP, walkability was assessed by Geographic Information Systems (GIS) and was explored in relation to individual income and moderate physical activity as measured by accelerometers (Arvidsson et al. 2013). They found that the level of physical activity was higher in neighborhoods with high walkability, especially in the afternoon or early evening. Low individual income was associated with higher physical activity during the day while those with high income were more physically active during the afternoon/evening (Arvidsson et al. 2013). A study in Belgium investigated GIS-based walkability in relation to neighborhood SES which was based on median household income in the area (Van Dyck et al. 2010). They found that SES was not a mediating factor, thus concluding that high walkability was beneficial in all SES groups. Although these studies did not include children and did not examine walkability in relation to overweight, they give us an insight into the influence of the neighborhood on physical activity. Increasing the walkability of a neighborhood seems to be an effective way to enable people to be more physically active.

5.3.2 Public health promotion

It seems evident that multiple lifestyle factors could potentially influence whether a child develops overweight or not. Addressing some aspects of the lifestyle is a logical step in order to prevent or reverse excess weight gain. However, given the complex etiology of childhood obesity, and the environmental factors discussed earlier, measures need to be taken on several levels. Even if the actual change only occurs in the individual, the changes can be more or less conscious and an environment that facilitates a healthy lifestyle is therefore of utmost importance (Swinburn et al. 1999).

When it comes to public health initiatives, several benefits can come from focusing on structural changes at an area level. These actions may be easier to sustain because the changes are built in to people's everyday life (Swinburn et al. 1999). They may also reduce the risk of adverse effects such as eating disorders and body image issues by shifting the focus from the individual's body composition and the changing of physical appearance to the structures which enable or obstruct healthy choices.

Evaluations of health-promoting campaigns aimed at increasing fruit intake in the public show that there is also a possibility for success when focusing on the individual level. It has been suggested that the most successful programs are those with a wide collaboration between government, industry and non-profit organizations (Rekhy et al. 2014). Campaigns aimed at children have been found to be particularly successful and most effective when involving multiple factors such as proactive involvement of family, behavioral change and interactive features (Rekhy et al. 2014). In the British campaign "Food Dudes", children with the poorest consumption prior to the campaign were those who increased their consumption most, which is an important aspect when ensuring that inequalities are bridged and not enlarged

(Rekhy et al. 2014). In a review of interventions targeting obesity more generally than just fruit and vegetable consumption, Beauchamp and colleagues explored the effect of interventions in different SES groups (Beauchamp et al. 2014). They found only eight studies that included children and also reported the effects stratified by SES. Interventions that focused on changing structures or environments either at home or at the community/school level seemed to be more effective in low SES groups than those focusing on the individual level by delivering information through media or counselling (Beauchamp et al. 2014).

Health authorities in the region of West Sweden have been aware of inequality not only in obesity but in health in general for several years and have recently initiated a movement called “Together towards social sustainability” (VGR 2013). Three major themes have been identified, including “Creating the preconditions for safe and satisfactory early-life conditions”, where initiatives and measures needed to close the gap between children with high and low SES were identified. The implementation phase is yet to be started and is dependent on continued political decisions. Other local Swedish initiatives specifically targeting the inequality in childhood obesity levels have already been implemented during the last decade. One example is the Health Equilibrium Initiative (HEI), which was a community-based health intervention that took place in an area in Gothenburg with less advantageous socioeconomic conditions (Magnusson et al. 2011). Structural (school meals, outdoor environment) as well as individual levels were addressed. A wide scale of health-promoting actions such as cooking sessions and parental meetings were included in preschools, schools, primary care and dental care clinics. The intervention was driven by the idea that individuals interact with and influence their surrounding environment, and thus children, parents and staff members were involved from the planning stages through implementation of the intervention. After five years, several beneficial anthropometric as well as lifestyle changes had occurred. BMI z-score decreased significantly in girls and the prevalence of obesity was halved overall, although non-significantly (Magnusson et al. 2011). Although there was no control group, it is probable that the intervention was effective in reaching families in an area with low SES and a high proportion of immigrants. The intervention was recently implemented in other areas of the city of Gothenburg with an aim of evaluating whether the effects can be replicated, as well as conducting a health economic assessment (Magnusson et al. 2014).

The region of West Sweden includes municipalities of both urban and rural character. In one rural area, an attempt to prevent child obesity was initiated in 2005 (Ljungkrona-Falk et al. 2013). The strategy was to involve nurses in child health care centers where almost 100% of parents bring children for health checkups. The nurses used a manual developed by a dietician and engaged parents in a dialogue, focusing on healthy habits in parents. The effects of this initiative on children's weight still remains to be evaluated, but interesting findings of the nurses' experiences from the project have been published (Ljungkrona-Falk et al. 2013). Many of the nurses experienced barriers when it came to conveying a healthy message. The barriers could be related to lack of support in the work place or to their own insecurities. A majority of the 62 nurses who participated in the questionnaire based part of the study found it difficult to talk to parents about their child's obesity. They also experienced difficulty to talk about a child's obesity when the parents themselves were obese (Ljungkrona-Falk et al. 2013). This study was conducted in 2007 and it can be speculated that the experiences since then may be different, possibly with less barriers, as compared to early on in the project. Considering the strong relationship between parents' and children' weight status, it is important for health practitioners to find successful methods to address this issue.

In spite of several health-promoting initiatives in West Sweden, we observed increasing SES difference in obesity in girls in the region. Even though only 23 schools were included, they represented different municipalities and SES areas. However, to know whether this trend represents a fluctuation in the prevalence or a true increase, continuous surveillance of children's weight status is needed. Surveillance is also essential in order to evaluate the initiatives in the region. Without such monitoring it is difficult to know whether the interventions have had any effect or if the change in lifestyle and overweight prevalence is also occurring in the general population as a result of policy changes or other actions. With functioning childhood obesity and lifestyle surveillance that has national coverage and includes urban as well as rural settings and children from all socioeconomic strata, we can ensure that we have a good understanding of the prevalence and trends of these factors.

5.3.3 Surveillance

Public health surveillance is often described as the cornerstone of public health practice (Thacker et al. 2012). The history of public health surveillance can be traced as far back as the fourteenth century and the bubonic plague in Italy (Thacker 2010). The focus since then has been mainly on infectious diseases such as small pox and cholera. In 1965, the WHO established the epidemiologic surveillance unit in the Division of Communicable diseases (Thacker 2010). It was not until the year 2000 that the WHO World Health

Assembly endorsed "the global strategy for the prevention and control of non-communicable diseases" (WHO 2000). The WHO focuses on four main non-communicable diseases, namely cardiovascular diseases, cancers, chronic respiratory diseases and diabetes (WHO 2000). They have identified physical inactivity and unhealthy diet as major behavioral risk factors for the development of obesity, which in turn increases the risk for non-communicable disease. Given the burden of these diseases on the individual as well as society, and the fact that children's weight status often tracks into adulthood, the need for preventive measures in children is apparent.

A surveillance system for childhood weight status is important for the monitoring of obesity as well as thinness in all children and for risk groups in particular. Monitoring lifestyle is also important in order to assess changes in physical activity, sedentary behavior and diet in children. The WHO has identified a lack of such systems throughout the European region (Branca et al. 2007) and thus has launched the Childhood Obesity Surveillance Initiative (COSI) in several countries (WHO 2011). In total, 21 countries have been involved in one or more data collections in 2008, 2010 and 2013. In Sweden, the lack of funding other than from local government in West Sweden prevented participation in the second and third rounds. However, in our national survey we were able to obtain representative data on children's weight status. We were also able to implement the indicators suggested for surveillance by Wilkinson and colleagues – prevalence indicators, predictor indicators and intervention indicators (Wilkinson et al. 2007). This gives us a baseline for the comparison of weight status and risk factors across geographical areas and socioeconomic groups.

The objective of COSI was to implement the surveillance system into already-existing systems when possible. In Sweden, the logical place for implementation would be where children's weight and height are already being routinely measured, which is in the child- and school health service. According to Swedish law, children in compulsory school have the right to at least three health visits to the school health service (Socialstyrelsen 2014). Visits should be evenly spread out and even though no age is specified, they are recommended to take place around the ages of about six, eight, ten and 14–15 years. During these health visits, height and weight are measured and regular health exams are performed. Health topics such as diet and physical activity are often addressed, but there is no uniform structure for these health dialogues (Socialstyrelsen 2014). The anthropometric measurements are used on an individual basis, to discover any growth diversions and to be able to intervene at an early stage if necessary. In order to use these measurements as well as information on risk factors for the purpose of surveillance, standardization is crucial. Our experience during data collection was that the equipment used by school nurses varied between schools, as well as which age groups were measured yearly. In the Norwegian COSI, a study of the impact of measurement errors was conducted in the first data collection round in 2008 (Biehl et al. 2013). As opposed to the Swedish COSI, equipment already present in the school was used for measurements. Each school included in the study was therefor provided with a reference weight and length and thus calculated the correction value for each instrument – scale and stadiometer. Their analyses showed that without correction, the prevalence of overweight and obesity would be overestimated (Biehl et al. 2013). Good quality equipment is thus a prerequisite for obesity surveillance. In addition, measurement techniques may differ, along with the way measurements are reported. In order to compile the measurements for use on a national level, these methods need to be uniform.

Several attempts at establishing a database with information on weight and height measured in the school health service have been made in Sweden (Bjermo et al. 2014). One suggestion has been to join the measurements performed in the school health service with the existing National Birth Registry, where, among other things, information on anthropometry at birth is recorded (Socialstyrelsen 2014). The registry is connected to the unique personal number that each individual in Sweden is assigned at birth. This merging of systems was, however, not approved by the Data Inspection Board, since the integrity of children's personal information could be jeopardized (Bjermo et al. 2014). At birth, parents are asked to consent to the registering of birth data in the Medical Birth Registry. If they were also asked to consent to the tracking of children's growth throughout child- and school health services, such data could be merged automatically with the Medical Birth Registry. This would provide high quality data on anthropometry that could be linked to other registers containing individual socioeconomic and geographical data. Data in the Medical Birth Registry is already strongly protected by law and information is only shared for research purposes after special consideration (Socialstyrelsen 2014). Individual data is often merged by The National Board of Health and Welfare before it is shared with researchers. In this manner, children's personal information can be protected.

6 CONCLUSION

We were able to assess the national prevalence of overweight and obesity at one time point but were unable to establish a surveillance system for continuous surveillance. The collected nationally representative data will serve as a baseline for future comparisons.

In the national sample around one sixth of 7-9 year olds were overweight and around 3% of those were obese, 8% had high waist height ratio. Almost 8% were classified as thin, mainly the less severe grade.

There were substantial societal differences in overweight and obesity in Swedish school children with higher prevalence in areas and families with lower education level. When comparing individual and area classification of education level, only a small proportion was classified completely opposite. Further, higher levels of overweight were observed in less urbanized areas, regardless of which classification was used.

Similar differences according to urbanization, SEP and SES also occurred in several lifestyle variables associated with overweight and obesity, with generally less favorable habits in rural areas and areas and families with low education level.

The SES gradient was consistent and even increasing longitudinally in some lifestyle variables in West Sweden, implying that the difference in obesity could increase further as children grow older.

When applying the lower WHO-reference, prevalence of overweight and obesity were higher than according to the IOTF-reference, while the opposite was observed for thinness. Similar socioeconomic differences were detected but no trends could be observed when applying the lower WHO-reference.

In the regional cohorts an increased socioeconomic gap in obesity in girls was observed between 2008 and 2013, when using the IOTF-reference. Further, thinness increased in girls of higher SES indicating a downwards shift in the BMI distribution in high SES girls.

7 FUTURE PERSPECTIVES

Even though parent's weight and lifestyle have great impact on children's weight status, identifying families at risk may be difficult, especially in school aged children. A more successful tactic may be to target risk areas such as rural areas and areas with lower education level. Children in primary school seem to be susceptible to change in their lifestyle, both as they grow older and between cohorts as societal factors may change. Therefore, the school environment should be an ideal arena to enforce a healthy lifestyle and intervene on adverse lifestyle behaviors. There is also the opportunity to reach most children in an area and to target areas with less advantageous conditions. Targeting structural changes at the area level may also avoid stigmatization of obesity. It is however important to consider how to prevent stigmatization of groups and areas. Further one must also be prepared to tackle increases in the prevalence of thinness.

To be able to monitor any effects of prevention and intervention, surveillance systems of child weight status as well as lifestyle behaviors need to be installed. It is especially important to ensure that lifestyle intervention do not increase the socioeconomic gap by failing to reach those most in need. Using aggregated data of prevalence without linking it to socioeconomic factors is not enough if we want to be able to target interventions aimed at risk groups. A surveillance system that continuously collects standardized prevalence data with connection to socioeconomic markers, either on an individual or area level, should be installed in Sweden.

Ideally surveillance could be implemented in already existing systems such as the child- and school health service, where children's weight and height are already routinely measured. Linking these data to birth data in the Medical Birth Registry would provide longitudinal data for the vast majority of children born in the country. However, issued regarding parental consent would have to be solved. Further, standardization of equipment and methods as well as a uniform computerized report system in the child- and school health service is a prerequisite.

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