SOCIAL INEQUALITY IN CHILDHOOD AND LATER EFFECTS ON MENTAL HEALTH AND OVERWEIGHT

PhD Dissertation

Per Høgh Poulsen

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Danish Ramazzini Centre
Department of Occupational Medicine
Regional Hospital West Jutland
University Research Clinic
Herning, Denmark

Health, Aarhus University

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University Research Clinic, Herning, Denmark
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Supervisors

Johan Hviid Andersen, Professor, PhD (Main supervisor)
Danish Ramazzini Centre, Department of Occupational Medicine, Regional Hospital West Jutland — University Research Clinic, Herning, Denmark

Karin Biering, Associate Professor, PhD
Danish Ramazzini Centre, Department of Occupational Medicine, Regional Hospital West Jutland — University Research Clinic, Herning, Denmark

Trine Nøhr Winding, PhD
Danish Ramazzini Centre, Department of Occupational Medicine, Regional Hospital West Jutland — University Research Clinic, Herning, Denmark

Ellen Aagaard Nøhr, Professor, PhD
Institute of Clinical Research, University of Southern Denmark, Denmark

Evaluation committee

Henriette Nørmølle Buttenschøn, Associate Professor, PhD (chairman)
Department of Clinical Medicine - NIDO|danmark, Aarhus University, Herning Regional Hospital, Herning, Denmark

Erik Hemmingsson, Associate Professor, PhD
The Swedish School of Sport and Health Science, GIH, Stockholm, Sweden

Kirsten Nabe-Nielsen, Associate Professor, PhD
Department of Public Health, Section of Social Science, University of Copenhagen, Copenhagen, Denmark

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Preface

This PhD thesis is based on studies carried out between 2016 and 2019 during my employment at the Department of Occupational Medicine, Regional Hospital West Jutland, Herning, Denmark.

I wish to express my gratitude to all those who made this work possible.

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Abbreviations

Adj.	Adjusted
BMI	Body mass index
CES-D	Center for epidemiologic studies depression scale
CES-DC	Center for epidemiologic studies depression scale for children
CPR	Central person register
CT	Computer time
DKK	Danish kronor
DREAM	Danish register for evaluation of marginalization
E.g.	Example gratia
FAD	Family assessment device
LMP	Labour market participation
PSS	Perceived stress scale
PA	Physical activity
SEP	Socioeconomic position
SES	Socioeconomic status
SSS	Subjective social status in society
UK	United Kingdom
US	United States
WHO	World health organisation
Yr	Year

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1. Introduction

Inequality in health is a major public health concern worldwide and has been an important research focus for many years, spanning across different research traditions from bio-medical science to psychological and epidemiological research areas. There is persistent and widespread inequalities in health across Europe (1) and inequalities in health exist both between and within countries (2). Some of the challenges for research and policymakers are the social gradient in health and the disadvantage through the life course (3). The longer people live in stressful economic and social circumstances the higher the risk of potential negative consequences (4).

A large number of research papers have been published as an attempt to disentangle how social inequality impacts future physical and mental health in humans. There are many studies which have, for example, examined socioeconomic inequality in health among adults and observed that people with lower income, lower educational attainment or poorer occupational status more often suffer from adverse health outcomes and die earlier than people who are more privileged (5-9).

Denmark is a welfare state characterised by equal access to health care and education for all citizens and has for many years been defined as an egalitarian society due to a very low grade of economic inequality. However, observations have shown that the economic inequality, measured by the Gini coefficient has increased during recent years. This pattern has also been observed in other Northern countries (10).

Recent studies indicate that social inequality in both mental health areas such as depression and stress, as well as physical health areas such as overweight and obesity have increased in Denmark during recent years. More specifically, the Danish Council on Health and Disease published in 2014 a report concerning children and young people's mental health. The report showed that children aged 10-16 years with the highest incidence of mental symptoms came from lower socioeconomic groups and that the prevalence of stress among the 16-24 years old was twice as high among the young people from the lower socioeconomic classes compared to young people from the higher socioeconomic classes (11).

Results from the review by Magnusson and colleagues showed that across the Nordic countries, an inverse social gradient in overweight and obesity was present, and they concluded that social inequality in overweight and obesity is present and persistent in children, adolescents and adults (12). This seems to be supported by recent findings from the Danish National Health Profile 2017 that showed an increase in overweight and obesity especially among young Danish men aged 16 to 24 years from lower socioeconomic classes, compared to earlier Health Profiles (13).

Although Denmark is considered an equal and an egalitarian society striving to provide the same possibilities for all citizens, it remains important to examine early social inequality, since being brought up in a lower socioeconomic family may result in fewer resources which could influence

future life and health (14). A recent study showed that compared to the other Nordic countries Denmark showed the strongest relative inequality on poor self-rated health among adolescents (15). The study also emphasised the differences between the Nordic countries with regard to public health programmes. In Norway, for example, they highlight the role of the social determinants of health, whereas in Denmark policies highlight individual responsibility and sensible health choices (15,16).

In summary, continuous research within the area of social inequality during childhood, its potential relation to mental health and overweight/obesity later in life seems highly relevant in order to improve future preventive initiatives.

2. Background

Children and young people's lives are shaped by a large and complex variety of structural, environmental and social factors. Across countries, some of the strongest determinants of young people's mental and physical health are structural factors in terms of national wealth, income inequality and access to education (17). In Denmark, these structural factors are also very important, however, it is important to address attention to social and environmental factors at the individual and family level as well, in order to understand some of the underlying mechanisms within social inequality, mental health and obesity.

As mentioned in the introduction, Denmark is a welfare state and a fairly equal society. However, inequality in health still exists in spite of equal rights to education and healthcare (14). Mackenbach refers to the persistence of health inequalities in modern welfare states as a paradox (18). He points to the fact that despite extensive welfare arrangements in, for example, the Northern countries, inequality in health have not been eliminated (18). In a recent paper Mackenbach states that substantial inequalities in mortality exist in the Nordic countries and that this paradox may be explained by a combination of three interrelated factors (19). These factors refer to a continuous inequality in material resources, changes in social stratification and social mobility and that although there has been improvements in population health and decline in mortality, those who are higher educated seem to have benefited more from these improvements than those who are lower educated (19).

Social inequality in health and related concepts used in the thesis

A main approach to study inequality in health is to examine differences in health outcomes at the group level (20). The approach refers to defining certain social groups and then examine the health differentials between them (21). From the literature it is observed that a social gradient in health exists where increasing quantities of social resources, for example, education or income correspond with increasing levels of health (20). Thus, social inequality in health is defined by "a systematic relationship between people's social position in society and their health" (22).

In the literature the terms SEP (socioeconomic position) and SES (socioeconomic status) are often used synonymously despite the two terms may represent different aspects (23,24). In this PhD thesis, SEP is applied as a term covering household income, parental educational level and LMP (labour market participation). When the term mental health problems are applied in the thesis, this refers primarily to depressive symptoms. However, when cited literature has applied other terms for SEP or mental health problems, these will be used.

Within the psychological literature, lower SEP has also been applied as a proxy term for adverse childhood experiences or childhood adversity. The concept of adverse childhood experiences is broadly used in the literature (25), and there is no consensus on what constitutes adverse childhood experiences (26). When we refer to childhood social adversity in Paper I, we apply a

very broad term which covers both adverse socioeconomic and psychosocial factors such as parental low labour market attachment and poorer family functioning.

Social inequality in childhood

A number of studies have examined different aspects of early life exposure to social adversity and potential short and long term consequences. For example, being exposed to a low SEP or other adverse experiences for a longer period in early childhood may increase a child's stress levels which may negatively influence the developing brain (27) and a child's future health (28).

Findings from the review by Galobardes et al. confirmed that mortality risk was higher among those who experienced poorer childhood socioeconomic circumstances compared to peers from higher socioeconomic families (29). Low SEP in childhood and during the life course has also been linked to an increased risk of unhealthy life style and health problems in adolescence and adulthood (30-34).

Growing up in a family where material resources may be sparse for a longer period due to, for example, financial problems related to household income or parental unemployment may negatively influence the family environment where the children are growing up (35). Financial problems in family or parental job insecurity may induce a stressful family environment which may negatively affect the child's social and psychological development (36,37). Growing up in a family with lower educated parents may also affect a child's life in a negative manner as lower educated parents may contribute with fewer resources than higher educated parents (38) and perhaps pass on unhealthy habits to the children, which may increase risk of later poorer health (28). Previous research has provided evidence that Danish children who grow up in families with lower educated parents more often end up with a lower educational attainment, compared to peers with higher educated parents (39).

Defining sensitive periods in childhood and adolescence

The first 1000 days from conception until the child is 2 years of age have been established as a critical period of life with respect to care and nurturing. However, the years from age 5 to 19 are also considered of outmost importance due to the different developmental phases which occur during these years, for example, puberty which involves rapid somatic growth, brain development and sexual maturation (17,40,41).

The WHO (World Health Organisation) defines the early childhood period as years 0 to 8 (42); an extremely important period where children are highly sensitive to external influences (43). During this early period of life, the foundations are set for the child's physical and mental capacities, which influence health and development later on (43).

There is growing recognition that the period of adolescence is very important for shaping health over the life course, hence adolescence is the period of greatest and most rapid development after infancy (44,45). The WHO defines adolescence as the age period from 10 to 19 years of age (46) and emphasises that this is also a highly sensitive period of life in relation to developing and maintaining social and emotional habits, which is an important factor for both current and later physical and mental health (46). These years involve tremendous physiological and psychosocial changes and adolescence is a period where future patterns of health behaviour are established (45). During this period of a child's life, a supportive family environment is still considered very important despite decreased parental involvement and increased peer contact (46,47).

A life course approach

Previous research has argued that when examining inequality in health it is highly relevant to include a life course perspective because health problems develop over time and people are often exposed to on-going stressors which may affect their health at various stages of life (2).

A life course perspective refers to the assumption that adult health is partly determined by exposure to biological and social factors in early life. Thus, the roots of health inequalities may therefore lie in inequalities experienced very early in life and during childhood and adolescence (18,48). Studies indicate that being exposed to prolonged or chronic lower SEP in childhood or later in life may be related to later health outcomes depending on the time of exposure (49). Glymour and colleagues emphasise that ''In order to identify effective approaches to address social inequalities in health, it is critical to incorporate the dimension of time and, in particular, the differential influence of stages of the life course'' (50). Thus, social inequality in health may not only concern differences between social groups but also timing of exposure and potential periods of vulnerability during the life course.

Timing of childhood socioeconomic exposure

Within life course epidemiology (48,51,52) several conceptual models have been proposed. In the paper by Cohen and colleagues (49), they explore different environmental, behavioural, and psychological pathways through which SES (socioeconomic status) in early life may influence adult health. The authors refer to three different conceptual models (timing, accumulation and change) regarding how exposure to low SES-related physical and psychosocial factors during childhood and adolescence has important implications for adult health. Below the timing and accumulation models are briefly introduced. The timing model will be applied as the primary theoretical framework in this thesis. In the timing model, SES-related factors appear to have the largest impact on adult health if they are experienced during specific developmental (sensitive) periods defined by an age range from, for example, age 0 to 5 years or defined in a broader sense as a period (childhood, adolescence). That is; the timing model refers specifically to sensitive periods in

a child's life (periods of development) where he or she may be most vulnerable to lower SES exposure (48,49). A sensitive period in a child's life is thus a time period where an exposure to, for example, lower SEP has a stronger influence on development and later disease than it would at other times (51,53). Previous research suggests that different models of life course socioeconomic factors may provide an important approach to examining the relation between social factors and health outcomes such as the development of cardiovascular disease (54), where consistent support for both the timing and the accumulation models have been found (49). The accumulation model is indifferent in relation to when exposure to SES-related factors occurs during childhood or adolescence. This model encompasses the notion that the risk of poor adult health increases in relation to the increasing intensity and duration of the SES disadvantage throughout the life course (49). It is, however, emphasised that these conceptual models are heuristic and that more than one model could potentially apply at the same time (49).

In the literature, there has been an increasing interest in exploring how timing of childhood low SES may affect different health outcomes later in childhood or adolescence. In a review by Spencer et al. (55), the authors examined the literature regarding early childhood low SES (0—5 years) and physical health status in later childhood and adolescence. Their results showed that early life exposure to lower SES was associated with later physical health outcomes in adolescence; however, the authors also emphasised the need for further research using longitudinal datasets due to limited evidence (55).

In summary, a life course perspective is a relevant theoretical framework that will be used in the current thesis in the attempt to understand the relation between early low SEP/ social adversity and health developments in later life.

Mental health and obesity- two areas of concern to public health

Mental health problems and obesity are recognised as two major public health concerns among children and young people (56). Both mental health problems and obesity are very prevalent and associated with negative health consequences (57,58). In the following an introduction to mental health and obesity will be presented along with well-known risk factors for each of them and a possible bidirectional relationship between them will briefly be discussed. This will be followed by a literature review with a focus on childhood socioeconomic exposure in relation to later mental health and obesity, respectively.

Introduction to mental health

Severe mental health problems in terms of depression are the 9th leading cause of illness and disability globally among young people aged 10 to 19 years (46), and mental health problems are one of the greatest disease burdens among European children and adolescents (59). According to the National Health Profile 2017 (13), a national survey on physical and mental health in Danish

people aged 16 and older, an increase in poor mental health was observed from year 2010 to 2017. Results from this survey also showed that nearly 24% of young women between the ages of 16 to 24 years reported poor mental health (13). A recent report on mental health in children and young people aged 10 to 24 years showed that the incidence of mental symptoms (being sad, in a bad mood or nervous) was on a weekly basis between 10 and 50% among young people aged 10—16 years (11). Likewise more than one in five 10 to 24 year olds felt stressed often; the occurrence of feeling stressed, increased with age and was more often present in girls (11).

It seems highly important to address mental health problems especially among children and young people, since the presence of, for example, depressive symptoms in adolescence may potentially develop into more severe mental health problems later in life (60,61).

Risk factors for mental health problems

Indicators of social inequality are well-known risk factors for the development of depressive symptoms in children and young people. In the extensive review by Reiss (62), the author found that children and adolescents from socioeconomic disadvantaged families were 2 to 3 times more likely to develop mental health problems than their peers from higher socioeconomic classes and that low SES which persisted over time was strongly related to more mental health problems. These findings are also supported by findings in recent cross-sectional studies (63-67) and in studies that have examined factors like financial stress (68), SES combined with negative life events (69,70) and higher stress reactivity and stressful life events in childhood (71). Other common risk factors for mental health problems in young people are gender, genetic disposition, psychosocial and family environment (72). Freed et al. also found that factors like family functioning, emotional clarity and depressive symptoms were strongly related constructs among young people (47). It was furthermore argued by McLaughlin et al. that the use of subjective social status (SSS) showed a stronger association with mental health than the use of the objective socioeconomic measures (73), which is supported by other studies (74), and the use of subjective information on SEP may provide unique information in terms of understanding health disparities (75).

In summary, mental health problems are very prevalent among children and young people and some of the important risk factors seem to be related to low SEP and the family environment. Adolescence is defined as a sensitive period of the life course and it is during this period that most mental health problems have its first onset, which may potentially develop into more severe psychological problems later on (61).

Introduction to overweight and obesity

The prevalence of obesity rates by BMI (body mass index) has nearly tripled between 1975 and 2016 across the world and has become worryingly high. In 2016, more than 29% of American adults aged 18 years and older were obese, whereas the prevalence of obese adults in the European Region was 23% (76-78). Among children and adolescents aged 5 to 19 years, approximately 18% were overweight or obese by the year 2016 worldwide (79).

In Denmark, as in most high-income countries, overweight is common; hence more than 50% of the adult population are overweight and almost one in five adults is obese (13,80). In 2016, one in four Danish children aged 5 to 19 years was overweight and one in every 14 children (7%) was obese (80). Research has, however, shown a possible levelling off in the prevalence of overweight and obesity (81).

Obesity is often defined by a state of excess adiposity that presents a risk to a person's health in terms of increased risk of several chronic diseases (type II diabetes, cardiovascular diseases, cancer), reduced life expectancy and a greater degree of disability (58,79,82,83). Obesity is a consequence of sustained positive energy balance over time (84), however, there is no consensus on causes of obesity in children and adults (85).

Overweight and obesity among children and young people is a very complex and multifaceted health issue. Initiatives aimed at reducing weight in children, adolescents and adults have primarily focused on a thermodynamic approach, with life style changes showing modest effects (86). This has encouraged research in exploring alternative pathways which may help disentangle the complexities of overweight and obesity among children, adolescents and adults (87,88). Previous research has observed that countries with a low grade of economic equality have a high prevalence of obesity. This has inspired ideas that exposure to economic, social or psychological insecurity and inequality during childhood or adolescence may induce an excessive weight gain over time (89-91), where insecurity may refer to a person's own perception of security related to e.g., employment (38).

Risk factors for overweight and obesity

Being pre-obese or obese as a child increases the risk of being an obese adult. In the literature many potential risk factors are outlined for the development of overweight and obesity: genetic factors (92), low physical activity (93), sleep-duration (94), psychological (lower self-esteem, depression), social and environmental stressors (95-97) and ultra-processed food (98). Other important risk factors for later overweight and obesity are birth-weight (99,100) and parental marital status (101,102). Moreover, in the review by Halliday and colleagues (103), the majority of studies reported significant associations between poorer family functioning and overweight and obesity in both children and adolescents. These results indicate the value of considering family functioning in the research on overweight and obesity among children and young people (103).

However, the one exposure which most consequently has been linked to obesity is socioeconomic disadvantage (104). In the review by Barriuso et al., they examined SEP and childhood-adolescent weight status in European countries and the US (United States) (105). Results showed an inverse relationship between SEP and child-adolescent obesity, and that the SEP indicator which showed the strongest association with the outcome was the educational attainment of the parents (105). This is supported by findings from the paper by Matthiessen et al. showing a strong inverse social gradient in overweight and obesity for both girls and boys and furthermore an increase in prevalence of overweight among Danish boys with lower educated parents (106).

In summary, overweight and obesity is very prevalent among children and young people. Overweight and obesity among children and young people is a very complex and multifaceted health issue with a range of different socioeconomic and psychosocial risk factors such as parental lower educational attainment and psychological distress. It is still a common and very stigmatizing opinion that obese individuals are lazy and eat large amounts of unhealthy food. This stigma may increase the risk of lower self-esteem and depression in the individual (107,108).

Mental health and obesity

Several studies have examined how overweight/obesity and mental health are related in adolescents and adults. Previous research have suggested that depression/ depressive symptoms and obesity may be causally linked through direct physiological mechanisms, in terms of mechanisms related to inflammation or stress responses or through psychosocial and behavioral pathways (109-111) with possible gender-differences (112).

Some studies have provided support for a bi-directional relationship between these two major public health issues (56). Quek et al. examined the association between childhood and adolescent obesity and depression, as well as depressive symptoms in persons 21 years old and younger (113). Results showed a significant association between obesity and depression, as well as between more severe depressive symptoms in the obese group compared to a normal weight group, meaning that obese children and adolescent were more likely to suffer from depression and depressive symptoms, and especially young women were at higher risk (113).

Literature-review on childhood socioeconomic exposure, mental health and obesity.

In the following, primary studies and reviews which have examined socioeconomic and psychosocial factors in childhood in relation to later mental health (Table 1) or overweight and obesity (Table 2), respectively, will be presented. We conducted an up-to-date systematic literature search for meta-analyses, systematic reviews and primary studies on childhood SEP, childhood psychosocial factors and mental health and overweight/ obesity in Medline (OVID), Embase (OVID), Cochrane Library, Web of Science and PsycINFO (OVID). Searches were carried out

with MeSH-terms using controlled vocabulary when possible and text words (keywords) in addition to the controlled vocabulary (Appendix I+II). Search limits were applied due to a large amount of references (10 years and English language). Relevant references were screened by title and abstract. Primary studies were included in the following if they were conducted in western high-income countries within the last 10 year and examined childhood socioeconomic or psychosocial factors in childhood in relation to mental health or overweight and obesity in adolescence and early adulthood as the primary outcome.

Childhood socioeconomic exposure and mental health

Table 1 presents an overview of recent studies, which have examined childhood SEP/ social adversity in relation to depressive symptoms in adolescence and adulthood.

Table 1. Overview of studies examining childhood socioeconomic position/social adversity and depressive symptoms

First author	Ref.	Year	N	Population	Follow-up	Primary exposure	Primary outcome
Elovainio	114	2012	1613	3-18 years	Age 30-45	Parental educational level	Depressive symptoms (Beck Depression Inventory)
Wirback	35	2014	1880	11-12 years	17-18 years	Parental educational level, occupational class	Depressive symptoms (12-item inventory, non validated)
Joinson	115	2016	9193	Born 1990-1992	10-20 years	Mother´s education, occupation	Depressive symptoms (the Short Mood and Feelings Questionnaire)
Bjorkenstam	37	2017	2223	Born 1985-1995	2002-2008	Childhood social adversity	Depressive symptoms, (13-item Internalizing-Index, Children´s Depression Inventory)
Green	119	2018	9408 (US)	Born 1979-1996	Age 15/16	Annual household income	Depressive symptoms (Center for-Epidemiological Studies Depression scale)
			1204 (UK)	Born 1991-1997	Age 16		Mental health (12-item-General Health Questionnaire)
Boe	120	2017	9154	8-11 years	16-19 years	Family income	Symptoms of depression (short version of-the Moods and Feelings Questionnaire)
Lindström	121	2014	28198	18-80 years	Cross-sectional	Self-reported economic stress	Psychological health (General health questionnaire)

Elovainio and colleagues examined the association between childhood SEP, measured by parental occupational grade and income at baseline (1980), and trajectories of self-rated depressive symptoms in Finnish children and adolescents in 1992 to 2007 (114). Their results indicated that childhood SEP (parental occupational grade) seemed to influence the risk of depressive symptoms; however, this effect diminished over time indicating no strong association (114). Results also showed that parental income was not associated with depressive symptoms. This was a longitudinal analysis across 27 years of follow-up. A limitation of this study was that their analyses, due to missing data, were based on less than half of the original study population. This increases the risk of an underrepresentation of participants from disadvantaged backgrounds which may bias the true underlying association (114). Wirback et al. examined the association between social

status in childhood (age 11—12 years) and risk of depressive symptoms among Swedish adolescents aged 17 to 18 years (35). Their results showed that low parental social position (measured by occupational class and educational level) in childhood increased the risk of depressive symptoms among adolescents with an odds ratio of 1.8-2.1 (35). This was a Swedish longitudinal study conducted with adolescents using several predictors of SEP in relation to depressive symptoms, which reduces the likelihood of reversed causality hence the exposure were assessed before the outcome. A limitation of this study, however, was the fact that both the exposure and the outcome variables were based on self-reported information which can be prone to information bias.

Joinson, Kounali and Lewis examined the association between family SEP in early life (at birth) and onset of depressive symptoms in English children and adolescents. Their results showed that low SEP (measured by maternal occupation and educational attainment) was associated with an increased incidence of depressive symptoms from ages 10 to 20 (115). This was a longitudinal study with a large community-based sample (9193) and repeated measures of depressive symptoms. A limitation of this study was, however, the fact that information on the exposure and outcome variables was based on self-reported information.

Being exposed to lower SEP/social adversity in childhood may affect future health differently depending on the period of exposure with reference to the life course theory on timing presented earlier in this thesis (49). Previous research examining the timing of exposure has primarily focused on more severe childhood social adversities in relation to later mental health problems (116) or psychiatric disorders (117,118).

Bjorkenstam et al. examined the association between childhood adversities (poverty, long-term parental unemployment) and depressive symptoms in adolescence and the impact of timing and accumulation of adversity in the US (37). Their results showed that children exposed to social adversity reported higher levels of depressive symptoms in adolescence, albeit timing of exposure (age 0—6.9 years and 7—12 years) had little association to the risk of depressive symptoms (37).

Green and colleagues used a structured life course approach to examine associations between different patterns of childhood exposure in terms of timing or accumulation of exposure to poverty at different stages of childhood (age 0—5 years, age 6—10 years, age 11—15 years) in relation to mental health in the US and the UK (United Kingdom) (119). Their results did not show an association between poverty in any of the childhood periods and adolescent mental health in either the US or the UK (119). Boe et al. examined duration, timing and sequencing of exposure to low family income during late childhood/early adolescence in relation to symptoms of mental health problems among Norwegian adolescents (120). Their results showed that having experienced relative poverty in childhood was associated with more symptoms of mental health problems in adolescence, relative to young people who had never experienced relative poverty. They did, however, not find a strong effect of timing in the patterns of associations (120). In the

study by Lindström et al. they investigated three life course hypotheses (accumulation, social mobility, critical period) in the association between economic stress in childhood and adulthood and poor psychological health among Swedish adults in Skåne (121). Findings from their study confirmed the accumulation and the social mobility hypotheses, but not the critical period hypothesis (49), since both childhood and adulthood economic stresses were associated with the outcome. The authors did, however, conclude that all three life course hypotheses were interconnected and that both childhood and adulthood may be sensitive periods (121). Limitations of this study were the cross-sectional study design and the self-reported information on both childhood and adulthood exposures and the outcome variable.

In summary, it seems fairly consistent from the review by Reiss (62) and the primary studies presented in this section that exposure to lower SEP in childhood is associated with later mental health problems, however, several of the studies had some limitations with regard to attrition and measurements of exposure and outcome. Some of the studies, for example, apply information on SEP exposures from only one time-point (at birth of the child or in adolescence), it is therefore not possible to know whether the measured time point reflect a sensitive period for later risk or perhaps the beginning of an accumulation of low SEP exposures (49). Previous research examining the issue of timing has mainly focused on more severe childhood social adversities in relation to later mental health problems. There are only few studies, especially in Scandinavian countries, to the knowledge of the author, which have examined exposure to lower SEP/ social adversity in more than one age period in childhood in relation to depressive symptoms in adolescence and early adulthood and the studies focus mainly on the most vulnerable groups in society. The literature search revealed only four studies and none of the findings from the studies showed particular sensitive periods in relation to the outcome. The two studies by Bjorkenstam et al. (37) and Green and colleagues (119), however, were carried out in the US and the UK which are countries with neoliberal political systems and high levels of income inequality at the national level and results may therefore be difficult to transfer to a Danish welfare society. The study by Lindström et al. did, however, conclude that both childhood and adulthood may be possible sensitive periods between economic stress and psychological health (121).

Childhood socioeconomic exposure and overweight and obesity

Table 2 provides an overview of recent studies and reviews examining childhood SEP and overweight and obesity in adolescence and early adulthood.

Table 2. Overview of review and studies examining childhood socioeconomic position and overweight and obesity in adolescence and early adulthood

First author	Ref.	Year	N	Population	Follow-up	Primary exposure	Primary outcome
Kestilä	122	2009	1,894	18-29 years	Cross-sectional	Parental education/ unemployment	Adult BMI
Morgen	123	2010	1,656	14-16 years	21,3 years (mean)	Parental occupation	BMI
Brisbois (Review)	124	2012	135 (studies)	European, North-America, Australia	18-50 years	Early childhood SES	Adult obesity
Bann	125	2017	5,362 16,383 16,172	1946 NSHD 1958 NCDS 1970 BCS	60-64 year 33, 42, 44, 50 yr 30 and 42 years	Childhood SEP- (Father´s social class)	Adult BMI
Newton (Review/ meta-analysis)	126	2017	35 (studies)/ 15 (studies)	US, UK, DK, Brazil, Singapore, Scotland, Spain Australia	N/a	Life course SES Childhood SES	BMI

In the study by Kestilä et al., they examined the association between childhood social circumstances and overweight and obesity among young adults in Finland (122). Their findings showed an association between parental low education and adult obesity in both genders when adjustments were made for other childhood social circumstances (childhood adversities, family structure) and own educational attainment (122). Limitations of this study were the cross-sectional design with retrospective information on childhood social circumstances and the main results had very wide confidence intervals. Morgen and colleagues examined the association between parental SEP (measured by parental occupation) and the risk of developing overweight in Danish adolescents aged 15 to 21 years (123). Findings from the study showed that primarily girls of lower parental SEP had a higher risk of developing overweight during adolescence compared to the reference group. A strength of this study was the longitudinal design and the nationally representative sample of adolescents. One of the limitations was the high attrition rate from baseline to follow-up which may have biased the results. Another limitation may be that parental SEP was based on occupation which was determined by the school physician at baseline rather than from available Danish registers (123). In the review by Brisbois, Farmer and McCargar they examined which factors in early childhood (≤5 years of age) that was the most significant predictors of adult obesity. Despite diversity in primary outcome and study designs, they concluded that maternal BMI, childhood growth patterns, childhood obesity and father's employment status were probably early markers of adult obesity (124). Some of the limitations mentioned with the studies were the variation in study designs and the methodology, which made comparisons between studies very challenging and difficult to generalise conclusions (124).

In the recent study by Bann et al., they examined how childhood and adult SEP relates to BMI across adulthood in the UK. They found that father's occupational class measured when the child was age 10/11 years was associated with higher BMI in both adult women and men (125). One of

the strength of this study was the use of three national birth cohort studies with harmonised data for SEP and BMI. A limitation of the study was that attrition and non-response were more pronounced among people with lower SEP and higher BMI which might have biased the results.

In a recent systematic review and meta-analysis by Newton, Braithwaite and Akinyemiju, the literature was summarized regarding the association of childhood, adulthood and life course socio-economic status with obesity in adulthood (126). The included studies based the socio-economic exposures with regard to father's occupation, family income or parental education. Their findings showed a consistent association between lower life course SES and obesity among women- but not among men (126). A limitation with the studies included in the systematic review was the fact that many studies applied self-reported information on life course SES leading to potential recall bias on the exposures.

In summary, it seems consistent from the presented studies that exposure to early lower SEP is associated with overweight and obesity, however, some studies have some methodological limitations with regard to study design, potential problems related to the quality of exposure variables and problems with attrition and non-response. Some studies have applied information from only one time-point in childhood, which makes it difficult to know whether this reflect a sensitive period (49). Studies, which apply information from more than one time-point in the association between childhood SEP and later overweight and obesity, has mainly focused on the early childhood period as a possible sensitive period. Furthermore, there seems to be some inconsistences whether early exposure to lower SEP may be associated with obesity in both genders. Although a large amount of research within childhood SEP and overweight and obesity have been conducted, further research within childhood SEP and physical health using longitudinal datasets due to limited evidence is emphasised (55) and further research on the timing of exposure is also warranted (127).

The fact that especially children and young people from lower SEP may experience a higher prevalence of mental health problems, higher levels of stress and increased overweight and obesity is worrying. It seems highly relevant to further examine potential underlying mechanisms in the association between childhood low SEP and mental health or overweight/obesity. In previous research, it has been established that some of the difference in health outcomes between children from different SEP can be attributed to accumulated stress- mechanisms (68,128).

The potential role of stress mechanisms

Most people, regardless of age, are probably quite familiar with the word or terminology "stress" and also have some sort of an opinion about what it means to experience the feeling of being stressed. This may be related to a specific situation or perhaps to a longer period in one's life.

Within the research of stress, it is common to distinguish between two types of stress namely an acute and a chronic type of stress. The acute type of stress is related to the ‘‘fight and flight’’ mechanism, for example, if one’s safety is threatened (129), whereas prolonged, repeated or chronic stress can occur in response to exposure to different psychological stressors (e.g. job pressures) as well as exposure to adverse events in childhood (130,131).

There are many different ways of understanding and also conceptualising the term "stress" depending on the areas of research. Within the bio-medical tradition "stress" is primarily referred to as “the non-specific response of the body to any factor that overwhelms or threatens to overwhelm the body’s ability to maintain homeostasis” (132). Within the area of psychology, Lazarus and Folkman defined "stress" as ‘‘a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being’’ (133). Epidemiologists have, on the other hand, conceptualised "stress" as exposure to different negative life events (for example job loss, divorce, death of a parent or abuse) and examined this in relation to later health outcomes (134). In spite of these different perspectives on stress within different research fields, many researchers have employed an integrative approach to stress. This approach takes into account the different aspects of the stress process (134). The stress process represents the process of how stressors in the environment may contribute to individual stress reactions and potential health risks (134). In this view stress relies on both the surroundings as well as the individual and the persons experience of his or her situation as stressful. When a person is not able to resolve the stressful situation or circumstance, physiological stress responses related to emotional arousal may be continuously activated or under-activated (134). Over time, this may potentially contribute to mental or physical health risk through both psychophysiological stress mechanisms and related hormones and neuro transmitters affecting the organism as well as through negative health behaviours (135,136).

Psychosocial stressors and obesity

Previous research by Wardle et al. showed that perceived psychosocial stress among adults was related to increased risk of obesity (137); however, among younger individuals, overweight and obesity may be linked to other social and psychosocial patterns. In the review by Gundersen et al., findings showed that both individual and environmental (household) psychosocial stressors in terms of, for example, mental health, overall perception of stress, financial stress and maternal stress increased the risk of overweight and obesity in childhood (97).

In a recent review, Claassen et al. examined the psychosocial pathways, which may underlie the relationship between socioeconomic status and BMI (138). Findings showed inconclusive evidence due to the low quality of studies; however, some cautious conclusions could be drawn, namely that SES was related to BMI partially through environmentally and psychological factors. However,

only five out of twelve studies found that factors related to stress mediated the association between SES and BMI (138). Elsenburg and colleagues examined the longitudinal relationship between stressors in terms of adverse life events in relation to BMI from early adolescence to young adulthood. Their findings showed that adverse life events in early childhood and late adolescence were related to a higher BMI in young adults (139).

Erik Hemmingsson has recently developed a conceptual obesity causation model which is a step-by-step model that mainly focuses on a wide array of psychosocial stressors in the family during childhood which may be associated with socioeconomic disadvantage (104).

Each step in the model is represented by different domains: socioeconomic disadvantage, adult distress, disharmonious family environment, offspring distress, psychological and emotional overload, homeostasis disrupted, start of weight gain and obesity. The model can be viewed below in Figure 1.

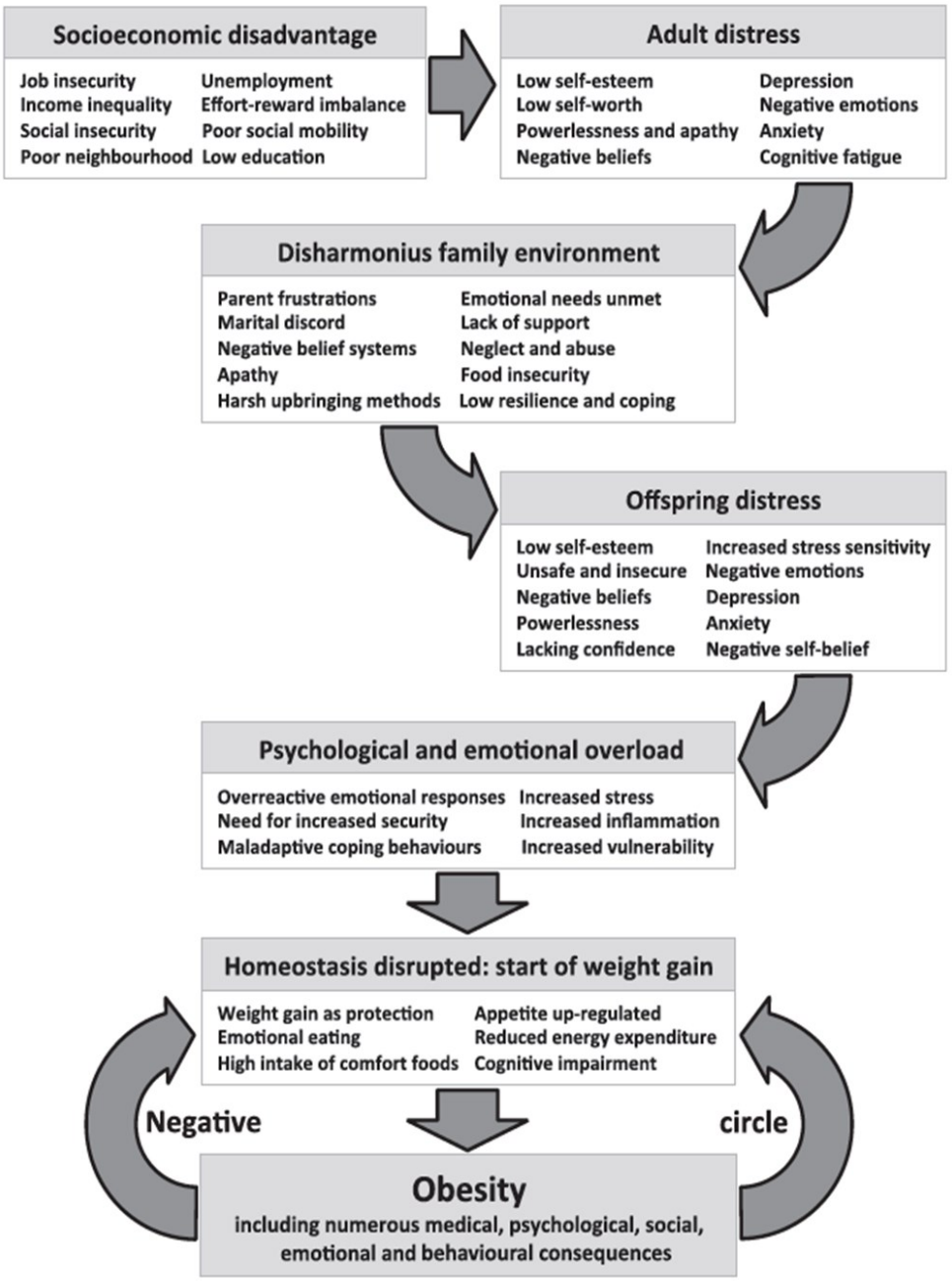

Figure 1. Proposed step-by-step model of obesity causation. Although the figure only shows reverse causality in step 6, all steps in the model are likely to be more or less bidirectional, especially once severe obesity has been established. Skipping of intermediary steps can also occur, e.g., in adult-onset obesity. Erik Hemmingsson. Obesity Reviews, Volume: 15, Issue: 9, Pages: 769-779, First published: 16 June 2014, DOI: (10.1111/obr.12197).

In the following, the different steps in Hemmingsson's model are very briefly described. It is emphasised by Hemmingsson that not all steps necessarily appear between socioeconomic disadvantage and obesity.

Socioeconomic disadvantage/ adult distress

Socioeconomic disadvantage in terms of, e.g., lower educational attainment may increase the risk of negative emotions and depression in adults.

Adult distress/disharmonious family environment

This increased distress in the adults may negatively influence the family environment where the children are growing up with increased risk of a disharmonious family environment caused by, e.g., lack of family cohesion and support.

Disharmonious family environment/offspring distress/psychological and emotional overload

Living in a disharmonious family environment during sensitive periods where children are emotional and developmentally vulnerable may increase their risk of psychological and emotional distress.

Psychological and emotional overload/ homeostasis disrupted: start of weight gain

When the individual is unable to cope with a high amount of experienced psychological and emotional distress, this may lead to the use of maladaptive coping mechanisms in terms of, for example, eating high-energy-dense-food to suppress negative emotions, which eventually may result in increased weight.

Obesity

In the last step where obesity has been established, there is the existence of some situations of reverse causality in terms of the direct impact of obesity on mental health or psychological and emotional distress (104).

To the knowledge of the author, only one study has previously applied empirical data to examine aspects of Hemmingsson's model. Spinosa and colleagues examined via cross-sectional data associations between SES, psychological distress, emotional eating and BMI in adults in UK (140). Their findings supported components of Hemmingsson's model regarding psychological distress and emotional eating in the association between SES and BMI.

In summary, this proposed obesity causation model appears to encompass several of the aspects which have been presented earlier in this thesis regarding exposure to social inequality in childhood and include different psychosocial stress mechanisms. This model holds promise as a new approach to understand obesity causation. The model is, however, primarily based on literature from the US and the UK, where children and young people may experience different levels of chronic stress (141,142) due to higher levels of inequality and insecurity at the national levels.

Synthesis

Children and adolescents who are exposed to different kinds of social inequality in terms of lower SEP or/ and psychosocial stressors during childhood may face an increased risk of later mental and physical health problems even in a welfare state like Denmark. During this period of an individual's life, there appears to be different sensitive periods where exposure to lower SEP may exert a greater effect on later health outcomes. Despite extensive research regarding social inequality in childhood and later mental and physical health problems, many studies have applied self-reported information on both exposure and outcome variables, and some studies have applied information on childhood exposure from only one time point. It also seems that very few studies have examined the timing of childhood SEP in more than one age period in relation to mental health and overweight/obesity in adolescence and early adulthood. Furthermore, there is a lack of studies using longitudinal data to examine potential associations (55). The prevalence of overweight and obese children and young people from low SEP families is increasing, and preventive initiatives within overweight and obesity have focused mainly on a thermodynamic approach with limited effect (86). It seems important to disentangle the underlying mechanisms between lower SEP in childhood and later overweight/obesity in order to be able to identify possible important psychosocial factors to take into account when targeting relevant preventive initiatives. It furthermore appears that no previous studies have applied longitudinal empirical data on Hemmingsson's obesity causation model to examine the underlying associations between socioeconomic disadvantage and overweight and obesity in adolescence and early adulthood.

3. Aim of the thesis

The overall aim of the PhD thesis was to examine social inequality and mental and physical health among young Danish people by examining the associations between socioeconomic and psychosocial factors in early and late childhood and depressive symptoms and overweight/obesity in adolescence and early adulthood. Furthermore, we also examined the underlying associations between socioeconomic disadvantage and overweight and obesity in children and young people using the obesity causation model by Erik Hemmingsson (104).

Study I:

The aim was to examine the timing of early (years 0—8) and late childhood (years 9—14) family socioeconomic factors in relation to depressive symptoms in adolescence and early adulthood; including the psychosocial factors family functioning, negative life events in childhood and subjective social status in society to the late childhood exposures.

Study II:

The aim was to examine the association between socioeconomic position in early childhood (years 0—8) and late childhood (years 9—14) and overweight and obesity at age 15, 18 and 21 years.

Study III:

The aim was to explore the associations between socioeconomic disadvantage and overweight and obesity and examine whether these associations were attenuated, when the effect of the domains: adult distress, disharmonious family environment, offspring distress, psychological and emotional overload and homeostasis disrupted from Erik Hemmingsson's model was taken into account.

4. Material and methods

In this PhD thesis, questionnaire and register data from the West Jutland Cohort Study (Vestliv cohort) were applied.

The Vestliv cohort

The West Jutland Cohort Study is an on-going Danish longitudinal study following a complete regional cohort of young people who were born in 1989 and were residing in the former Ringkoebing County in 2004. The main purpose of this youth cohort is to study inequality in health in a life course perspective. In 2004, the county had around 275,000 inhabitants. Using the Central Office of Civil Registration (or Central Person register) and information from public schools, the potential participants were identified by using the personal identification number (CPR number), which is given to every citizen at birth (or upon entry for immigrants).

The source population comprised 3,681 young people aged 14/15 years. The project has so far included waves of questionnaires in 2004, 2007, 2010 and 2017 (www.vestliv.dk). The questionnaires comprehend a wide array of questions related to the participants' psychological, social and physical health. This has been supplemented with a range of register-based information on, e.g., birth-weight of the participants, parental and participants' socioeconomic status. Due to the use of the participants' CPR number, the researchers could link each child to parental information from registers (143,144). The data material also encompasses questionnaires completed by parents to the participants in 2004 regarding parental psychosocial factors.

Recruitment and data collection

Recruitment of participants took place at the schools within the county, where a baseline questionnaire was completed during school hours in 2004 when the participants were approximately 15 years old. Those not at school on the day of collection received the questionnaire by mail. Of the potential 3,681 responders, 3,054 (83%) participated in the first questionnaire wave. All the potential responders in 2004 were re-invited to participate at the later waves.

Ethical considerations

When the cohort was established in 2004 the parents were informed that their children were asked to participate in a survey wave. However, if the parents contacted the research team conducting the surveys informing that they did not want the children to participate they were excluded. At the following waves every participant was informed that it was voluntary to participate.

Table 3 provides an overview of the response rates at the four waves conducted in the Vestliv study in relation to the overall source population at each wave.

Table 3. Collection points and response rates in the Vestliv cohort

	Data collection			
	2004	2007	2010	2017
Cohort 1989	Age 14/15 years	Age: 17/18 years	Age 20/21 years	Age 27/28 years
(N=3,681)	n: 3,054	n: 2,400	n: 2,145	n: 2,102
	Response rate: 83%	Response rate: 65%	Response rate: 58%	Response rate: 57%

Register information

In this thesis, various register information was obtained from Statistics Denmark. By using the CPR number, linkages between the cohort and the different registers and databases were performed.

The Danish Civil Registration System (CPR Register)

The Danish Civil Registration System contains information for administrative purposes on all persons who are alive and living in Denmark. The register includes individual information on the CPR number, name, gender, date and place of birth, citizenship, identity of parents and continuously updated information on place of residence and civil status (identity of spouses) (144). Information about addresses, gender, and age of the potential participants to the Vestliv cohort was identified prior to the first questionnaire collection (2004). Using the CPR register, the participants were linked to their parents or legal guardians.

Danish Registers on Personal Income and Transfer payments

The Danish Register on Personal Income and Transfer payments includes information on the income composition of all individuals who are economically active in Denmark or abroad. The register contains over 160 variables, which are generally considered to be of high quality as they come from administrative registers (145). We used the register to obtain information on yearly household income and equivalised disposable household income in Danish Kronor (DKK) for the participants' residence from birth until age 14 years (1989-2003).

Danish Education Registers

The Danish Education Registers include all individuals attending an educational institution in Denmark and link information within and across years through the CPR number. Each year, the

educational institutions provide individual-level information on enrolment status, completed levels of education, and exams. We applied information from the Population's Education Register on the highest completed education for each of the parent's, which was obtained for 96.4% of the Danish population aged 15 to 69 years. The education registers are generally considered to be of high quality (146). We used the registers to obtain information on parental highest education level in 1989 (birth) and 2003 (14 years). We also applied information from the register about the participants' own highest completed education at the age of 28 years.

Danish Register for Evaluation of Marginalization (DREAM Register)

The DREAM register contains information on all public transfer payments administered by Danish ministries and municipalities for Danish citizens on a weekly basis since the second half of 1991 (147). We used the DREAM register to construct a labour market participation variable for each parent in early and late childhood (1991-2003).

Danish Medical Birth Register

The Danish Medical Birth Register is a national register with information about all hospital and home births in Denmark (148). It was established in 1973 and is a key component of the Danish health information system. The register enables monitoring of the health of pregnant women and their offspring and is used extensively for research. The register contains information on maternal age which is provided by the Danish Civil Registration System (149).

We used the Danish Medical Birth Register to obtain information on birth weight of the participants (1989). We also used the register to obtain information about pregnancies at the time of the four questionnaire waves.

Study designs and samples

The three studies in this thesis were all based on both questionnaires and register information from children and parents.

Table 4 provides an overview of the three study designs with information on topic, inclusions criteria, sample, data sources, exposures and outcome variables and data analyses of the three studies.

Table 4. Overview of study designs with topic, design, inclusions criteria, sample sizes, data sources, exposure and outcome variables and data analysis

	Study I	Study II	Study III
Topic	Childhood SEP and depressive symptoms	Childhood SEP and overweight/ obesity	Socioeconomic disadvantage and overweight/ obesity
Design	Cohort study	Cohort study	Cohort study
Inclusions criteria	Respond to questions on depressive symptoms in 2004, 2007 or 2010	Respond to questions on weight and height in 2004, 2007 or 2010	Respond to questions on weight and height in 2004, 2007, 2010 or 2017
Sample sizes	N=3,014 (2004), N=2,373 (2007), N=1,968 (2010)	N=2,879 (2004), N=2,308 (2007), N=1,974 (2010)	N=2,879 (2004), N=2,305 (2007), N=1,961 (2010), N=1,872 (2017)
Data sources	Questionnaires 2004-2010, CPR, Danish Registers on Personal-Income and Transfer payments Danish Education Registers, DREAM register	Questionnaires 2004-2010, CPR, Danish Registers on Personal-Income and Transfer payments Danish Education Registers, DREAM register	Questionnaires 2004-2017, parental questionnaire 2004 Danish Registers on Personal-Income and Transfer payments CPR, Danish Education Register, DREAM register, Danish Medical Birth Register
Dependent variables (outcomes)	Depressive symptoms (CES-DC)	Overweight/ obesity (BMI)	Overweight/ obesity (BMI)
Independent variables (main exposure)	Equivalised household income, mother´s educational level, mother´s LMP, family functioning SSS, negative life-events	Household income, parental educational level, parental LMP, family functioning	Equivalised household income, mother´s educational level, mother´s LMP
Data analysis	Logistic regression models	Multinomial logistic regression models	Logistic regression models

Outcomes

Depressive symptoms (Study I)

Many epidemiologic studies have applied self-administered questionnaires with different rating scales to measure current levels of depressive symptoms among children, young people and adults. One of the most extensively used measures of depressive symptoms is the Center for Epidemiologic Studies Depression Scale (CES-D), which originally was a 20-item version developed to measure the current level of depressive symptoms in a general population. The scale has hereafter been shortened to versions including 4 to 16 items and used within various populations including children (150).

The scale was originally developed for research purposes but it is also used as a screening tool to identify persons who are in risk of clinical depression. The scale has been translated into several

languages (Danish among others) and validated for both children and adults (150,151). Depressive symptoms were in this thesis measured at ages 15, 18 and 21 years using the abbreviated 4-item validated version of the Center for Epidemiologic Studies Depression Scale for Children (CES-DC) (151). The reliability of this abbreviated scale was in our data; 0.63 in 2004, 0.63 in 2007 and 0.70 in 2010, measured by Cronbach's alpha. The CES-DC scale consists of four items asking about a participant's mental state over the past week: "During the past week, how much have you had the following feelings?" a. "I was happy this week"; b. "I felt like kids I knew were not friendly or that they didn't want to be with me"; c. "I felt sad"; d. "It was hard to get started doing things this week". There are four categories of answers to each question in the form of "not at all", "a little", "some" and "a lot". The answers were awarded scores of 0 to 3, where high values correspond to having depressive symptoms. The answer for question a. was therefore reversed. The four items summed up to a score between 0 and 12. We applied single item imputation if one item was missing by taking the mean of the other three items, assuming that the answer to these questions would reflect a possible answer to the missing item. We primarily analysed the outcome as a dichotomous variable, however, the outcome was also analysed as a continuous variable in a sensitivity analysis in Study I. For the dichotomous variable the definition of depressive symptoms was obtained using the cut-off point of 3, and a score above (≥3) indicated depressive symptoms, as Fendrich et al. have recommended for this abbreviated 4-item scale (151). This cut-off was based on an American sample of young people and corresponded to a sensitivity of 63% and specificity of 55% when major depressive disorder was the criterion diagnostic group (151).

Overweight and obesity (Studies II+III)

In epidemiologic studies, BMI based on participants' self-reported information on weight and height is widely used to categorize overweight and obesity using standardized BMI thresholds in children and young people (152,153). BMI is a fairly simple measure of the body composition and has been accepted as an adequate measure and useful tool to detect body fatness (154). BMI is calculated as weight in kilograms divided by height in metres squared (weight/height^2).

In this thesis, overweight and obesity defined by BMI were used as an outcome in Study II and as a combined outcome measure in Study III.

Information about weight and height was derived from all four questionnaires in 2004, 2007, 2010 and 2017. At age 15, participants were categorized into "normal weight" (<23.29 kg/m^2 for boys and <23.94 kg/m^2 for girls) and "overweight" (≥23.29 kg/m^2 for boys and ≥23.94 kg/m^2 for girls) using thresholds for 15-year-old girls and boys (155), because there were very few obese at this age. At ages 18, 21 and 28 years, participants were categorized according to the International Classification of adult overweight (BMI≥25) and obesity (BMI≥30)(156); however, in Study II, we additionally applied the cut-offs for obesity (BMI≥27.5) from the Global Database on Body Mass Index (153) to enhance the statistical strength to estimate the associations.

Women who were more than 3 months pregnant at the collection point were excluded from analyses related to that survey wave due to a temporally higher BMI (Study III).

Exposure variables

In Study I and Study II, we defined early childhood as the age span between age 0 to 8 years, and the late childhood period was defined as the years between the ages of 9 to 14 years. We made this distinction between early and late childhood from a pragmatic point of view since the literature is mixed. The WHO defines the early childhood as spanning from age 0 to 8 years (42) and referring to adolescence spanning from 10 to 19 years of age (46). Spencer, Thanh and Louise referred to the early childhood period as age 0 to 5 years (55) and in the study by Björkenstam et al. they divided the childhood period into the age range of 0—6.9 and 7—12 years (37). We do believe that applying an age range for the early childhood period, which is recognised and applied by the WHO seem reasonable. This decision can, however, make it difficult to compare results from studies which have applied other age ranges (e.g. 0-5 years) because of shorter period of exposure and the fact that the early childhood period in our studies includes an entrance in school, which may also influence a child's life.

Childhood family factors

In this thesis, childhood family factors covered socioeconomic exposure factors, while psychosocial factors covered self-reported exposure factors. We included the subjective psychosocial factors because these variables may contribute with valuable knowledge regarding the family environment and the experienced social adversity in childhood, which may not be captured by the socioeconomic exposures. By applying the different indicators of parental SEP, the intention was to measure variation in both access to material and to psycho-social resources for the children.

The chosen variables were yearly household income, parental highest educational level and parental labour market participation, which all were based on register information when the participants in the youth cohort were children. These socioeconomic exposure variables were supplemented with self-reported information on family functioning (Studies I+II), subjective social status in society (Study I) and negative life events in childhood (Study I), all derived from the baseline questionnaire (2004).

Two different types of income variables were applied: yearly household income (Study II) and annual equivalised disposable household income (Studies I+III). These two types of income are very different, as described below, and cannot be compared.

Yearly household income covers information about tax-related income for all residents above 18 years in the household living together with the child. This income variable was available from 1989 and onwards.

Annual equivalised disposable household income is a measure for welfare, hence it informs about the inequality in the wealth distribution among Danish families independent of the size and age-distribution of the family. Equivalent disposable household income is a weighted value, which uses an equivalence scale that takes into account that a family of two adults consumes more, but does not need twice the income as a family with only one adult. The scale also reflects that children do not need as much income as adults to achieve the same standard of living. This variable was available from 1990 and onwards.

Since both types of income were continuous variables and can be fluctuating parameters over time, we decided to take the mean value across the early childhood (age 0—8 years) and across the late childhood (age 9—14 years). This decision was inspired by previous research which has applied an average family income calculated over several years instead of applying income from only one time point (157).

Both types of income were then categorized into low, medium and high income grouped by the 33.3^{th} and 66.6^{th} percentile based on the entire source population. If a participant's parents were divorced, this information stemmed from the household where the participant's address was listed.

Information about maternal and paternal highest educational level in 1989/1997 (early childhood) and 2003 (late childhood) was derived from different educational registers (146). The variable was divided into three categories: ≤10 years, 11-13 years and >13 years of education. If information was missing for year 2003, information from previous years was applied (last observation carried forward). It was decided to categorise the variable in these three categories, where information on higher education was collapsed as one category (>13 years) to prevent rendered results. However, this made it difficult to disentangle whether there would be any exposure-response effect according to years of higher educational attainment.

Highest educational level was provided for both parents in Study II. In Study I and Study III it was merely mother's highest educational level which was applied as an exposure variable. This decision was taken, since it was expected that children in the early part of life might have a closer emotional connection with the mother because it is often the mother who are considered the main caregivers of children (158) and stays on prolonged maternity leave. Furthermore, mothers tend to play a larger role in child-rearing (159).

Information on mother's and father's LMP was derived from the DREAM register. Mother's and father's LMP was defined according to the degree of receiving social benefits (e.g. sickness absence compensation or unemployment benefits) within each year from 1991-2003. When the variable was defined, payments related to maternity leave and educational grants were omitted. LMP was a continuous variable in the range from 0 to 100 and calculated as a mean LMP score between 0 and 1 for each parent in each childhood period and categorized into "high LMP" and "low LMP" at a cut-off value of ≥0.80 indicating high LMP, which has been applied in previous

studies in the same cohort. LMP was provided for both parents in Study II. In Study I and Study III it was only the mother's LMP which was applied as an exposure variable.

Psychosocial factors

SSS (Subjective social status in society), negative life events in childhood and family functioning were self-reported from the baseline questionnaire in 2004.

SSS was measured by the youth version of the MacArthur Scale of Subjective Social Status (160), using a Danish translated version. This instrument is a 10-rung ladder with the following instruction: "Imagine that this ladder pictures how the Danish society is set up". The participants were asked to place an X on the ladder representing where their family would be in relation to income, education and prestigious jobs. The scale was categorized into three groups composed of the three lowest rungs (low SSS in society), the three highest rungs (high SSS in society) and the four in the middle (average SSS in society).

Negative life events were measured by six items taken from Newcomb et al.'s (161) measure and the Social Stress Indicator (162). The wording of the questions was the following: ''In your life-time": 1: "Have your parents divorced?" 2: "Have you lost any of your parents because they died?" 3: ''Have any of your parents abused alcohol or drugs to an extent where it caused problems in the family?'' 4: ''Have you been abused by someone you knew''? 5: ''Have you witnessed a very violent event''? 6: ''Have your parents suffered a life-threatening disease or accident''?. Response options were yes/no and were summated for each individual yielding an index score between 0 and 5 since none of the participants indicated to have experienced all six negative life events (163). The variable was dichotomized into <2 negative life events and ≥2 negative life events as applied in a previous study on the same cohort (164).

Family functioning was a categorical variable based on the general functioning subscale of the McMaster Family Assessment Device (FAD), developed by Epstein et al. (165). The FAD consists of seven subscales where the General Functioning scale assesses the overall health/pathology of the family with questions about how the family handles e.g., crisis or other family issues. It consists of 12 items with four response categories ranging from "strongly agree" to "strongly disagree" (scores 1—4), where higher values indicate poorer family functioning. A mean value for the 12 items was calculated. Family functioning was applied as a continuous exposure variable (Study I) and as a dichotomised exposure variable (Study II+III). The dichotomous variable family functioning was dichotomised at the 75th percentile, which indicated poor family functioning at ≥2.08, which lies between the mean value for the non-clinical and clinical samples on General Functioning (165).

The following psychological, social and life style factors were all applied as proxy variables in Study III to cover the exposure domains: adult distress, disharmonious family environment, offspring

distress, psychological and emotional overload and homeostasis disrupted: start of weight gain from Hemmingsson's proposed step-by-step model of obesity causation (104).

Definition of exposure domains

Adult distress was measured as parental self-rated health (2004). Information was provided by the parents in the parental questionnaire in 2004 and measured using a single item from the SF-36 on general health (GH-1) (166). The question was "In general, would you say your health is…" with five response options ranging from "excellent" to "poor", which was subsequently dichotomised to indicate ''good'' (excellent, very good) versus ''poor'' (good/less good/poor) self-rated health. The decision to include the response "good self-rated health" as part of the "poor" category was due to the fact that this is a healthy population and we expect a high level of self-rated health. Furthermore, very few participants rated their self-rated health as less good/poor, so to avoid rendered results this procedure was applied.

Disharmonious family environment was measured as family functioning. Please see the previous description of this variable below the section psychosocial factors. In Study III we applied the variable family functioning as a dichotomous variable.

Offspring distress was measured as participant's self-rated health, self-esteem and depressive symptoms. From the baseline questionnaire (age 15), we applied information about these three variables. Self-rated health was measured using a single item from SF-36 on general health (GH-1) (166) and the response categories were dichotomised as described above with the domain adult distress.

Self-esteem of the participants (2004) was measured using six items from the Rosenberg's self-esteem scale with scores from 1—4 and a total score between 6 and 24 (167). Scores were reversed so higher scores indicated lower self-esteem. The variable was dichotomised at the 75th percentile into "high" and "low" self-esteem.

Depressive symptoms were measured using the abbreviated 4-item validated version of the "The Center for Epidemiologic Studies Depression Scale for Children" (151). For further description I refer to the previous description of the variable below the section with the outcomes. In Study III we applied the variable as a dichotomous measure.

Information on the following proxy variables to cover the two domains psychological and emotional overload and homeostasis disrupted: start of weight gain was all retrieved from the questionnaires in 2004, 2007 and 2010.

Psychological and emotional overload was measured as avoidance coping, perceived stress and smoking status.

Avoidance coping was measured using three subscales of two items each from the BRIEF COPE Scale (168). The three subscales employed in this thesis were “self-distraction”, “substance use” and “behavioural disengagement”. Each item had four response categories (scores 1—4), where higher scores indicated a higher level of avoidance coping. The avoidance coping scale was created by the mean of the item scores. The distribution of the avoidance coping for this population was skewed to the right, so we decided to dichotomise the avoidance coping scale into high and low avoidance coping at the 75th percentile, respectively.

Perceived stress was measured using a Danish four item version of the Perceived Stress Scale (PSS), originally developed by Cohen et al. (169). It consists of four items asking about the responder’s experience of being in control of one’s personal life during the last month. Each item had a score between 0 (‘‘never’’) and 4 (‘‘very often’’). The total scale ranged from 0 to 16 points, where higher values indicated higher levels of perceived stress. PSS has no clinical cut points, so the variable was dichotomised into high and low PSS at the 75th percentile, respectively.

Smoking status was a categorical variable with four possible answers that were dichotomised into smoking (“yes, but not every week”, “yes, but not every day”, “yes, daily”) and no smoking (“no, I do not smoke”).

Homeostasis disrupted: start of weight gain was measured by physical activity (PA) and computer time (CT). PA was a categorical variable where each participant was asked in a single item, “How many hours a week during leisure time do you usually exercise or play sports where you are out of breath or sweating?”. The six possible answer categories were ranging from “none” to “≥7 hours”. The variable was dichotomised according to the recommendation on daily PA for adolescents and young adults (170). At age 15: “Low level of PA” (≤2–3 hours/week) and “high level of PA” (≥4–6 hours/week). At ages 18 and 21: “Low level of PA” (≤1 hour/week) and “high level of PA” (≥2–3 hours/week).

CT was a categorical variable where each participant was asked in a single item, ‘‘On an average (school) day, how many hours of your leisure time do you spend in front of a computer?’’. The seven possible answer categories were ranging from ‘‘I am not using the computer’’ to ‘‘≥4 hours’’. There are to the knowledge of the authors only official recommendations regarding screen time for small children (171) and none for adolescent children and young people’s time spend in front of a computer, so a pragmatic decision was taken to dichotomise the variable at the 75th percentile, which resulted in slightly different cut-offs depending on age. At age 15: ‘‘Low level of CT’’ (≤2 hours/day) and ‘‘high level of CT’’ (≥3 hour/day). At ages 18 and 21: ‘‘low level of CT’’ (≤3 hours/day) and ‘‘high level of CT’’ (≥4 hour/day).

Additional variables

The following variables birth-weight, split-home and participant's own educational attainment were chosen á priori as potential confounders. Information on birth-weight was obtained from the Danish Medical Birth Register (148). Birth-weight was applied as a potential confounder in Study II+III since birth-weight has previously been found associated with SEP (172) and later overweight and obesity (99). Information on the variable split-home was obtained from the CPR register (144) on whether the child lived with both parents or not in 1989 and 2003. The variable split-home was included in Study II as a potential confounder since parental marital status has previously been found associated with overweight and obesity (101,102).

Information on participants' educational attainment at age 28 years was obtained from educational registers (146). When examining associations between childhood SEP and later health outcomes in early adulthood previous research has shown that it is relevant to include adjustments for adult SEP (173). We included an adjustment for this variable in Study III where the outcome was measured at age 28 years. We did, however, not apply this adjustment to Study I+II because many of the participants' at the age of 21 years are still living at home or receiving financial help from their parents during study years.

Statistical analyses

All analyses were performed using the statistical package Stata, statistical software version 14.2 (Stata Corporation, College Station, Texas, USA). All results are presented with 95% confidence intervals (CI).

Study I

We examined the associations between childhood family factors in early and late childhood and depressive symptoms at ages 15, 18 and 21 using logistic regression analyses. We included the psychosocial variables: SSS, negative life events and family functioning to the late childhood exposures.

We carried out mutual adjustments for other socioeconomic exposure variables from the same childhood period and gender. We included adjustments for early childhood socioeconomic exposures when examining the late childhood socioeconomic factors in relation to the outcome. When we examined the associations between each of the three psychosocial variables and depressive symptoms we made mutual adjustments for the other psychosocial variables and SEP in late childhood.

Study II

We applied multinomial logistic regression analyses to examine the association between socioeconomic position and family functioning in early and late childhood and overweight and obesity at ages 15, 18 and 21. We mutually adjusted for other socioeconomic exposures in each childhood period. When we examined the associations between SEP in late childhood and overweight/obesity we included an adjustment for the same SEP exposure in early childhood to take the effect of the early childhood exposure into account. All analyses were stratified by gender. We furthermore included adjustments for birth weight and split-home in all analyses.

Figure 2 illustrates the hypothesised causal relations between the different variables presented in Study I+II.

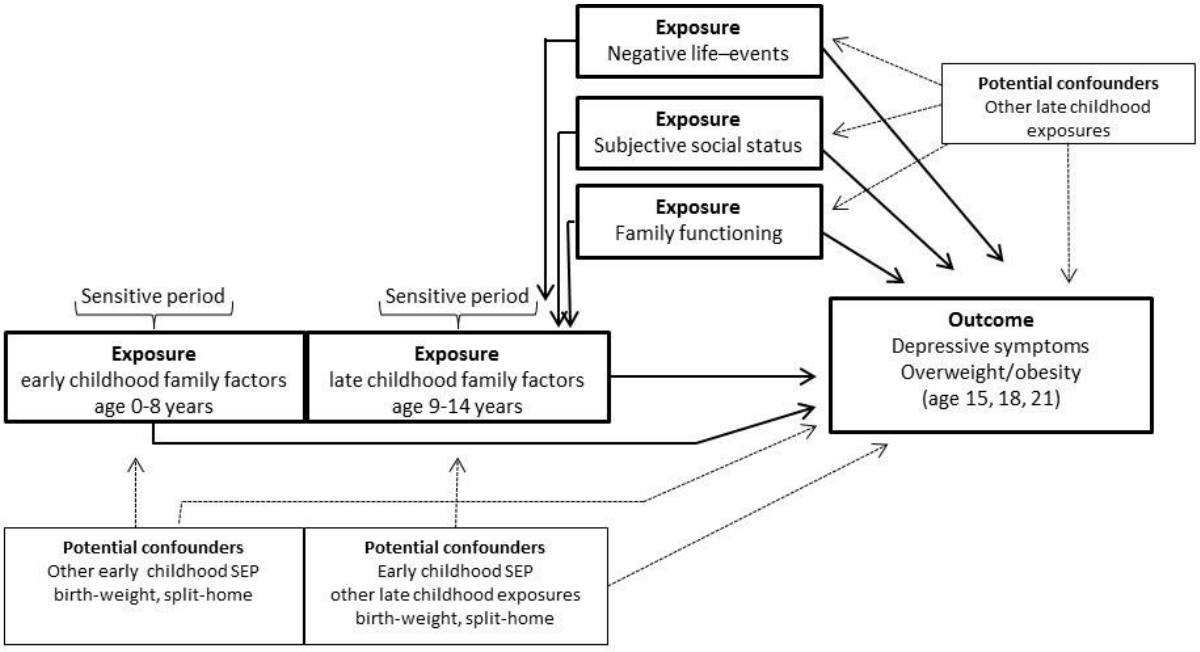

Figure 2 is illustrating possible causal relations in study I+II. The arrows between negative life-events, subjective social status and family functioning towards the box with the late childhood exposures show that the three psychosocial factors represent exposures in the late childhood. The dotted lines represents the relation between potential confounders and exposures and outcomes.

Study III

We examined the association between socioeconomic disadvantage and obesity using logistic regression analyses. We examined the unadjusted association between each of the three exposure variables and the outcome at age 15, 18, 21 and 28 years (Model I). We then applied a three-step adjustment model, where we mutually adjusted for other socioeconomic exposures (Model II), adjusting further for the domains adult distress, disharmonious family environment and offspring distress (Model III). In the fourth and fully adjusted model (Model IV), we adjusted for Models II+III and the domains psychological and emotional overload and disrupted homeostasis. We adjusted

all the analyses for birth weight at all four time points and included adjustments for own educational attainment in the analyses at age 28 years. All analyses were stratified by gender.

5. Results

Summary of results

This section will summarise the main findings from the three individual studies in this PhD thesis. Additional and more detailed information on the findings is available in the embedded papers.

Description of the cohort

In table 5 is presented proportions and distributions of the two outcomes at age 15, 18 and 21 years for the entire cohort along with the main exposure variables included in the three studies. In the three studies sub-samples of the cohort have been applied and for further description of these subsamples please see Paper I-III.

Table 5. Descriptive statistics of main exposure variables (selected) and the two outcomes for the entire cohort in 2004, 2007 and 2010 (N=3,681)

	age=15		age=18		age=21	
Variables						
	N		N		N	
Gender	3,054		2,400		2,145	
Girls		1,536 (50%)		1,289 (54%)		1,163 (54%)
Boys		1,518 (50%)		1,111 (46%)		982 (46%)
Depressive symptoms 0-12 (mean/sd[1])	3,014	2,22 (2,2)	2,373	2,86 (2,3)	1,968	2,47 (2,3)
Body Mass Index in kg/m^2 (mean/sd[1])	2,879	20,1 (2,9)	2,308	22,3 (3,3)	1,974	23,6 (4,0)
Early childhood						
Yearly household income in DKK (mean/sd[1])	2,916	394,146 (145,484)	2,317	398,684 (138,993)	2,085	395,358 (132,357)
Equivalised household income in DKK (mean/sd[1])	2,933	80,251 (23,103)	2,312	80,651 (23,062)	2,079	79,563 (22,281)
Mother´s highest educational level 1989	2,797		2,251		2,034	
>13 years		645 (23%)		555 (25%)		506 (25%)
11-13 years		1,250 (45%)		998 (44%)		902 (44%)
≤10 years		902 (32%)		698 (31%)		626 (31%)
Mother´s labour market participation	2,988		2,397		2,140	
High		2,073 (69%)		1,693 (71%)		1,508 (70%)
Low		915 (31%)		704 (29%)		632 (30%)
Late childhood						
Yearly household income in DKK (mean/sd[1])	2,994	526,147 (207,941)	2,363	534,356 (204,020)	2,112	530,764 (202,426)
Equivalised household income in DKK (mean/sd[1])	2,989	145,418 (56,337)	2,368	146,970 (58,084)	2,107	145,597 (57,435)
Mother´s highest educational level 2003	2,944		2,360		2,120	
>13 years		883 (30%)		746 (32%)		669 (32%)
11-13 years		1,361 (46%)		1,076 (45%)		957 (45%)
≤10 years		700 (24%)		538 (23%)		494 (23%)
Mother´s labour market participation	2,974		2,386		2,129	
High		2,239 (75%)		1,842 (77%)		1,637 (77%)
Low		735 (25%)		544 (23%)		492 (23%)
Family functioning (mean/sd[1])	3,015	1,75 (0.52)	N/A[2]	N/A[2]	N/A[2]	N/A[2]

[1] standard deviation, [2] Not available

As presented in table 5, it can be observed that more girls than boys participated at each survey wave. We observed the highest mean level of depressive symptoms at age 18 years which declined at age 21 years. It can also be observed that the mean BMI increased from 22,3 kg/m^2 to 23,6 kg/m^2 in the years from 18 to 21. We omitted the column at age 28 years which presented that 1,189 women and 913 men participated at this wave with a mean BMI equivalent to 25,3 kg/m^2 (standard deviation=5,4 kg/m^2). It can also be observed from table 5 that the distribution of mother's highest educational level changed from 1989 to 2003 revealing a smaller proportion of young people from homes where mother's had ≤10 years of education.

Study I

Main results from Study I is presented in Table 6. The table shows adjusted estimates for the association between early and late childhood exposures in relation to depressive symptoms at ages 15, 18 and 21.

Table 6. The associations between childhood socioeconomic and psychosocial factors and depressive symptoms at ages 15 (N=3,014), 18 (N=2,373) and 21 years (N=1,968).

	15	18	21
Early childhood	AOR[1] (95% CI[2])	AOR[1] (95% CI[2])	AOR[1] (95% CI[2])
Equivalised household income			
High (ref.grp.[3])	1[a]	1[a]	1[a]
Medium	1.0 (0.8;1.2)	1.1 (0.9;1.3)	1.2 (0.9;1.6)
Low	1.0 (0.8;1.2)	1.1 (0.8;1.3)	1.4 (1.1;1.8)
Mother's labour market participation			
High (ref.grp.[3])	1[a]	1[a]	1[a]
Low	1.3 (1.1;1.5)	1.1 (0.9;1.3)	1.0 (0.8;1.3)
Mother's highest educational level			
>13 years (ref.grp.[3])	1[a]	1[a]	1[a]
11-13 years	0.9 (0.7;1.0)	0.8 (0.7;1.0)	0.9 (0.7;1.2)
≤10 years	1.0 (0.8;1.2)	1.0 (0.8;1.2)	1.3 (1.0;1.7)
Late childhood			
Equivalised household income			
High (ref.grp.[3])	1[b]	1[b]	1[b]
Medium	1.2 (0.9;1.4)	0.9 (0.8;1.2)	1.2 (0.9;1.6)
Low	1.2 (0.9;1.5)	1.0 (0.8;1.4)	1.1 (0.8;1.6)
Mother's labour market participation			
High (ref.grp.[3])	1[c]	1[c]	1[c]
Low	1.0 (0.8;1.2)	1.0 (0.8;1.3)	1.4 (1.0;1.8)
Mother's highest educational level			
>13 years (ref.grp.[3])	1[d]	1[d]	1[d]
11-13 years	1.1 (0.7;1.9)	1.1 (0.6;1.9)	0.5 (0.2;0.9)
≤10 years	1.5 (0.8;2.9)	1.2 (0.6;2.4)	0.9 (0.4;2.0)
Poor family functioning			
Increase per unit	2.6 (2.2;3.1)[f]	1.8 (1.5;2.2)[f]	1.9 (1.6;2.4)[f]
Subjective social status			
High (ref.grp.[3])	1[f]	1[f]	1[f]
Average	1.2 (1.0;1.5)	1.1 (0.9;1.3)	1.1 (0.8;1.3)
Low	1.0 (0.5;2.1)	0.9 (0.4;2.1)	0.7 (0.3;1.8)
Negative life events			
<2 (ref.grp.[3])	1[f]	1[f]	1[f]
≥2	1.7 (1.3;2.2)	1.4 (0.9;1.9)	1.2 (0.8;1.7)

[1] Adjusted Odds Ratio, [2] Confidence interval, [3] Reference group

[a] Mutual adjusted for other early childhood socioeconomic exposures

[b] Mutual adjusted for other late childhood exposures, early childhood equivalised household income

[c] Mutual adjusted for other late childhood exposures, mother´s labour market participation in early childhood

[d] Mutual adjusted for other late childhood exposures, mother´s highest educational level in early childhood

[f] Mutual adjusted for other late childhood exposures

We observed in Study I that being exposed to mother's low LMP, low equivalised household income or mother's low level of education in early childhood was significantly associated with a higher risk of depressive symptoms at ages 15 and 21 years. We also observed that being exposed to mother's low LMP in late childhood was associated with a higher risk of depressive symptoms at age 21 years. Furthermore, adjusted analyses showed that exposure to mother's low level of education in late childhood was associated with a higher risk of depressive symptoms at age 15 years although the confidence intervals were wide.

When we examined the associations between each of the psychosocial variables in late childhood in relation to depressive symptoms at the three time points, we observed that especially family functioning showed a consistent association with depressive symptoms. For each unit increase in poor family functioning, the odds of depressive symptoms increased between 1.8 and 2.6-fold at ages 15, 18 and 21 years. We also observed that participants who had experienced more than two negative life events before the age of 15 years had almost twice the odds of depressive symptoms at age 15 years, compared to peers who had experienced less than two negative life events.

Study II

In the following tables 7 and 8 main findings from Study II are presented. All analyses were stratified by gender. The two tables show adjusted estimates for the association between childhood SEP and family functioning in early and late childhood in relation to overweight and obesity at ages 18 and 21 years. For further information regarding the outcome at age 15 years, please see Paper II.

Table 7. The association between early childhood socioeconomic position, family functioning and overweight and obesity at age 18 and 21 years.

	Girls				Boys			
Early Childhood	**18** (n=970)		**21** (n=864)		**18** (n=840)		**21** (n=698)	
	ARR[1,5] (95% CI[2])		ARR[1,5] (95% CI[2])		ARR[1,5] (95% CI[2])		ARR[1,5] (95% CI[2])	
	Overweight	Obesity	Overweight	Obesity	Overweight	Obesity	Overweight	Obesity
Household income								
High (ref.grp.[3])	1	1	1	1	1	1	1	1
Medium	1.5 (0.9;2.6)	1.4 (0.7;2.9)	0.7 (0.4;1.2)	1.4 (0.9;2.4)	0.7 (0.4;1.1)	1.0 (0.5;1.9)	0.7 (0.4;1.1)	1.1 (0.6;2.0)
Low	0.9 (0.5;1.9)	0.9 (0.4;2.1)	0.5 (0.3;1.0)	1.1 (0.6;1.9)	0.7 (0.3;1.4)	1.2 (0.6;2.4)	0.5 (0.3;1.0)	0.9 (0.5;1.9)
LMP[4] (mother)								
High (ref.grp.[3])	1	1	1	1	1	1	1	1
Low	1.3 (0.8;2.1)	1.0 (0.6;2.0)	1.6 (1.0;2.6)	1.2 (0.8;1.8)	1.1 (0.6;2.0)	1.3 (0.7;2.3)	2.0 (1.2;3.2)	2.2 (1.3;3.8)
LMP[4] (father)								
High (ref.grp.[3])	1	1	1	1	1	1	1	1
Low	1.4 (0.7;2.9)	0.8 (0.3;2.2)	0.7 (0.3;1.5)	0.8 (0.4;1.6)	1.1 (0.4;2.8)	2.8 (1.3;6.1)	0.7 (0.3;2.1)	1.6 (0.7;4.1)
Highest educational level 1989 (mother)								
>13 years (ref.grp.[3])	1	1	1	1	1	1	1	1
10-13 years	0.8 (0.4;1.6)	0.7 (0.3;1.7)	0.9 (0.5;1.7)	1.0 (0.5;1.7)	1.4 (0.7;2.5)	0.8 (0.4;1.6)	1.7 (1.0;3.0)	0.7 (0.4;1.4)
<10 years	1.4 (0.7;2.7)	1.9 (0.8;4.7)	1.9 (1.0;3.8)	2.1 (1.1;3.9)	1.4 (0.7;2.8)	1.5 (0.7;3.2)	1.4 (0.7;2.7)	1.3 (0.7;2.6)
Highest educational level 1989 (father)								
>13 years (ref.grp.[3])	1	1	1	1	1	1	1	1
10-13 years	2.1 (1.0;4.3)	4.5 (1.3;15.7)	2.5 (1.2;5.1)	1.8 (1.0;3.4)	1.1 (0.6;1.9)	1.0 (0.5;2.0)	1.6 (0.9;2.8)	1.9 (0.9;4.0)
<10 years	1.4 (0.6;3.2)	5.2 (1.4;19.3)	2.6 (1.2;5.8)	1.8 (0.9;3.6)	1.1 (0.5;2.2)	1.6 (0.8;3.5)	1.8 (0.9;3.4)	2.4 (1.1;5.4)
Family functioning								
Good (ref.grp.[3])	1	1	1	1	1	1	1	1
Poor	1.6 (1.0;2.7)	1.2 (0.6;2.3)	1.5 (0.9;2.5)	2.0 (1.3;3.1)	1.1 (0.6;1.9)	0.5 (0.3;1.0)	0.9 (0.5;1.5)	0.5 (0.3;1.0)

[1] Adjusted Relative Risks, [2] Confidence interval, [3] Reference group, [4] Labour market participation

[5] Mutual adjusted for other exposure variables, birth weight and split-home 1989

In girls, we observed that exposure to parental lower educational level in early childhood was associated with a higher risk of overweight and obesity, compared to peers with high educated parents. Being exposed to maternal low level of education was associated with a 2-fold higher risk of girls being overweight or obese at the age of 18 or 21 years, whereas exposure to father's lower educational level was associated with an up to 5-fold higher risk of girls being overweight or obese. Fifteen year-old girls, who reported poor family functioning, had between 1.6 and 2-fold higher risk of being overweight or obese at the age of 18 or 21 years, compared to their peers who reported good family functioning.

Being exposed to lower household income or to parental low LMP during late childhood was associated with higher risk of obesity in girls at the age of 18 or 21 years. Being exposed to parental lower educational level was associated with a 2 to 3-fold higher risk of girls being overweight or obese, compared to peers with higher educated parents.

Table 8. The association between late childhood socioeconomic position, family functioning and overweight or obesity at ages 18 and 21.

Late Childhood	Girls				Boys			
	18 (n=972)		21 (n=862)		18 (n=838)		21 (n=698)	
	ARR[1, 5] (95% CI[2])		ARR[1, 5] (95% CI[2])		ARR[1, 5] (95% CI[2])		ARR[1, 5] (95% CI[2])	
	Overweight	Obesity	Overweight	Obesity	Overweight	Obesity	Overweight	Obesity
Household income								
High (ref.grp.[3])	1[a]	1[a]	1	1	1[b]	1[b]	1[c]	1[c]
Medium	0.8 (0.4;1.4)	2.1 (0.9;5.0)	0.6 (0.4;1.2)	1.3 (0.7;2.3)	0.9 (0.5;1.6)	1.5 (0.7;3.0)	0.8 (0.4;1.3)	0.8 (0.4;1.5)
Low	0.7 (0.3;1.5)	2.0 (0.7;5.9)	1.0 (0.5;2.0)	1.8 (0.9;3.5)	0.9 (0.4;2.0)	1.3 (0.5;3.3)	0.6 (0.3;1.4)	1.0 (0.4;2.2)
LMP[4] (mother)								
High (ref.grp.[3])	1	1	1	1	1	1	1	1
Low	1.6 (0.9;2.8)	1.6 (0.8;3.2)	1.1 (0.6;2.0)	1.3 (0.8;2.1)	1.1 (0.6;2.1)	0.6 (0.3;1.3)	1.1 (0.6;2.0)	0.9 (0.5;1.8)
LMP[4] (father)								
High (ref.grp.[3])	1	1	1	1	1	1	1	1
Low	1.3 (0.6;2.8)	2.0 (0.8;5.1)	1.5 (0.7;3.2)	1.6 (0.8;3.1)	0.6 (0.2:1.9)	1.0 (0.4;2.8)	0.1 (0.0;0.9)	0.7 (0.3;2.2)
Highest educational level 2003 (mother)								
>13 years (ref.grp.[3])	1	1	1	1	1	1	1	1
10-13 years	1.2 (0.7;2.2)	1.1 (0.5;2.4)	1.3 (0.7;2.3)	1.4 (0.8;2.3)	1.3 (0.8;2.2)	0.9 (0.5;1.6)	1.6 (1.0;2.7)	1.0 (0.6;1.8)
<10 years	1.8 (0.9;3.5)	2.2 (0.9;5.2)	1.8 (0.9;3.4)	2.0 (1.1;3.7)	0.9 (0.4;1.8)	1.8 (0.9;3.6)	1.6 (0.9;3.0)	1.6 (0.9;3.1)
Highest educational level 2003 (father)								
>13 years (ref.grp.[3])	1	1	1	1	1	1	1	1
10-13 years	1.5 (0.8;2.8)	3.1 (1.0;9.3)	2.1 (1.1;4.0)	1.4 (0.8;2.4)	1.2 (0.7;2.2)	0.9 (0.4;1.7)	1.5 (0.9;2.6)	2.5 (1.3;5.0)
<10 years	1.1 (0.5;2.4)	3.7 (1.2;11.9)	2.5 (1.2;5.2)	1.5 (0.8;2.9)	1.2 (0.6;2.4)	1.3 (0.6;2.8)	1.9 (1.0;3.6)	2.9 (1.4;6.4)
Family Functioning								
Good (ref.grp.[3])	1	1	1	1	1	1	1	1
Poor	1.5 (0.9;2.5)	1.0 (0.5;2.0)	1.3 (0.8;2.1)	1.7 (1.1;2.7)	1.1 (0.6;1.9)	0.5 (0.3;1.1)	1.1 (0.7;1.8)	0.6 (0.3;1.2)

[a] n=970, [b] n=837, [c] n=697

[1] Adjusted Relative Risks, [2] Confidence interval, [3] Reference group, [4] Labour market participation

[5] Mutual adjusted for other exposure variables, birth weight and split-home 2003

When we examined the associations between childhood SEP and overweight and obesity in boys, we observed that being exposed to parental low LMP during early childhood was associated with an almost 3-fold higher risk of boys being overweight or obese at ages 18 or 21 years, compared to peers with parents having a high LMP. Exposure to parental lower educational level during early childhood was also associated with a higher risk of boys being overweight and obesity, where especially paternal low educational level was associated with a 2.4-fold higher risk of obesity at age 21 years.

Being exposed to parental lower educational level in late childhood was associated with a higher risk of boys being overweight or obese at ages 18 and 21 years, where exposure to paternal lower educational level was associated with an almost 3-fold higher risk of obesity.

Study III

Table 9 presents the main findings from Study III for girls. The table shows both unadjusted and adjusted estimates for the association between socioeconomic disadvantage and overweight and obesity at ages 15, 18, 21 and 28 years.

Table 9. Unadjusted (Model I) and adjusted estimates for the association between the socioeconomic disadvantage domain and overweight and obesity (combined) at ages 15, 18, 21 and 28 years (girls).

	15 (N=1,438)				**18** (N=1,238)			
	Model I	**Model II[a]**	**Model III[b]**	**Model IV[c]**	**Model I**	**Model II[a]**	**Model III[b]**	**Model IV[c]**
Socioeconomic disadvantage	OR[1]	AOR[2] (n=1,133)	AOR[2] (n=1,210)	AOR[2] (n=1,089)	OR[1]	AOR[2] (n=1,181)	AOR[2] (n=943)	AOR[2] (n=920)
Mother's highest educational level								
>13 years (ref.gr.[3])	1	1	1	1	1	1	1	1
11-13 years	1.0 (0.6;1.5)	1.0 (0.6;1.6)	1.1 (0.7;2.0)	1.2 (0.7;2.0)	1.1 (0.4;2.9)	1.3 (0.5;3.6)	1.1 (0.4;3.2)	1.1 (0.4;3.2)
≤10 years	1.6 (0.9;2.6)	1.6 (0.9;2.8)	1.8 (0.9;3.3)	1.8 (0.9;3.4)	2.8 (1.1;6.9)	3.1 (1.1;8.4)	2.5 (0.8;7.3)	2.6 (0.9;7.8)
Mother's LMP[4]								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Low	0.8 (0.5;1.3)	0.7 (0.5;1.1)	0.7 (0.4;1.2)	0.7 (0.4;1.1)	0.7 (0.3;1.6)	0.6 (0.3;1.4)	0.4 (0.2;1.2)	0.4 (0.1;1.2)
Equivalised household income								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Medium	1.4 (0.9;2.3)	1.7 (1.0;2.7)	1.1 (0.7;1.9)	1.0 (0.6;1.8)	1.7 (0.7;4.1)	1.7 (0.7;4.2)	1.8 (0.6;5.0)	1.7 (0.6;4.8)
Low	1.3 (0.8;2.1)	1.2 (0.7;2.0)	0.8 (0.5;1.5)	0.7 (0.4;1.4)	2.0 (0.8;4.9)	1.7 (0.7;4.4)	1.5 (0.5;4.7)	1.5 (0.5;4.6)

	21 (N=1,075)				**28** (N=1,045)			
	Model I	**Model II[a]**	**Model III[b]**	**Model IV[c]**	**Model I**	**Model II[a]**	**Model III[b]**	**Model IV[d]**
Socioeconomic disadvantage	OR[1]	AOR[2] (n=1,035)	AOR[2] (n=824)	AOR[2] (n=730)	OR[1]	AOR[2] (n=984)	AOR[2] (n=783)	AOR[2] (n=583)
Mother's highest educational level								
>13 years (ref.gr.[3])	1	1	1	1	1	1	1	1
11-13 years	2.1 (1.0;4.4)	2.1 (1.0;4.3)	2.8 (1.2;6.7)	2.5 (1.0;6.0)	2.1 (1.3;3.5)	1.9 (1.1;3.1)	2.5 (1.4;4.5)	2.1 (1.1;4.1)
≤10 years	4.0 (1.9;8.5)	3.9 (1.8;8.5)	5.2 (2.1;12.9)	5.2 (2.1;13.2)	2.6 (1.5;4.5)	2.3 (1.3;4.1)	2.5 (1.3;4.9)	1.6 (0.7;3.5)
Mother's LMP[4]								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Low	1.1 (0.6;1.8)	0.9 (0.5;1.5)	1.0 (0.5;1.9)	1.0 (0.5;2.0)	1.6 (1.1;2.3)	1.4 (0.9;2.0)	1.2 (0.7;1.9)	1.3 (0.8;2.3)
Equivalised household income								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Medium	1.5 (0.8;2.7)	1.5 (0.8;2.7)	1.4 (0.7;2.7)	1.5 (0.7;3.1)	1.1 (0.7;1.6)	0.9 (0.6;1.4)	0.8 (0.5;1.4)	0.8 (0.5;1.5)
Low	1.3 (0.7;2.4)	1.1 (0.6;2.2)	0.9 (0.4;2.0)	1.0 (0.4;2.2)	1.2 (0.8;1.8)	0.9 (0.6;1.4)	0.6 (0.4;1.1)	0.5 (0.2;0.9)

[1] Unadjusted Odds ratio, [2] Adjusted Odds ratio with 95% Confidence intervals, [3] Reference group, [4] Labour market participation

[a] Mutual adjustments (adj.) for other socioeconomic variables

[b] Adj. for Model II+adult distress, disharmonious family environment and offspring distress, birth-weight

[c] Adj. for Model II+III, psychological and emotional overload, homeostasis disrupted, birth-weight

[d] Adj. for Model II+III, psychological and emotional overload, homeostasis disrupted, birth-weight, young people's own education (age 28)

When we examined the association between maternal low educational level and overweight and obesity at ages 15 to 28 years in girls, results showed an almost 3-fold higher odds of overweight and obesity among girls aged 18 years, compared to girls with high educated mothers. This association attenuated when adjustments were made for the domains: adult distress, disharmonious family environment and offspring distress. We observed 4-fold greater odds of overweight and obesity in 21-year-old girls who came from homes with a low educated mother, which became even higher when we adjusted for adult distress, disharmonious family environment and offspring distress. We observed more than 2.5-fold higher odds of overweight

and obesity in 28-year-old women with low or medium educated mothers. This association was considerably attenuated when we did the fully adjusted model including the young women's own educational level.

Table 10 presents the main findings from Study III for boys. The table shows both unadjusted and adjusted estimates for the association between socioeconomic disadvantage and overweight and obesity at ages 15, 18, 21 and 28 years.

Table 10. Unadjusted (Model I) and adjusted estimates for the association between the socioeconomic disadvantage domain and overweight and obesity (combined) at ages 15, 18, 21 and 28 years (boys).

	15 (N=1,441)				**18** (N=1,067)			
	Model I	**Model II[a]**	**Model III[b]**	**Model IV[c]**	**Model I**	**Model II[a]**	**Model III[b]**	**Model IV[c]**
Socioeconomic disadvantage	OR[1]	AOR[2] (n=1,344)	AOR[2] (n=1,098)	AOR[2] (n=1,077)	OR[1]	AOR[2] (n=1,014)	AOR[2] (n=786)	AOR[2] (n=769)
Mother's highest educational level								
>13 years (ref. gr.[3])	1	1	1	1	1	1	1	1
11-13 years	1.5 (1.0;2.2)	1.4 (0.9;2.1)	1.5 (0.9;2.3)	1.5 (0.9;2.4)	1.3 (0.6;3.3)	1.3 (0.5;3.1)	1.3 (0.5;3.4)	1.8 (0.6;5.4)
≤10 years	1.9 (1.2;3.0)	1.8 (1.1;2.8)	1.8 (1.0;3.0)	1.8 (1.0;3.1)	2.9 (1.2;7.0)	2.5 (1.0;6.1)	1.7 (0.6;5.2)	2.2 (0.7;7.2)
Mother's LMP[4]								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Low	1.4 (1.0;2.0)	1.3 (0.9;1.8)	1.3 (0.8;1.9)	1.2 (0.8;1.9)	1.6 (0.8;3.0)	1.2 (0.6;2.5)	1.0 (0.4;2.4)	1.0 (0.4;2.5)
Equivalised household income								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Medium	1.0 (0.7;1.5)	0.9 (0.6;1.4)	0.9 (0.5;1.4)	0.8 (0.5;1.3)	0.5 (0.2;1.4)	0.5 (0.2;1.2)	0.6 (0.2;1.7)	0.4 (0.1;1.5)
Low	1.2 (0.8;1.8)	1.1 (0.7;1.7)	1.2 (0.7;2.0)	1.2 (0.7;1.9)	1.6 (0.8;3.2)	1.2 (0.6;2.6)	1.5 (0.6;3.9)	1.7 (0.6;4.4)

	21 (N=886)				**28** (N=827)			
	Model I	**Model II[a]**	**Model III[b]**	**Model IV[c]**	**Model I**	**Model II[a]**	**Model III[b]**	**Model IV[d]**
Socioeconomic disadvantage	OR[1]	AOR[2] (n=851)	AOR[2] (n=658)	AOR[2] (n=551)	OR[1]	AOR[2] (n=776)	AOR[2] (n=572)	AOR[2] (n=390)
Mother's highest educational level								
>13 years (ref. gr.[3])	1	1	1	1	1	1	1	1
11-13 years	2.5 (1.1;5.7)	2.3 (0.9;5.2)	2.7 (1.1;6.6)	2.5 (0.9;6.3)	2.2 (1.3;3.7)	1.9 (1.1;3.3)	1.9 (1.0;3.4)	1.7 (0.8;3.4)
≤10 years	4.5 (2.0;10.3)	3.8 (1.6;9.0)	3.9 (1.5;10.4)	3.6 (1.3;10.2)	3.2 (1.8;5.5)	2.6 (1.5;4.6)	2.0 (0.9;3.9)	0.9 (0.3;2.6)
Mother's LMP[4]								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Low	2.2 (1.3;3.8)	1.8 (0.9;3.2)	1.7 (0.9;3.4)	1.4 (0.7;3.1)	1.9 (1.3;2.9)	1.6 (1.0;2.4)	1.5 (0.9;2.6)	1.5 (0.7;3.0)
Equivalised household income								
High (ref.gr.[3])	1	1	1	1	1	1	1	1
Medium	0.9 (0.4;1.7)	0.7 (0.3;1.3)	0.6 (0.3;1.3)	0.6 (0.2;1.3)	1.1 (0.7;1.9)	0.9 (0.6;1.5)	0.8 (0.5;1.5)	0.7 (0.3;1.5)
Low	1.0 (0.5;1.9)	0.6 (0.3;1.3)	0.6 (0.3;1.4)	0.4 (0.2;1.1)	1.5 (0.9;2.5)	1.2 (0.7;2.0)	1.2 (0.6;2.1)	1.1 (0.5;2.4)

[1] Unadjusted Odds ratio, [2] Adjusted Odds ratio with 95% Confidence interval, [3] Reference group, [4] Labour market participation

[a] Mutual adjustments (adj.) for other SES variables

[b] Adj. for Model II+adult distress, disharmonious family environment and offspring distress, birth-weight

[c] Adj. for Model II+III, psychological and emotional overload, homeostasis disrupted, birth-weight

[d] Adj. for Model II+III, psychological and emotional overload, homeostasis disrupted, birth-weight, young people's own education (age 28)

When we examined the association between maternal low educational level and overweight and obesity among boys, we observed almost 2-fold higher odds of overweight and obesity in 15-year-old boys, compared to boys with high educated mothers. We observed likewise 3-fold higher odds

of overweight and obesity in 18-year-old boys from homes with a low educated mother, which attenuated when we adjusted for equivalised household income, maternal LMP and the domains adult distress, disharmonious family environment and offspring distress. In 21-year-old boys with a low educated mother, we observed a more than 4-fold higher odds of overweight and obesity, which attenuated primarily when we made adjustments for equivalised household income and maternal LMP. In 28-year-old men, we observed more than 3-fold greater odds of overweight and obesity which primarily attenuated when adjustments were made for equivalised household income, maternal LMP, adult distress, disharmonious family environment and offspring distress. However, when we carried out a fully adjusted analysis including the educational level of the young men, the association between maternal low educational level and overweight and obesity vanished.

The associations between mother's low LMP and overweight and obesity in 15-year-old boys showed that the association attenuated to some extent in the fully adjusted model, which was also observed at the age of 21 years. When we examined the association at the ages 18 and 21 years, the associations attenuated when we included the variables equivalised household income, maternal LMP, and the domains: adult distress, disharmonious family environment and offspring distress in the model.

6. Discussion

In the following section, the main findings from Studies I-III are discussed in relation to results from other studies. This is followed by a general section about methodological considerations across the three studies.

In a Danish youth cohort, we examined whether exposure to socioeconomic factors in early and late childhood was associated with depressive symptoms (Study I) and overweight and obesity (Study II) in adolescence and early adulthood and if any timing effect was apparent. We supplemented the objective exposure variables with the self-reported variables family functioning (Studies I+II), subjective social status and negative life events (Study I). In Study III we examined whether the underlying association between socioeconomic disadvantage and overweight and obesity in adolescence and early adulthood could be explained by psychosocial stressors in childhood.

Main findings

Depressive symptoms (Study I)

Exposure to low equivalised household income, mother's low education or mother's low LMP in early and late childhood was associated with a higher risk of depressive symptoms at ages 15, 18 and 21 years, which are in line with previous studies in this field (35,114,115,120). Low equivalised household income and mother's low educational level in early childhood was associated with depressive symptoms at age 21, whereas exposure to these socioeconomic variables in late childhood was associated with a higher risk of depressive symptoms at age 15. The opposite pattern was observed with mother's LMP where maternal low LMP in early childhood was associated with a higher risk of depressive symptoms at age 15. Mother's low LMP in late childhood was associated with a higher risk of depressive symptoms at age 21 years.

Several of the socioeconomic variables showed an association with the outcome at different time points depending on the childhood period of exposure, which could suggest a possible timing effect, which was not found in previous studies that examined the timing of exposure to low equivalised income in relation to later mental health (37,119,120). Those studies, however, examined exposure to relative poverty (<60% of mean national equivalised household income) in relation to later mental health. We did not examine exposure to relative poverty as we defined low income as below the 33.3th percentile. The study by Boe et al. (120) was carried out in Norway, a country with a political and social system similar to that in Denmark. They obtained information on equivalised household income when the child was aged 8—11 years (2004) until 2010. In our study, we had a different approach with regard to the income variable because we applied information on equivalised household income during the entire childhood period (0—14 years) divided into an early and late period. We also applied a different measure of the outcome

and another statistical approach than in the study by Boe et al. Altogether, this may explain some of the differences in findings between the two studies.

In Study I, we observed some associations between SEP and the outcome at different time points depending on which childhood period we examined. We did, however, not find a clear pattern reflecting that exposure to low SEP in one childhood period showed higher association with the outcome. This may perhaps reflect that both the early and the late childhood period may be possible sensitive periods in relation to later depressive symptoms or it could also reflect that the increased risk could be due to an accumulation of exposure. Findings from several studies (37,121,174) support the theoretical life course model of accumulation (49). It is also emphasised by Ben-Shlomo and colleagues that it may be more sensible to view a sensitive period model as a sub-set of an accumulation model, when considering the effects of an exposure over time (175). We did not examine whether the accumulated model could better explain the relationship between low SEP and later depressive symptoms, or if more than one life course model were apparent as suggested in other studies (49,121). A comparison between different life course models may pertain to a future study.

Our results showed that exposure to poorer family functioning or more negative life events in late childhood was associated with higher risk of depressive symptoms as observed in other studies (47,176). Our results showed, however, only small to modest effect at age 15 years between negative life events in childhood and depressive symptoms, which may be attributed to the fact that we dichotomised the variable negative life events at two and above because the majority in this cohort had experienced only one negative life event. The review by Hughes et al. presented strong evidence that individual's with at least four adverse childhood experiences had more than 3-fold the odds of mental health problems compared to individuals with no adverse childhood experiences (177). Previous research has also shown a higher effect when combining negative life events and lower SEP, as suggested in the study by Boe et al. (70).

Childhood is the period in life where the brain is highly sensitive to experiences and hence most easily influenced in positive and negative ways (37). During this time of life, experiences of social, emotional, cognitive and physical nature will shape neural systems that may influence functioning onwards. Some of the most important determinants of emotional and behavioral functioning later on in life are the home and family environment (37). With regard to a childhood and low SEP, findings from the study by Pryor and colleagues suggests that it is the fluctuating changes in household income above and below the poverty line, which may have long-term consequences for children's development and well-being (178). Children or young people who grow up in families which are characterised by low SEP due to parental low LMP, parents losing jobs or perhaps single parenthood may experience a more stressful family environment than peers from higher SEP (35,179). These low socioeconomic conditions may influence parental mental health, which may adversely affect the family environment and also increase the risk of more negative life events for the offspring (68,180). Adults, who have none or low educational attainment may likewise more

often than high educated individuals be employed in jobs with less prestige, reduced job security and increased job strain, which may increase their stress levels (179,181) which potentially can influence the family environment in a negative manner thereby perhaps trigger some stress mechanisms in the children (182). During the period of puberty, where the children may be more vulnerable (41), being exposed to environmental stressors in terms of low SEP or poor family functioning may trigger negative emotions and the possibility of depressive symptoms, especially among females (71,72). This may increase the risk of applying maladaptive coping mechanisms (68,183) in terms of, for example, smoking and alcohol, which may track over time (184) and potentially result in poor physical and mental health later on in life (128).

In Study I, we examined exposure to SEP in two different childhood periods in relation to later depressive symptoms and we made some methodological choices in the analyses. When we examined the association between childhood SEP in late childhood and depressive symptoms at age 15, 18 and 21 years we included an adjustment for the same SEP exposure in early childhood to take into account the effect of the early childhood exposure. In the associations between equivalised household income or mother's LMP in late childhood and depressive symptoms, these adjustments did not alter the estimates at all. With regard to the associations between mother's low educational level, adjustments for early childhood exposure increased the estimates at age 15 and 18 years, whereas it reduced the estimate at age 21 years. We applied the three psychosocial factors SSS, negative life events and family functioning to the late childhood exposure variables. Including adjustments for these psychosocial factors reduced the estimates of the associations between low income or mother's LMP and depressive symptoms slightly. With regard to the analyses of mother's educational level we observed that adjustments increased the estimate slightly at age 15 years and reduced the estimate slightly at age 18 years.

Overweight and obesity (Study II)

Maternal and paternal low educational level in early and late childhood was associated with a higher risk of overweight and obesity at ages 18 and 21 years in both genders, which is in line with findings from previous studies (12,122,123,185). Especially paternal educational level showed some exposure-response relationship in both genders. Children who grow up with lower educated parents may carry less social and cultural capital compared to peers from higher educated families (38). This may increase the risk of applying an unhealthy life style during adolescence which may include poorer eating habits (98), alcohol use (31) and increased sedentary behaviour (93), all potentially resulting in later overweight and obesity.

Our results also showed some gender-specific differences; hence poor family functioning was associated with higher risk of overweight and obesity among girls, not boys. These gender-specific differences are less apparent in the review by Halliday et al., where it appeared that better family

functioning was associated with increased BMI in girls (103,186). It may be that girls at 15 years of age, more often than boys, may apply maladaptive coping mechanisms involving overeating or emotional eating to deal with stress related to poor family functioning, which may increase the risk of overweight and obesity later on (28,187).

Our results showed that parental low LMP in early childhood was associated with a higher risk of overweight and obesity in boys, whereas parental low LMP in late childhood was associated with higher risk of overweight and obesity in girls. Paternal low LMP in early childhood was associated with later overweight and obesity, which is in line with findings from the review by Brisbois et al. (124), which observed that father's employment status was an early marker of adult obesity.

We cannot, however, rule out the possibility that our results, showing an association between parental LMP in early childhood and later overweight and obesity, may be mediated by parental low LMP in late childhood.

To the best of our knowledge, this is the first study to show that girls exposed to parental low LMP during late childhood showed, to some extent, higher risk of overweight and obesity in adolescence and early adulthood compared to the estimates observed in boys.

As mentioned briefly in the introduction, newer theories regarding inequality and insecurity in relation to overweight and obesity have been proposed. This perception of insecurity may be related to a person's employment status in adults, which through stress mechanisms may increase risk of later overweight and obesity (38). It is possible that children's perception of insecurity may be related to, for example, parental low LMP. Children often reflect themselves in their parents during childhood; so when boys experience their father being unemployed or having a low labour market attachment during the early childhood, this may increase a feeling of perceived social insecurity. This may over time be translated into various psychological processes that can result in possible biological consequences later in life (89). This may involve stress mechanisms, where maladaptive coping mechanisms may be related to comfort eating which eventually may increase the risk of overweight and obesity (28). These maladaptive coping mechanisms may pertain particularly to girls (187) and perhaps especially through the period of puberty, which may be an important issue to take into account when targeting preventive initiatives within overweight and obesity.

Psychosocial stressors and overweight and obesity (Study III)

Maternal low educational level was a robust risk factor for overweight and obesity at ages 15, 18, 21 and 28 years in both genders, whereas maternal low LMP was a risk factor for later overweight and obesity in boys only. For this, we have no good explanation.

Our study, to some extent, confirmed that the chosen proxies for the different domains imbedded in Hemmingsson's obesity causation model (104) may explain some of the underlying associations

between socioeconomic disadvantage and the development of overweight and obesity. In our data, it appeared that the model was primarily applicable to our cohort at ages 18—28 years when maternal educational level was the main exposure variable; hence adjustments did not influence the associations at age 15 years.

When we examined the association between maternal educational level and obesity at age 18 years, we observed that adjustments for the domains adult distress, disharmonious family environment and offspring distress attenuated the association in girls; in boys this was merely adjustments for offspring distress. In girls, it appeared that the variables parental self-rated health, family functioning and a participant's self-rated health attenuated the associations; in boys this was primarily a participant's self-rated health. It was, however, not surprising to observe gender-differences with respect to family functioning since findings from Study II showed similar results, namely that poor family functioning was associated with later overweight and obesity in girls, not boys.

When we examined the association between maternal educational level and obesity at age 21 years, we observed that adjustments increased the associations in girls, whereas in boys associations attenuated. An interesting observation in our data was that introducing the young people's own educational attainment in the analyses at age 28 years appeared to completely remove the association between maternal low educational level and obesity in boys; in girls a similar attenuation of the association was observed.

To the best of our knowledge only one other study has examined Hemmingsson's model with use of empirical data. In the study by Spinosa et al. (140), the aim was to elucidate the associations between SES, psychological distress, emotional eating, and BMI in 150 participants in the age range between 18 and 65 years in the UK (140). Findings supported components of Hemmingsson's model; hence results showed an indirect effect of SES on BMI via psychological distress and emotional eating. We applied a different statistical approach than Spinosa et al., where we included 3-step adjustments for the different domains in Hemmingsson's model. Despite the use of cross-sectional data and an older and quite small study population, their results seem to support the theoretical model by Hemmingsson, which was in line with results from our study. Our results may add further knowledge that both individual psychosocial stressors and environmental stressors may underlie the association between social disadvantage and overweight and obesity in young people when applying Hemmingsson's obesity causation model to empirical data. This may help increase focus on the importance of including psychosocial factors when initiating future preventive initiatives and research within overweight and obesity in children and young people from low SEP families. Our results support the importance of focusing on various psychosocial factors in the association between childhood social disadvantage and later overweight and obesity. It also emphasises the importance of good surveillance data in future research by including more self-reported information about for example children's self-rated health. It is, however, important to clarify that due to the chosen proxies it was difficult to

examine Hemmingsson's model in full since the proxies may not fully capture the content of the different domains. We did, for example, not have the opportunity to include information about food in the homeostasis disrupted domain.

Gender-specific differences in Studies II+III

We stratified all our analyses by gender in Study II+III. We did not apply this strategy in Study I because preliminary analyses, stratified by gender, showed similar estimates for girls and boys. In both Study II and Study III, we observed some possible gender-specific differences when the exposure variables were household income and parental labour market participation. In Study III, we observed an association between maternal LMP and overweight and obesity in boys, not girls. We also observed that parental low educational level overall asserted higher odds of later overweight and obesity in girls than in boys. In Study III, we furthermore observed that when we examined the association between maternal educational level and obesity at age 21, adjustments increased the effect of maternal low educational level in girls, whereas in boys, the association attenuated.

With regard to the issue of timing of exposure to low household income and parental low LMP in childhood (Study II), it appeared that the higher risk of later overweight and obesity in boys or young men was only observed with exposure in early childhood, whereas exposure in late childhood appeared to almost have a protective effect towards overweight and obesity.

In girls, we observed more or less the opposite, with the late childhood exposures showing an association with later overweight and obesity, whereas exposure to low household income and parental LMP in early childhood showed much more mixed results. That the timing of these exposure variables in relation to later physical health seems to be gender-specific may be of interest to public health because it appears that preventive initiatives towards social inequality in boys should be prioritised in early childhood, whereas in girls this perhaps should be prioritised in late childhood. However, since our results showed associations with very wide confidence intervals more studies using other statistical approaches are warranted to examine whether these gender-differences with regard to sensitive periods are important. In the study by Matthiessen et al. they found an increase in the prevalence of overweight among boys (aged 4-14 years), not girls which was due to an increasing social inequality in overweight among boys (106). The authors argued that public health initiatives within prevention and reducing overweight and obesity therefore should consider gender differences and target especially boys with parents of low educational level (106). Our results showed associations between parental low educational level and obesity in both genders and may therefore suggest target both genders with parents of low educational level.

With respect to the self-reported exposure variable family functioning and its association with overweight and obesity, we only observed an association in girls, not boys. It was also clear that

among girls in Study III more of the self-reported psychosocial variables at age 15 years such as poorer family functioning, higher perceived stress, depressive symptoms, poorer self-rated health and higher levels of avoidance coping were associated with later overweight and obesity. In boys, it was primarily poorer self-rated health that was associated with obesity. It appears from our data material that the risk of later overweight and obesity in girls to some extent may be more influenced by various stressors at the environmental and individual level, whereas in boys it was primarily at the individual level.

These observed gender-differences seem plausible due to the developmental age period of puberty, a period with increased peer contact and decreased parental attachment, which may have gender-specific effects (71). It appears that girls may be more vulnerable than boys during these years, and they may more often than boys resort to maladaptive coping mechanisms that may increase risk of overweight and obesity (28). It also seems that girls may be more influenced by a negative family environment during these years than boys, which may be more pronounced in low SEP families due to more stressful environments (28).

As mentioned in the background, previous studies have shown that a possible bidirectional relation between depressive symptoms and obesity exists, which also may be gender-specific. To further explore this possible bidirectional relationship, some unadjusted analyses between the two outcomes were carried out. Results showed a possible bidirectional relation between the two outcomes over time among girls, and this was most pronounced in the years from 15 to 21 years. Similar results were not found in these associations among boys (results not shown).

Findings from our three studies overall confirm the consistent association between low SEP in childhood and higher risk of depressive symptoms and obesity among children and young people.

Childhood and adolescence are sensitive periods in children and young people's life due to the different developmental phases, the environment where they are living and also when facing increasing demands from schools and society which may explain the increasing stress levels. Our results regarding exposure to low SEP/ social adversity in early or late childhood and later depressive symptoms, overweight and obesity showed associations at different ages depending of the exposure variables in Study I+II which may imply that the timing of exposure in childhood could be of relevance. However, our results should be interpreted with caution due to small estimates and estimates with wide confidence intervals. Findings from Study I showed that including the psychosocial factors to the late childhood exposures revealed a quite consistent association between poor family functioning and depressive symptoms. It also showed that the relationships between these psychosocial variables may be more complex than our statistical analyses took into account.

In this thesis, the focus was primarily on the timing model as a theoretical framework to try to understand the associations between childhood SEP/ social adversity and later mental and

physical health problems within a life course perspective. Our findings from Study I+II may show a tendency that applying this heuristic model could be a reasonable way of examining these associations in a Danish context.

With our three studies we have tried to further disentangle the associations between childhood SEP/ social adversity and later mental and physical health problems. We believe that our results contribute with further knowledge to the area of social inequality in mental and physical health problems among young people; by the use of a prospective study design and applying register-based information on SEP exposures from the entire childhood instead of only one time point, supplemented with psychosocial exposure variables. Our results from Study III may add further knowledge with regard to applying Hemmingsson's obesity causation model to empirical data and shed light upon the importance of focusing on psychosocial factors in the association between socioeconomic disadvantage and obesity.

Methodological considerations

Bias in cohort studies

One of the main concerns to acknowledge in observational studies is the risk of bias, which may be due to selection, information errors or confounding. In the following sections a discussion on how these different types of bias may have affected our results will be carried out.

Selection bias

The process of selecting participants for a study and factors which may influence participants' interest to participate may cause selection bias (188,189). Á priori, there were concerns regarding selection due to initial non-participation and loss to follow-up in the study. However, as observed in Table 3, which is presented in the methods section, the initial response rate in 2004 was 83%; this did however decline in the later waves (65% in 2007, 58 and 57% in 2010 and 2017, respectively). In the embedded papers, it is also possible to see flow charts for each of the three studies which display the different study samples according to attrition, missing information on the outcome of interest, and author exclusions.

Individuals, who decide to participate in studies, may have a different disease risk compared to non-participants, since they tend to be more healthy and affluent (188,189).

There were 627 individuals who decided not to participate in the initial questionnaire in 2004. There was significant difference between responders and non-responders in 2004 with respect to SEP in childhood; however, since we did not have any information from non-responders on the outcomes in any of the studies, it is impossible to conclude whether this selection was also associated with the risk of depressive symptoms/ obesity. A previous study in the same cohort

examined the potential bias on other outcomes due to non-participation and drop-outs. Their findings indicate that differential selection due to initial non-participation was not a problem (190). In longitudinal studies which examine social inequality based on socioeconomic status, a considerably attrition may result in biased estimates of socioeconomic inequalities, which, depending of the size of attrition and the mechanisms behind, may worsen as participation rates decline (191). As it can be seen in the tables showing the main results, we operated with different numbers of participants at each wave. It is likely that attrition was highest in individuals with the lowest SEP. However, to bias our estimates, such attrition should also be associated with the outcomes, for instance that individuals, that were both of low SEP and depressed/ obese, were more likely not to participate, than those of low SEP that were not depressed/ obese. In the previous study just mentioned, the potential bias due to attrition was also examined in the same cohort (190). The authors did not find any significant influence on the relative risks associations measured, which we find reassuring for the results in our three studies. However, if some differential selection was present, one might speculate that it would likely attenuate the associations between SEP and depressive symptoms/ obesity. Regrettably, we do not have data on non-participants to examine this. We carried out a sensitivity analysis in Study I using a multiple imputation chained model with 100 imputations. This analysis showed only small deviations of the estimates in both directions. However, the assumptions of missing at random may not be fulfilled with the model as we do not know the mechanisms behind loss to follow-up in this study, which may be related to unmeasured factors not included in the imputation model.

Information bias

One of the main considerations when applying self-reported information in research studies is the risk of information bias which may occur if there is a systematic error in the information about or from the participants included in a study. When information bias is discussed, this can be either differential or non-differential and may also be a result of random measurement error (189). When the term differential misclassification is referred to, this means that the systematic error on the exposure or the outcome variable occurs more often in one group than in the other group(s) and this increases the risk of over- or underestimating a potential association (189). With respect to non-differential misclassification this causes the same error in all study groups and produces estimates which are mainly biased towards the null hypothesis (188,189).

In this PhD thesis, information bias occurred most likely as a consequence of self-reported information which we used for both exposure and outcome variables in all three studies.

Applying register information may also result in information bias because the quality of data used for research depends fundamentally on the purpose of the register, the way the collection was done, and the coverage. It is, however, most likely that any misclassification may be non-differential in nature (189).

In the next section, a discussion regarding possible sources and reasons for misclassification of exposure or outcome and to what extent this may be classified as differential or non-differential, will be carried out.

One of the main considerations of all three studies was to which degree the chosen exposure variables were correlated. We carried out correlation analyses which showed small to moderate correlation between the socioeconomic exposure variables (See Appendix in Paper II).

Misclassification of exposure

Register data

Because (equivalised) household income and educational level of the parents were obtained from registers, none or limited information bias was expected on these exposure variables, and if any it would most likely be non-differential (189). Information about parental labour market participation was obtained from the DREAM register, which is based on administrative data on transfer income. The register is as such not designed for use in research; however, it has been validated in previous studies and showed high validity (147,192). A potential problem with the register is related to the registration of sick leave, because only sick leave longer than 2—3 weeks is registered and this also depends on whether the employer claims reimbursement for the employee. This could also potentially result in non-differential misclassification and bias towards the null-hypothesis.

We wanted to examine the timing of exposure to socioeconomic factors in childhood in relation to mental health and overweight/obesity in Studies I+II.

With respect to the construct of the variables (equivalised) household income and labour market participation of the parents, we calculated these exposure variables as mean values across each of two age periods instead of a mean across the entire childhood period. We made this decision inspired by previous research (157) and because we thought it of public health interest to disentangle whether exposure to SEP in one period of childhood differed from another period in relation to later mental and physical health.

We applied two different types of household income in the three studies. It would, however, have been more correct to include only information on equivalised household income in studies which examine inequality in health in societies with a low grade of income inequality. We did, however, first become aware of this income variable after submitting Paper II.

Questionnaire data

Information about family functioning, SSS and negative life events was obtained from the baseline questionnaire when the participants were 15 years of age.

In Study I, we observed that the associations between subjective social status and depressive symptoms completely disappeared when adjusting for family functioning. This may be attributed to the fact that family functioning and SSS were measured in the same questionnaire, leaving the possibility that answers regarding family functioning may also reflect the answers regarding subjective social status. Another explanation may be that the association between SSS and depressive symptoms were mediated by family functioning (68).

Misclassification of outcome

The main outcome variables in the three studies in terms of depressive symptoms and overweight and obesity categorized by BMI were based on self-reported information from the participants at ages 15, 18, 21 and 28 years.

In Study I, we applied information on young people's own perception of their mental health state during the past week. It seems unlikely that participants should systematically over- or underestimate their mental health state. Since the participants were unaware of the exposure variables in this study, it would seem reasonable to conclude that misclassification regarding the outcome may be non-differential and bias the estimates towards the null-hypothesis. However, previous research has shown that growing up in lower SEP families may influence children's academic achievements negatively (193), which may influence lower SEP children's ability to interpret questions in surveys as compared to children from higher SEP families. This might introduce some differential misclassification that may bias the estimates in both directions.

In Study I, the abbreviated version of the CES-D scale for children, primarily validated to the use for children aged 12—18 years was applied. We decided to dichotomise the scale at a cut-off of 3 and above reflecting depressive symptoms, as recommended by Fendrich et al. (151) to facilitate comprehensibility of results. This, however, results in loss of information (189) and eliminates the possibility of detecting nuances. The proportions of children and young people with symptoms of depression were quite high, especially at the age of 18 years; however, this has also been observed in other studies using the same scale (65,194). It has been argued that shorter versions of the CES-D scale in adults have a tendency to classify, for example, patients with multiple chronic health complaints as depressed (150). We applied a cut-off value for the CES-DC scale which was originally based on an American sample nearly 30 years ago, which may not be applicable to a Danish youth cohort. We therefore carried out a sensitivity analysis with the cut-off set at the 90th percentile. This showed similar or stronger estimates (results not shown), which we find reassuring with regard to the results in our study.

In Studies II+III, the outcome variable of interest was overweight and obesity. BMI was calculated from participants' self-report of height and weight. Applying self-reported information on weight and height in epidemiologic studies is prone to errors (152). Another issue is that there among adolescents may be a large diversity in how often they measure themselves, which may influence

the accuracy even further (195,196). Previous research has documented that especially overweight girls tend to underestimate their weight in surveys (152,197). This might lead to pollution by obese individuals in the non-obese categories and make it harder to identify differences, in its simplest form to non-differential misclassification. We do not know, however, if the degree of underreport of weight depends on SEP, but it may be possible that individuals of lower SEP do not seek information about their overweight problem to the same degree as those of higher SEP, and if such problems exist, some differential misclassification might be present. Applying self-reported BMI does, however, provide a reliable proxy measure among adolescents when direct measurements are not possible (198).

We excluded women from analyses in Study III if they were more than 3 months pregnant when they completed the questionnaire due to a temporally higher BMI. This resulted in exclusions of 64 women at age 28 years; however there were also 13 women aged 21 years who were excluded. We did not exclude these 13 women in Study II where the outcome also was BMI because we did not have the information from the Danish Medical Birth Register for these analyses at that point of time. This may have resulted in an overestimation of the associations between the exposure and the outcome at age 21 years because pregnancies at this age may occur more often among young girls from low SEP (199).

Temporal relation

To be able to determine a possible causal relationship in observational studies it is important that information on the exposure variable is obtained prior to and independent of the outcome. We applied a prospective design in all three studies because our main exposure variables were based on register information when the participants were children and collected prior to the measurement of the main outcomes.

We did, however, also apply self-reported information on both exposure and outcome variables obtained from the 2004 questionnaire in all three studies. Results reflecting the associations between exposure and outcome variables measured at the same time are cross-sectional and determining a causal relationship is therefore difficult (200), however, we cannot rule out that a potential association may show a causal relationship. There is also the possibility that results may have risen from reverse causality; that is: if participants were depressed at the time they completed the baseline questionnaire, this may have influenced answers on the variables family functioning, SSS and negative life events. Since we applied these exposure variables in relation to the outcome at ages 15, 18 and 21 years, it is possible that the observed associations could reflect this instead.

Follow-up time

The primary analyses in this thesis were based on register and questionnaire data from birth (1989) until the 4th follow-up in 2017, in total 28 years.

In Study I we examined depressive symptoms at age 15, 18 and 21 years. It is possible that the risk of the outcome may have changed during follow-up. We did not adjust for the mental health at baseline when we examined the outcome at age 18 and 21 years, because we were concerned that an adjustment might be an over-adjustment, since baseline mental health could be an intermediate factor. We carried out supplementary analyses to examine whether adjustment for baseline mental health would change our findings. Both for the associations between SEP in early or late childhood and depressive symptoms at age 18 or 21 years, this did not change our estimates at all (results not shown). As previously noted in the background, several studies have shown a relationship between mental health problems and obesity. We did not include adjustments for mental health when we examined the association between childhood SEP and overweight and obesity in Study II, and this may have influenced our results. We did, however, carry out supplementary adjusting for mental health. This did not show any clear pattern and did not alter the results much (results not shown).

In Study II, we examined overweight and obesity as the outcome at ages 15, 18 and 21 years and it may be argued whether these 6 years of follow-up between the first and the third questionnaire are sufficient to investigate overweight and obesity as an outcome in a healthy active population of young people. We did have to apply additional BMI limits (153) for obesity due to relatively few young people with a BMI>30. This may be regarded a power problem, and it would have been more optimal with a larger population with a higher prevalence of obesity and with a longer follow-up to examine the associations between childhood SEP and obesity.

The fourth follow-up was carried out when the participants were 28 years of age. It is possible that the causes of overweight and obesity may have changed at this last follow-up due to competing factors such as stressful events like becoming parents or unemployment.

We did not examine changes in the outcomes between each survey waves, which would have allowed us to fully integrate the longitudinal information in the data material. We will in future studies attempt to integrate as much longitudinal information as possible when examining the mental health and obesity in this cohort, which seems especially important when the participants are now adults with own SEP and family.

Statistical issues

We made mutual adjustments for other socioeconomic exposures in Studies I—III because we sought to observe the independent effect of each socioeconomic factor in relation to the outcome. We assumed in Study III that there was no interaction between the socioeconomic variables and the other included proxy variables.

In the paper by Cohen and colleagues, it is recommended that studies which examine the timing of exposure to childhood lower SES and health outcomes in adulthood should include adjustments for adult SES (49). We did not include adjustments for adult SEP in Studies I+II, and this decision was taken because it is common for young Danish people aged 21 years to still be living at home with parents or to receive financial support during studies. We did, however, adjust for the young people's own educational attainment in Study III.

When examining social inequality and mental health problems in children and young people, it is recommended to include the mental health state of the parents. Previous research has shown that mental problems in the parents is a strong risk factor for mental health problems in the offspring (62) and mental health problems is more common among parents with low SEP (68). We did not include this information in Study I due to incomplete data related to parental mental health, and this may have influenced our findings. It is possible that the observed associations between low SEP in childhood and later depressive symptoms may reflect this. We carried out a supplementary analysis where we applied parental self-rated health as a proxy for parental mental health. Results showed that some estimates increased slightly, especially when we examined the associations between mother's educational level and depressive symptoms, whereas others did not show a clear pattern in the associations.

Confounding

A confounder is defined by three things. The confounding factor must be associated with both the exposure and the outcome. The confounding factor has to be unequal distributed among the groups compared and not a part of the causal pathway from the exposure to the outcome (189).

We made mutual adjustments for the other socioeconomic variables in each of the three studies to show the independent effect of each variable in relation to the outcome; however, it is possible that other unmeasured factors may have influenced our findings. We did, for example, not have the opportunity to include information about food intake in Study II+III. In Study II, we made adjustments for split-home to take into account the effect of single parenthood with respect to a lower household income. We did not adjust for this in Study I and Study III, which may have influenced our results. We did, however, carry out some supplementary analyses to examine whether our results were biased due to the lack of this adjustment. Our results did not change after the adjustment for split-home (results not shown).

We stratified our analyses on gender in Study II and Study III because there can be large differences between genders with respect to BMI during adolescence. We did not apply this approach in Study I, where we adjusted for gender instead.

Generalisability

This cohort of young Danish people was born in the western part of Denmark in 1989. The participants were approximately 15 years of age when the cohort was established in 2004 and it was a quite active, healthy and homogenous cohort. In a previous study on the Vestliv cohort, the authors concluded that the members of this youth cohort are similar to young people in other parts of Denmark with regard to, for example, average household income (163). The main exposure variables in this thesis were obtained from registers and with respect to the outcomes we applied conventional cut-points for BMI thresholds and a recommended cut-off for depressive symptoms. The proportions of young people presenting with depressive symptoms in this cohort were similar to findings from other study populations who applied the same depression scale (65,194).

Denmark is quite similar to other Nordic countries and countries like Holland and Canada in terms of health patterns and socioeconomic health gradients (201). The results presented in this PhD thesis may therefore be transferred to young people and young adults who live in social and environmental conditions similar to this Danish cohort, taking the aforementioned limitations into account.

7. Conclusion

Results from this PhD thesis showed that lower SEP and psychosocial factors in childhood were associated with higher risks of depressive symptoms and overweight and obesity in adolescence and early adulthood. Our findings showed that the timing of low SEP in early and late childhood seemed to be of some importance in relation to both mental health and overweight and obesity and to some degree be gender-specific. Results showed in particular that the late childhood exposures, to some degree, were associated with higher risk of overweight/ obesity in girls whereas some of the early childhood exposures seemed to be associated with higher risk of overweight/ obesity in boys. It should, however, be further examined in future studies whether our results reflect sensitive periods, an accumulation of exposures or perhaps a combination when applying a life course perspective.

Parental educational level was a risk factor for both later mental health problems and overweight and obesity in this cohort. Parental lower educational level was associated with higher risks of overweight and obesity in both genders in Study II, and this exposure variable in terms of maternal educational level was also by far the strongest and most consistent risk factor observed in Study III. Study III confirmed to some extent that the robust association between socioeconomic disadvantage and later overweight and obesity could be explained by including the domains from Hemmingsson's obesity causation model. Results from this thesis should, however, be interpreted with some caution due to the risk of selection bias due to attrition and information bias related to self-reported information.

8. Perspectives and future research

Growing up in families which are characterised by fewer resources related to low SEP may constitute an increased risk of mental health problems and overweight and obesity in adolescence and early adulthood. It is important to face the fact that many children and young people from low SEP report poorer mental health and higher levels of stress compared to their peers from higher SEP. Children and young people from low SEP may more often than their peers from higher SEP experience a stressful family environment, which increases the risk of applying maladaptive coping mechanisms and unhealthy habits. It is therefore important to address increased attention to these vulnerable families to decrease the risk of mental health problems related to social inequality.

It is important to facilitate the educational attainment of young people in general because of the value and the different forms of capital a person may gain during education. As observed in this thesis, children and young people who grow up with lower educated parents have a considerably higher risk of overweight and obesity, compared to children and young people with higher educated parents. However, it appeared that the educational attainment of the participants' to some extent mitigated the association. This is of great political interest because it emphasises the importance of increased support to young Danish people from lower socioeconomic families to obtain an education to prevent overweight and obesity. It also seems very relevant due to the fact that especially young people from lower educated families more often than their peers from higher educated families end up with a lower educational attainment (39).

Another very important issue to address is the fact that society has to reduce the stigmatising behaviour towards overweight and obese children and young people. Living in a society where slim bodies and body awareness are an important daily part of young people's lives due to media such as Instagram, YouTube and Facebook, where people expose themselves, making obese people feel stigmatised and shameful about their body.

With regard to preventive and intervention initiatives aimed at reducing weight in children and young people, it seems important to focus on a multifaceted strategy involving the entire family due to the complexity of obesity and importance of evaluating the long-term effect of these interventions.

In future studies examining social inequality in relation to mental health and overweight it seems important to address more attention to children and young peoples self-report of psychosocial stressors since this information may carry great value (75). In the Vestliv cohort, it is also important to examine the effect of, for example, income mobility in relation to later health, as suggested in a change model (49). If a person grows up in low SEP during childhood and during adulthood increases his own SEP, does this mitigate his/her risk of mental and physical health problems? This is an area of research which needs further attention in a Danish context.

9. English summary

Background

Growing up in families characterised by social inequality due to parental low SEP may increase young peoples' risk of mental health problems and overweight later on. The timing of childhood exposure to a low SEP may be of relevance in relation to future mental health and overweight.

Aim

The aim of this PhD thesis was to examine the associations between socioeconomic and psychosocial factors in early and late childhood and depressive symptoms and overweight/obesity in adolescence and early adulthood. Furthermore, the aim was to examine the association between socioeconomic disadvantages and overweight/obesity in young people using Hemmingsson's obesity causation model.

Material and methods

Questionnaire- and register-based information from project Vestliv was applied. Vestliv is an on-going Danish longitudinal cohort study of young people aged 15 years living in Western Jutland in 2004 (N=3,681). Questionnaire information was obtained from surveys carried out in the years 2004, 2007, 2010 and 2017. Information on parental socioeconomic position was obtained from various registers. Outcome variables were depressive symptoms measured by the Center for Epidemiologic Studies Depression Scale for Children and overweight and obesity calculated from the participants' height and weight. Exposure variables were household income, educational level and labour market participation (LMP) of the parents, supplemented with participants' report of family functioning, negative life events and subjective social status (2004).

Results

Study I:

Early childhood: Being exposed to maternal low LMP was associated with higher risk of depressive symptoms at age 15, while exposure to maternal low educational level and equivalised household income was associated with higher risk of depressive symptoms at age 21 years. **Late childhood:** Being exposed to low equivalised household income, maternal low level of education and low LMP was associated with higher risk of depressive symptoms at ages 15 and 21 years. Poor family functioning was associated with higher the risk of depressive symptoms at ages 15, 18 and 21. Two

or more negative life-events was associated with higher risk of depressive symptoms at ages 15 and 18.

Study II:

Early childhood: Low educational level of parents was associated with higher risk of girls being overweight and obese with up to 5-fold at ages 18 and 21 years. Poor family functioning was associated with higher risk of girls being overweight and obese by 2-fold at age 21 years. Being exposed to low parental LMP was associated with more than 2-fold higher risk of boys being obese at ages 18 and 21 years. Being exposed to paternal low educational level was associated with up to 2.4-fold higher risk of boys being obese at age 21 years. **Late childhood:** Low educational level of parents was associated with up to 3-fold higher risk of overweight and obesity at age 18 years (girls) and age 21 years (both genders).

Study III:

Maternal low educational level was associated with 3-fold higher odds of obesity in girls aged 18 years, which attenuated after adjustments for the domains: adult distress, disharmonious family environment and offspring distress. A more than 2.5-fold higher odds of obesity was observed in women aged 28 years which attenuated considerably in the fully adjusted model. Boys had between 3- and 4-fold higher odds of obesity at ages 18 and 21 years, which attenuated after adjustments. A more than 3-fold higher odds of obesity was observed in men aged 28 years, which vanished in the fully adjusted model.

Conclusion

This PhD thesis showed that children and young people who grow up in low SEP families have higher risk of depressive symptoms and overweight and obesity in adolescence and early adulthood. Especially parental low level of education was associated with overweight and obesity in the offspring with an up to 5-fold higher risk of overweight and obesity at ages 18 and 21 years. Poor family functioning was a risk factor for later mental health problems and for overweight and obesity in girls. Results from Study III confirmed to some extent that including the domains from Hemmingsson's model could disentangle the association between socioeconomic disadvantage and obesity.

10. Dansk resume

Baggrund

En barndom præget af social ulighed på grund af forældrenes lavere socioøkonomiske position kan øge unges risiko for mentale helbredsproblemer og overvægt senere i livet. Timing af den lav socioøkonomisk eksponering i barndommen kan være relevant i forhold til fremtidigt mentalt helbred og overvægt.

Formål

Formålet med denne ph.d.- afhandling var at undersøge sammenhænge mellem socioøkonomiske og psykosociale faktorer i tidlig og sen barndom og depressive symptomer og overvægt/fedme i ungdomsårene og tidlig voksenalder. Formålet var desuden at undersøge sammenhængen mellem socioøkonomiske ulemper og overvægt/fedme hos unge ved hjælp af Hemmingssons *obesity causation model*.

Materiale og metoder

Spørgeskema- og registerbaseret information fra projekt Vestliv blev anvendt. Vestliv er et igangværende dansk longitudinelt kohorte studie af unge i 15 års alderen, der boede i Vestjylland i 2004 (N=3.681). Spørgeskema oplysninger blev indhentet i årene 2004, 2007, 2010 og 2017. Oplysninger om forældrenes socioøkonomiske position blev indhentet fra forskellige registre. Udfaldsvariable var depressive symptomer målt ved hjælp af *Center for Epidemiologic Studies Depression Scale* for børn og overvægt og fedme beregnet fra deltagernes højde og vægt. Eksponeringsvariable var husstandsindkomst, forældrenes uddannelsesniveau og arbejdsmarkedstilknytning (LMP), suppleret med deltagernes selvrapportering af familiens funktion, negative livs begivenheder og subjektiv social status (2004).

Resultater

Studie I:

Tidlig barndom: Moderens lave LMP var associeret med en højere risiko for at unge havde depressive symptomer i 15 års alderen, mens moderens lave uddannelsesniveau og en lav ækvivaleret husstandsindkomst var associeret med en højere risiko for at unge voksne havde depressive symptomer i 21 års alderen. **Sen barndom:** Lav ækvivaleret husstandsindkomst, moderens lavere uddannelsesniveau og en lav arbejdsmarkedstilknytning var associeret med en højere risiko for at unge havde depressive symptomer i 15- og 21 års alderen. Rapportering af

dårlig familie funktion var associeret med en højere risiko for at unge havde depressive symptomer i 15-, 18- og 21 års alderen. To eller flere negative livs begivenheder var associeret med en højere risiko for at unge havde havde depressive symptomer i 15- og 18 års alderen.

Studie II:

Tidlig barndom: Forældres lave uddannelseniveau var associeret med en op til 5 gange højere risiko for overvægt og fedme blandt piger i 18- og 21 års alderen. Rapportering af dårlig familie funktion var associeret med en op til 2 gange højere risiko for overvægt og fedme blandt 21 årige piger. Forældrenes lave arbejdsmarkedstilknytning var associeret med en mere en 2 gange højere risiko for fedme blandt drenge i 18- og 21 års alderen. Faderens lave uddannelsesniveau var associeret med op til 2,4 gange højere risiko for fedme i 21 års alderen hos drenge. **Sen barndom:** Forældrenes lavere uddannelsesniveau var associeret med en op til 3 gange højere risiko for overvægt og fedme ved 18 år (piger) og 21 år (begge køn).

Studie III:

Moderens lave uddannelsesniveau var associeret med 3 gange højere odds for fedme hos piger i 18 års alderen, hvilket svækkedes efter justeringer for domænerne: bekymring hos voksne, disharmonisk familie miljø og bekymring hos børn. Der blev observeret en mere end 2,5 gange højere odds for fedme hos kvinder i 28 års alderen, hvilket svækkedes betydeligt i den fuldt justerede model. Drengene havde mellem 3-4 gange højere odds for fedme i 18- og 21 års alderen, hvilket svækkedes efter justeringer. En mere end 3 gange højere odds for fedme blev observeret hos mænd i 28 års alderen, som forsvandt i den fuldt justerede model.

Konklusion

Denne ph.d.-afhandling viste at børn og unge, der vokser op i lavere socioøkonomiske familier har højere risiko for depressive symptomer og overvægt/fedme i ungdomsårene og tidlig voksenalder, sammenlignet med jævnaldrende som kommer fra højere socioøkonomiske familier. Specielt forældrenes lave uddannelsesniveau var associeret med overvægt og fedme hos børn og unge med op til 5 gange højere risiko i 18- og 21 års alderen. Dårlig familie funktion var en risiko faktor for senere mentale helbredsproblemer, samt overvægt og fedme hos piger. Resultaterne fra vores 3 studie bekræftede til en vis grad, at domænerne fra Hemmingssons model kunne forklare sammenhængen mellem socioøkonomisk ulempe og fedme.

11. Appendices

Appendix I.

Literature search on childhood socioeconomic position/ social adversity and mental health.

((((((((((((((((((((((((((social class[MeSH Terms]) OR socioeconomic factors[MeSH Terms]) OR socio-economic factors[Text Word]) OR socioeconomic status[Text Word]) OR socio-economic status[Text Word]) OR socioeconomic position[Text Word]) OR socio-economic position[Text Word]) OR socioeconomic disparit*[Text Word]) OR socio-economic disparit*[Text Word]) OR socioeconomic adversit*[Text Word]) OR socio-economic adversit*[Text Word]) OR socioeconomic inequalit*[Text Word]) OR socio-economic inequalit*[Text Word]) OR socioeconomic insecurit*[Text Word]) OR socio-economic insecurit*[Text Word]) OR social status[Text Word]) OR social inequalit*[Text Word]) OR life course[tw] OR lifecourse[tw]) OR lifespan[tw]) OR life span[tw]) OR early-life[tw]) OR early life[tw]) OR timing[tw] OR social pathway[tw])))) AND childhood[Text Word])) AND (((((mental health[MeSH Terms]) OR depressive symptoms[Text Word]) OR depression[MeSH Terms])) OR mental health[Text Word]))))

((((((((("family health"[MeSH Terms]) OR family func*[Text Word])) OR subjective social status[Text Word]) OR ((((life event*[Text Word]) OR negative life event*[Text Word])) OR adverse life event*[Text Word])))) AND childhood[Text Word])) AND (("Mental Health"[Mesh]) OR mental health[Text Word] OR "Depression"[Mesh] OR depressive symptoms[tw])))

Appendix II.

Literature search on childhood socioeconomic position and overweight/obesity.

((((((((((((((((((((((((((((((social class[MeSH Terms]) OR socioeconomic factors[MeSH Terms]) OR socio-economic factors[Text Word]) OR socioeconomic status[Text Word]) OR socio-economic status[Text Word]) OR socioeconomic position[Text Word]) OR socio-economic position[Text Word]) OR socioeconomic disparit*[Text Word]) OR socio-economic disparit*[Text Word]) OR socioeconomic adversit*[Text Word]) OR socio-economic adversit*[Text Word]) OR socioeconomic inequalit*[Text Word]) OR socio-economic inequalit*[Text Word]) OR socioeconomic insecurit*[Text Word]) OR socio-economic insecurit*[Text Word]) OR social status[Text Word]) OR social inequalit*[Text Word]) OR life course[tw] OR lifecourse[tw]) OR lifespan[tw]) OR early-life[tw]) OR early life[tw]) OR life span[tw]) OR timing[tw] OR social pathway[tw])))) AND ((((((((overweight[MeSH Terms]) OR obesity[MeSH Terms]) OR body mass index[MeSH Terms]) OR adiposity[MeSH Terms]) OR obesity[Text Word]) OR body mass index[Text Word]) OR overweight[Text Word]))))) AND childhood[Text Word])))))))

(((((((((("family health"[MeSH Terms]) OR family func*[Text Word])) OR subjective social status[Text Word]) OR ((((life event*[Text Word]) OR negative life event*[Text Word])) OR adverse life event*[Text Word])))) AND childhood[Text Word])) AND ((obesity OR overweight OR body mass index[tw])))

12. References

(1) Marmot M, Allen J, Bell R, Bloomer E, Goldblatt P, Consortium for the European Review of Social Determinants of Health and the Health Divide. WHO European review of social determinants of health and the health divide. Lancet 2012 Sep 15;380(9846):1011-1029.

(2) Allen J, Balfour R, Bell R, Marmot M. Social determinants of mental health. Int Rev Psychiatry 2014 Aug;26(4):392-407.

(3) Marmot M, Bell R. Social inequalities in health: a proper concern of epidemiology. Ann Epidemiol 2016 Apr;26(4):238-240.

(4) Wilkinson R, Marmot M. Social determinants of health: the solid facts. 2nd edition. 2003.

(5) Ullits LR, Ejlskov L, Mortensen RN, Hansen SM, Kraemer SR, Vardinghus-Nielsen H, et al. Socioeconomic inequality and mortality--a regional Danish cohort study. BMC Public Health 2015 May 14;15:490-015-1813-3.

(6) Fryers T, Melzer D, Jenkins R. Social inequalities and the common mental disorders: a systematic review of the evidence. Soc Psychiatry Psychiatr Epidemiol 2003 May;38(5):229-237.

(7) de Mestral C, Stringhini S. Socioeconomic Status and Cardiovascular Disease: an Update. Curr Cardiol Rep 2017 Sep 30;19(11):115-017-0917-z.

(8) Ribeiro WS, Bauer A, Andrade MCR, York-Smith M, Pan PM, Pingani L, et al. Income inequality and mental illness-related morbidity and resilience: a systematic review and meta-analysis. Lancet Psychiatry 2017 Jul;4(7):554-562.

(9) Mackenbach JP, Stirbu I, Roskam AJ, Schaap MM, Menvielle G, Leinsalu M, et al. Socioeconomic inequalities in health in 22 European countries. N Engl J Med 2008 Jun 5;358(23):2468-2481.

(10) Thevenot C. Inequality in OECD countries. Scand J Public Health 2017 Aug;45(18_suppl):9-16.

(11) Due P, Diderichsen F, Meilstrup C, Nordentoft M, Obel C, Sandbæk A. Børn og unges mentale helbred. Forekomst af psykiske symptomer og lidelser og mulige forebyggelsesindsatser. 2014.

(12) Magnusson M, Sorensen TI, Olafsdottir S, Lehtinen-Jacks S, Holmen TL, Heitmann BL, et al. Social Inequalities in Obesity Persist in the Nordic Region Despite Its Relative Affluence and Equity. Curr Obes Rep 2014 Jan 7;3:1-15.

(13) Rosendahl Jensen HA, Davidsen M, Ekholm O, Christensen AI. The Danish National Health Profile 2017. 2018 March 6.

(14) Diderichsen F, Andersen I, Manuel C, Working Group of Danish Review on Social Determinants of Health, Andersen AM, Bach E, et al. Health inequality--determinants and policies. Scand J Public Health 2012 Nov;40(8 Suppl):12-105.

(15) Torsheim T, Nygren JM, Rasmussen M, Arnarsson AM, Bendtsen P, Schnohr CW, et al. Social inequalities in self-rated health: A comparative cross-national study among 32,560 Nordic adolescents. Scand J Public Health 2018 Feb;46(1):150-156.

(16) Vallgarda S. Public health policies: a Scandinavian model? Scand J Public Health 2007;35(2):205-211.

(17) Viner RM, Ozer EM, Denny S, Marmot M, Resnick M, Fatusi A, et al. Adolescence and the social determinants of health. Lancet 2012 Apr 28;379(9826):1641-1652.

(18) Mackenbach JP. The persistence of health inequalities in modern welfare states: the explanation of a paradox. Soc Sci Med 2012 Aug;75(4):761-769.

(19) Mackenbach JP. Nordic paradox, Southern miracle, Eastern disaster: persistence of inequalities in mortality in Europe. Eur J Public Health 2017 Oct 1;27(suppl_4):14-17.

(20) Arcaya MC, Arcaya AL, Subramanian SV. Inequalities in health: definitions, concepts, and theories. Glob Health Action 2015 Jun 24;8:27106.

(21) Kawachi I, Subramanian SV, Almeida-Filho N. A glossary for health inequalities. J Epidemiol Community Health 2002 Sep;56(9):647-652.

(22) Diderichsen F, Andersen I, Manuel C, Working Group of Danish Review on Social Determinants of Health, Andersen AM, Bach E, et al. Health Inequality--determinants and policies. Summary. Scand J Public Health 2012 Nov;40(8 Suppl):6-8.

(23) Galobardes B, Shaw M, Lawlor DA, Lynch JW, Davey Smith G. Indicators of socioeconomic position (part 1). J Epidemiol Community Health 2006 Jan;60(1):7-12.

(24) Matthews KA, Gallo LC. Psychological perspectives on pathways linking socioeconomic status and physical health. Annu Rev Psychol 2011;62:501-530.

(25) Liu RT. Childhood Adversities and Depression in Adulthood: Current Findings and Future Directions. Clin Psychol (New York) 2017 Jun;24(2):140-153.

(26) Mersky JP, Janczewski CE, Topitzes J. Rethinking the Measurement of Adversity. Child Maltreat 2017 Feb;22(1):58-68.

(27) Shonkoff JP, Garner AS, Committee on Psychosocial Aspects of Child and Family Health, Committee on Early Childhood, Adoption, and Dependent Care, Section on Developmental and Behavioral Pediatrics. The lifelong effects of early childhood adversity and toxic stress. Pediatrics 2012 Jan;129(1):e232-46.

(28) Jang M, Owen B, Lauver DR. Different types of parental stress and childhood obesity: A systematic review of observational studies. Obes Rev 2019 Dec;20(12):1740-1758.

(29) Galobardes B, Lynch JW, Smith GD. Is the association between childhood socioeconomic circumstances and cause-specific mortality established? Update of a systematic review. J Epidemiol Community Health 2008 May;62(5):387-390.

(30) Elhakeem A, Cooper R, Bann D, Hardy R. Childhood socioeconomic position and adult leisure-time physical activity: a systematic review. Int J Behav Nutr Phys Act 2015 Jul 3;12:92-015-0250-0.

(31) Wiles NJ, Lingford-Hughes A, Daniel J, Hickman M, Farrell M, Macleod J, et al. Socio-economic status in childhood and later alcohol use: a systematic review. Addiction 2007 Oct;102(10):1546-1563.

(32) Vohra J, Marmot MG, Bauld L, Hiatt RA. Socioeconomic position in childhood and cancer in adulthood: a rapid-review. J Epidemiol Community Health 2016 Jun;70(6):629-634.

(33) Melotti R, Heron J, Hickman M, Macleod J, Araya R, Lewis G, et al. Adolescent alcohol and tobacco use and early socioeconomic position: the ALSPAC birth cohort. Pediatrics 2011 Apr;127(4):e948-55.

(34) Poonawalla IB, Kendzor DE, Owen MT, Caughy MO. Family income trajectory during childhood is associated with adolescent cigarette smoking and alcohol use. Addict Behav 2014 Oct;39(10):1383-1388.

(35) Wirback T, Moller J, Larsson JO, Galanti MR, Engstrom K. Social factors in childhood and risk of depressive symptoms among adolescents--a longitudinal study in Stockholm, Sweden. Int J Equity Health 2014 Nov 11;13:96-014-0096-0.

(36) Amone-P'Olak K, Burger H, Ormel J, Huisman M, Verhulst FC, Oldehinkel AJ. Socioeconomic position and mental health problems in pre- and early-adolescents: the TRAILS study. Soc Psychiatry Psychiatr Epidemiol 2009 Mar;44(3):231-238.

(37) Bjorkenstam E, Pebley AR, Burstrom B, Kosidou K. Childhood social adversity and risk of depressive symptoms in adolescence in a US national sample. J Affect Disord 2017 Apr 1;212:56-63.

(38) Ulijaszek SJ. Inequalities. Models of Obesity
From Ecology to Complexity in Science and Policy. 1st ed. United Kingdom: Cambridge University Press; 2017. p. 71-93.

(39) Tverborgvik T, Clausen LB, Thorsted BL, Mikkelsen S, Lynge E. Intergenerational Educational Mobility in Denmark. SCAND J EDUC RES 2013 -10;57(5):544-560.

(40) Bundy D, Silva N, Horton S, Jamison D, Patton G. Child and adolescent health and development. 2017 Nov 20.

(41) Patton GC, Viner R. Pubertal transitions in health. Lancet 2007 Mar 31;369(9567):1130-1139.

(42) Irwin LG, Siddiqi A, Hertzman C. Early child development: A powerful equalizer
Final Report for the World Health Organization's commission on the social determinants of health. 2007.

(43) Pillas D, Marmot M, Naicker K, Goldblatt P, Morrison J, Pikhart H. Social inequalities in early childhood health and development: a European-wide systematic review. Pediatr Res 2014 Nov;76(5):418-424.

(44) Viner RM, Ross D, Hardy R, Kuh D, Power C, Johnson A, et al. Life course epidemiology: recognising the importance of adolescence. J Epidemiol Community Health 2015 Aug;69(8):719-720.

(45) Sawyer SM, Afifi RA, Bearinger LH, Blakemore SJ, Dick B, Ezeh AC, et al. Adolescence: a foundation for future health. Lancet 2012 Apr 28;379(9826):1630-1640.

(46) World Health Organization. Adolescent mental health. 18 September 2018; Available at: https://www.who.int/news-room/fact-sheets/detail/adolescent-mental-health. Accessed June 4, 2019.

(47) Freed RD, Rubenstein LM, Daryanani I, Olino TM, Alloy LB. The relationship between family functioning and adolescent depressive symptoms: The role of emotional clarity. Journal of Youth and Adolescence 2016 Mar 2016;45(3):505-519.

(48) Ben-Shlomo Y, Kuh D. A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives. Int J Epidemiol 2002 Apr;31(2):285-293.

(49) Cohen S, Janicki-Deverts D, Chen E, Matthews KA. Childhood socioeconomic status and adult health. Ann N Y Acad Sci 2010 Feb;1186:37-55.

(50) Glymour MM, Avendano M, Kawachi I. Socioeconomic status and health. In: Berkman LF, Kawachi I, Glymour MM, editors. Social epidemiology. 2nd ed. United States of America, 198 Madison Avenue, New York, NY 10016: Oxford University Press; 2014. p. 17.

(51) Kuh D, Ben-Shlomo Y, Lynch J, Hallqvist J, Power C. Life course epidemiology. J Epidemiol Community Health 2003 Oct;57(10):778-783.

(52) Cable N. Life course approach in social epidemiology: an overview, application and future implications. J Epidemiol 2014;24(5):347-352.

(53) Kuh D, Ben-Shlomo Y, Lynch J, Hallqvist J, Power C. Life course epidemiology. Glossary. 2003;57:778-783.

(54) Pollitt RA, Rose KM, Kaufman JS. Evaluating the evidence for models of life course socioeconomic factors and cardiovascular outcomes: a systematic review. BMC Public Health 2005 Jan 20;5:7-2458-5-7.

(55) Spencer N, Thanh TM, Louise S. Low income/socio-economic status in early childhood and physical health in later childhood/adolescence: a systematic review. Matern Child Health J 2013 Apr;17(3):424-431.

(56) Mannan M, Mamun A, Doi S, Clavarino A. Prospective Associations between Depression and Obesity for Adolescent Males and Females- A Systematic Review and Meta-Analysis of Longitudinal Studies. PLoS One 2016 Jun 10;11(6):e0157240.

(57) Clarke DM, Currie KC. Depression, anxiety and their relationship with chronic diseases: a review of the epidemiology, risk and treatment evidence. Med J Aust 2009 Apr 6;190(S7):S54-60.

(58) Sommer A, Twig G. The Impact of Childhood and Adolescent Obesity on Cardiovascular Risk in Adulthood: a Systematic Review. Curr Diab Rep 2018 Aug 30;18(10):91-018-1062-9.

(59) World Health Organization E. Adolescent mental health in the European Region http://www.euro.who.int/__data/assets/pdf_file/0005/383891/adolescent-mh-fs-eng.pdf?ua=1; 2018.

(60) Bertha EA, Balazs J. Subthreshold depression in adolescence: a systematic review. Eur Child Adolesc Psychiatry 2013 Oct;22(10):589-603.

(61) Patton GC, Coffey C, Romaniuk H, Mackinnon A, Carlin JB, Degenhardt L, et al. The prognosis of common mental disorders in adolescents: a 14-year prospective cohort study. Lancet 2014 Apr 19;383(9926):1404-1411.

(62) Reiss F. Socioeconomic inequalities and mental health problems in children and adolescents: a systematic review. Soc Sci Med 2013 Aug;90:24-31.

(63) Klanscek HJ, Ziberna J, Korosec A, Zurc J, Albreht T. Mental health inequalities in Slovenian 15-year-old adolescents explained by personal social position and family socioeconomic status. Int J Equity Health 2014 Mar 28;13:26-9276-13-26.

(64) Rajmil L, Herdman M, Ravens-Sieberer U, Erhart M, Alonso J, European KIDSCREEN group. Socioeconomic inequalities in mental health and health-related quality of life (HRQOL) in children and adolescents from 11 European countries. Int J Public Health 2014 Feb;59(1):95-105.

(65) Wojciech B, Magdalena M, Magdalena K, Elżbieta D, Wojciech D. Socioeconomic determinants of depressive symptoms in a Polish population. Mental Health and Prevention 2015 Dec 2015;3(4):152-156.

(66) Amroussia N, Gustafsson PE, Mosquera PA. Explaining mental health inequalities in Northern Sweden: a decomposition analysis. Glob Health Action 2017;10(1):1305814.

(67) Nielsen L, Damsgaard MT, Meilstrup C, Due P, Madsen KR, Koushede V, et al. Socioeconomic differences in emotional symptoms among adolescents in the Nordic countries: recommendations on how to present inequality. Scand J Public Health 2015 Feb;43(1):83-90.

(68) Devenish B, Hooley M, Mellor D. The Pathways Between Socioeconomic Status and Adolescent Outcomes: A Systematic Review. Am J Community Psychol 2017 Mar;59(1-2):219-238.

(69) Reiss F, Meyrose AK, Otto C, Lampert T, Klasen F, Ravens-Sieberer U. Socioeconomic status, stressful life situations and mental health problems in children and adolescents: Results of the German BELLA cohort-study. PLoS One 2019 Mar 13;14(3):e0213700.

(70) Boe T, Serlachius AS, Sivertsen B, Petrie KJ, Hysing M. Cumulative effects of negative life events and family stress on children's mental health: the Bergen Child Study. Soc Psychiatry Psychiatr Epidemiol 2018 Jan;53(1):1-9.

(71) Shore L, Toumbourou JW, Lewis AJ, Kremer P. Review: Longitudinal trajectories of child and adolescent depressive symptoms and their predictors – a systematic review and meta-analysis. Child Adolesc Ment Health 2018 05/01; 2019/06;23(2):107-120.

(72) Moreh S, O'Lawrence H. Common Risk Factors Associated with Adolescent and Young Adult Depression. J Health Hum Serv Adm 2016 Autumn;39(2):283-310.

(73) McLaughlin KA, Costello EJ, Leblanc W, Sampson NA, Kessler RC. Socioeconomic status and adolescent mental disorders. Am J Public Health 2012 Sep;102(9):1742-1750.

(74) Euteneuer F. Subjective social status and health. Curr Opin Psychiatry 2014 Sep;27(5):337-343.

(75) Cundiff JM, Matthews KA. Is subjective social status a unique correlate of physical health? A meta-analysis. Health Psychol 2017 Dec;36(12):1109-1125.

(76) World Health Organization E. World Health Organization, Europe. Data and Statistics. Available at: http://www.euro.who.int/en/health-topics/noncommunicable-diseases/obesity/data-and-statistics. Accessed March/18, 2019.

(77) Smith KB, Smith MS. Obesity Statistics. Prim Care 2016 Mar;43(1):121-35, ix.

(78) Marques A, Peralta M, Naia A, Loureiro N, de Matos MG. Prevalence of adult overweight and obesity in 20 European countries, 2014. Eur J Public Health 2018 Apr 1;28(2):295-300.

(79) World Health Organization. Obesity and overweight (fact sheet). Available at: http://www.who.int/mediacentre/factsheets/fs311/en/. Accessed October 30th, 2017.

(80) World Health Organization. Global Health Observatory (GHO) data Overweight and obesity. 2019; Available at: https://www.who.int/gho/ncd/risk_factors/overweight_obesity/obesity_adults/en. Accessed June 6., 2019.

(81) Schmidt Morgen C, Rokholm B, Sjoberg Brixval C, Schou Andersen C, Geisler Andersen L, Rasmussen M, et al. Trends in prevalence of overweight and obesity in danish infants, children and adolescents--are we still on a plateau? PLoS One 2013 Jul 24;8(7):e69860.

(82) Engin A. The Definition and Prevalence of Obesity and Metabolic Syndrome. Adv Exp Med Biol 2017;960:1-17.

(83) Llewellyn A, Simmonds M, Owen CG, Woolacott N. Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta-analysis. Obes Rev 2016 Jan;17(1):56-67.

(84) Romieu I, Dossus L, Barquera S, Blottiere HM, Franks PW, Gunter M, et al. Energy balance and obesity: what are the main drivers? Cancer Causes Control 2017 Mar;28(3):247-258.

(85) Ross SE, Flynn JI, Pate RR. What is really causing the obesity epidemic? A review of reviews in children and adults. J Sports Sci 2016;34(12):1148-1153.

(86) Al-Khudairy L, Loveman E, Colquitt JL, Mead E, Johnson RE, Fraser H, et al. Diet, physical activity and behavioural interventions for the treatment of overweight or obese adolescents aged 12 to 17 years. Cochrane Database Syst Rev 2017 Jun 22;6:CD012691.

(87) Offer A, Pechey R, Ulijaszek S. Obesity under affluence varies by welfare regimes: the effect of fast food, insecurity, and inequality. Econ Hum Biol 2010 Dec;8(3):297-308.

(88) Ulijaszek SJ. Socio-economic status, forms of capital and obesity. J Gastrointest Cancer 2012 Mar;43(1):3-7.

(89) Sorensen TI. Is obesity a healthy active response to an expected future lack of energy rather than a passive storage of surplus energy? Obes Facts 2012;5(3):431-435.

(90) Dhurandhar EJ. The food-insecurity obesity paradox: A resource scarcity hypothesis. Physiol Behav 2016 Aug 1;162:88-92.

(91) Nettle D, Andrews C, Bateson M. Food insecurity as a driver of obesity in humans: The insurance hypothesis. Behav Brain Sci 2017 Jan;40:e105.

(92) Narciso J, Silva AJ, Rodrigues V, Monteiro MJ, Almeida A, Saavedra R, et al. Behavioral, contextual and biological factors associated with obesity during adolescence: A systematic review. PLoS One 2019 Apr 8;14(4):e0214941.

(93) Pate RR. Factors associated with development of excessive fatness in children and adolescents: a review of prospective studies. Obesity reviews 2013 -08;14(8):645-658.

(94) Fatima Y, Doi SA, Mamun AA. Longitudinal impact of sleep on overweight and obesity in children and adolescents: a systematic review and bias-adjusted meta-analysis. Obes Rev 2015 Feb;16(2):137-149.

(95) Chung A, Backholer K, Wong E, Palermo C, Keating C, Peeters A. Trends in child and adolescent obesity prevalence in economically advanced countries according to socioeconomic position: a systematic review. Obes Rev 2016 Mar;17(3):276-295.

(96) Tamayo T, Christian H, Rathmann W. Impact of early psychosocial factors (childhood socioeconomic factors and adversities) on future risk of type 2 diabetes, metabolic disturbances and obesity: a systematic review. BMC Public Health 2010 Sep 1;10:525-2458-10-525.

(97) Gundersen C, Mahatmya D, Garasky S, Lohman B. Linking psychosocial stressors and childhood obesity. Obes Rev 2011 May;12(5):e54-63.

(98) Costa CS, Del-Ponte B, Assuncao MCF, Santos IS. Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. Public Health Nutr 2018 Jan;21(1):148-159.

(99) Schellong K, Schulz S, Harder T, Plagemann A. Birth weight and long-term overweight risk: systematic review and a meta-analysis including 643,902 persons from 66 studies and 26 countries globally. PLoS One 2012;7(10):e47776.

(100) Zhao Y, Wang SF, Mu M, Sheng J. Birth weight and overweight/obesity in adults: a meta-analysis. Eur J Pediatr 2012 Dec;171(12):1737-1746.

(101) Biehl A, Hovengen R, Groholt EK, Hjelmesaeth J, Strand BH, Meyer HE. Parental marital status and childhood overweight and obesity in Norway: a nationally representative cross-sectional study. BMJ Open 2014 Jun 4;4(6):e004502-2013-004502.

(102) Hohwu L, Zhu JL, Graversen L, Li J, Sorensen TI, Obel C. Prenatal parental separation and body weight, including development of overweight and obesity later in childhood. PLoS One 2015 Mar 16;10(3):e0119138.

(103) Halliday JA, Palma CL, Mellor D, Green J, Renzaho AM. The relationship between family functioning and child and adolescent overweight and obesity: a systematic review. Int J Obes (Lond) 2014 Apr;38(4):480-493.

(104) Hemmingsson E. A new model of the role of psychological and emotional distress in promoting obesity: conceptual review with implications for treatment and prevention. Obes Rev 2014 Sep;15(9):769-779.

(105) Barriuso L, Miqueleiz E, Albaladejo R, Villanueva R, Santos JM, Regidor E. Socioeconomic position and childhood-adolescent weight status in rich countries: a systematic review, 1990-2013. BMC Pediatr 2015 Sep 21;15:129-015-0443-3.

(106) Matthiessen J, Stockmarr A, Biltoft-Jensen A, Fagt S, Zhang H, Groth MV. Trends in overweight and obesity in Danish children and adolescents: 2000-2008--exploring changes according to parental education. Scand J Public Health 2014 Jun;42(4):385-392.

(107) Hayward LE, Vartanian LR, Pinkus RT. Weight Stigma Predicts Poorer Psychological Well-Being Through Internalized Weight Bias and Maladaptive Coping Responses. Obesity (Silver Spring) 2018 Apr;26(4):755-761.

(108) Pont SJ, Puhl R, Cook SR, Slusser W, SECTION ON OBESITY, OBESITY SOCIETY. Stigma Experienced by Children and Adolescents With Obesity. Pediatrics 2017 Dec;140(6):10.1542/peds.2017-3034. Epub 2017 Nov 20.

(109) Konttinen H, Kiviruusu O, Huurre T, Haukkala A, Aro H, Marttunen M. Longitudinal associations between depressive symptoms and body mass index in a 20-year follow-up. Int J Obes (Lond) 2014 May;38(5):668-674.

(110) Stunkard AJ, Faith MS, Allison KC. Depression and obesity. Biological Psychiatry 2003 1 August 2003;54(3):330-337.

(111) Markowitz S, Friedman MA, Arent SM. Understanding the Relation Between Obesity and Depression: Causal Mechanisms and Implications for Treatment. Clinical Psychology: Science and Practice 2008 03/01; 2019/11;15(1):1-20.

(112) Tronieri JS, Wurst CM, Pearl RL, Allison KC. Sex Differences in Obesity and Mental Health. Curr Psychiatry Rep 2017 Jun;19(6):29-017-0784-8.

(113) Quek YH, Tam WWS, Zhang MWB, Ho RCM. Exploring the association between childhood and adolescent obesity and depression: a meta-analysis. Obes Rev 2017 Jul;18(7):742-754.

(114) Elovainio M, Pulkki-Raback L, Jokela M, Kivimaki M, Hintsanen M, Hintsa T, et al. Socioeconomic status and the development of depressive symptoms from childhood to adulthood: a longitudinal analysis across 27 years of follow-up in the Young Finns study. Soc Sci Med 2012 Mar;74(6):923-929.

(115) Joinson C, Kounali D, Lewis G. Family socioeconomic position in early life and onset of depressive symptoms and depression: a prospective cohort study. Soc Psychiatry Psychiatr Epidemiol 2017 Jan;52(1):95-103.

(116) Dunn EC, McLaughlin KA, Slopen N, Rosand J, Smoller JW. Developmental timing of child maltreatment and symptoms of depression and suicidal ideation in young adulthood: results from the National Longitudinal Study of Adolescent Health. Depress Anxiety 2013 Oct;30(10):955-964.

(117) Bjorkenstam E, Cheng S, Burstrom B, Pebley AR, Bjorkenstam C, Kosidou K. Association between income trajectories in childhood and psychiatric disorder: a Swedish population-based study. J Epidemiol Community Health 2017 Jul;71(7):648-654.

(118) Dahl SK, Larsen JT, Petersen L, Ubbesen MB, Mortensen PB, Munk-Olsen T, et al. Early adversity and risk for moderate to severe unipolar depressive disorder in adolescence and adulthood: A register-based study of 978,647 individuals. J Affect Disord 2017 May;214:122-129.

(119) Green MJ, Stritzel H, Smith C, Popham F, Crosnoe R. Timing of poverty in childhood and adolescent health: Evidence from the US and UK. Soc Sci Med 2018 Jan;197:136-143.

(120) Boe T, Skogen JC, Sivertsen B, Hysing M, Petrie KJ, Dearing E, et al. Economic volatility in childhood and subsequent adolescent mental health problems: a longitudinal population-based study of adolescents. BMJ Open 2017 Sep 18;7(9):e017030-2017-017030.

(121) Lindstrom M, Fridh M, Rosvall M. Economic stress in childhood and adulthood, and poor psychological health: three life course hypotheses. Psychiatry Res 2014 Feb 28;215(2):386-393.

(122) Kestila L, Rahkonen O, Martelin T, Lahti-Koski M, Koskinen S. Do childhood social circumstances affect overweight and obesity in early adulthood? Scand J Public Health 2009 Mar;37(2):206-219.

(123) Morgen CS, Mortensen LH, Rasmussen M, Andersen AM, Sorensen TI, Due P. Parental socioeconomic position and development of overweight in adolescence: longitudinal study of Danish adolescents. BMC Public Health 2010 Aug 29;10:520-2458-10-520.

(124) Brisbois TD, Farmer AP, McCargar LJ. Early markers of adult obesity: a review. Obes Rev 2012 Apr;13(4):347-367.

(125) Bann D, Johnson W, Li L, Kuh D, Hardy R. Socioeconomic Inequalities in Body Mass Index across Adulthood: Coordinated Analyses of Individual Participant Data from Three British Birth Cohort Studies Initiated in 1946, 1958 and 1970. PLoS Med 2017 Jan 10;14(1):e1002214.

(126) Newton S, Braithwaite D, Akinyemiju TF. Socio-economic status over the life course and obesity: Systematic review and meta-analysis. PLoS One 2017 May 16;12(5):e0177151.

(127) Boylan SM, Gill TP, Hare-Bruun H, Andersen LB, Heitmann BL. Associations between adolescent and adult socioeconomic status and risk of obesity and overweight in Danish adults. Obes Res Clin Pract 2014 Mar-Apr;8(2):e163-71.

(128) Matthews KA, Gallo LC, Taylor SE. Are psychosocial factors mediators of socioeconomic status and health connections? A progress report and blueprint for the future. Ann N Y Acad Sci 2010 Feb;1186:146-173.

(129) Charmandari E, Tsigos C, Chrousos G. Endocrinology of the stress response. Annu Rev Physiol 2005;67:259-284.

(130) Evans GW, Kim P. Childhood Poverty, Chronic Stress, Self-Regulation, and Coping. CHILD DEV PERSPECT 2013 -03;7(1):43-48.

(131) Sinha R. Chronic stress, drug use, and vulnerability to addiction. Ann N Y Acad Sci 2008 Oct;1141:105-130.

(132) Sherwood L. Human Physiology From Cells to Systems. 4th ed. California: Brooks/Cole; 2001.

(133) Lazarus R, Folkman S. The Concept of Stress. Stress, Appraisal, and Coping New York, United States of America: Springer Publishing Company, Inc; 1984. p. 11-19.

(134) Cohen S, Gianaros PJ, Manuck SB. A Stage Model of Stress and Disease. Perspect Psychol Sci 2016 Jul;11(4):456-463.

(135) Lazarus. Stress and emotion: A new synthesis. Stress and emotion: A new synthesis. 1999.

(136) Dalgaard VL, Andersen LPS, Andersen JH, Willert MV, Carstensen O, Glasscock DJ. Work-focused cognitive behavioral intervention for psychological complaints in patients on sick leave due to work-related stress: Results from a randomized controlled trial. J Negat Results Biomed 2017 Aug 22;16(1):13-017-0078-z.

(137) Wardle J, Chida Y, Gibson EL, Whitaker KL, Steptoe A. Stress and adiposity: a meta-analysis of longitudinal studies. Obesity (Silver Spring) 2011 Apr;19(4):771-778.

(138) Claassen MA, Klein O, Bratanova B, Claes N, Corneille O. A systematic review of psychosocial explanations for the relationship between socioeconomic status and body mass index. Appetite 2019 -01;132:208-221.

(139) Elsenburg LK, Smidt N, Liefbroer AC. The Longitudinal Relation Between Accumulation of Adverse Life Events and Body Mass Index From Early Adolescence to Young Adulthood. Psychosom Med 2017 Apr;79(3):365-373.

(140) Spinosa J, Christiansen P, Dickson JM, Lorenzetti V, Hardman CA. From Socioeconomic Disadvantage to Obesity: The Mediating Role of Psychological Distress and Emotional Eating. Obesity (Silver Spring) 2019 Apr;27(4):559-564.

(141) Global Organization for Stress. Stress Facts. Available at: http://www.gostress.com/stress-facts/. Accessed March/11, 2019.

(142) American Psychological Association. Stress in America
Generation Z: Stress in America TM Survey. 2018, october.

(143) Schmidt M, Pedersen L, Sorensen HT. The Danish Civil Registration System as a tool in epidemiology. Eur J Epidemiol 2014 Aug;29(8):541-549.

(144) Pedersen CB. The Danish Civil Registration System. Scand J Public Health 2011 Jul;39(7 Suppl):22-25.

(145) Baadsgaard M, Quitzau J. Danish registers on personal income and transfer payments. Scand J Public Health 2011 Jul;39(7 Suppl):103-105.

(146) Jensen VM, Rasmussen AW. Danish Education Registers. Scand J Public Health 2011 Jul;39(7 Suppl):91-94.

(147) Hjollund NH, Larsen FB, Andersen JH. Register-based follow-up of social benefits and other transfer payments: accuracy and degree of completeness in a Danish interdepartmental administrative database compared with a population-based survey. Scand J Public Health 2007;35(5):497-502.

(148) Knudsen LB, Olsen J. The Danish Medical Birth Registry. Dan Med Bull 1998 Jun;45(3):320-323.

(149) Bliddal M, Broe A, Pottegard A, Olsen J, Langhoff-Roos J. The Danish Medical Birth Register. Eur J Epidemiol 2018 Jan;33(1):27-36.

(150) Smarr KL, Keefer AL. Measures of depression and depressive symptoms: Beck Depression Inventory-II (BDI-II), Center for Epidemiologic Studies Depression Scale (CES-D), Geriatric Depression Scale (GDS), Hospital Anxiety and Depression Scale (HADS), and Patient Health Questionnaire-9 (PHQ-9). Arthritis Care Res (Hoboken) 2011 Nov;63 Suppl 11:S454-66.

(151) Fendrich M, Weissman MM, Warner V. Screening for depressive disorder in children and adolescents: validating the Center for Epidemiologic Studies Depression Scale for Children. Am J Epidemiol 1990 Mar;131(3):538-551.

(152) He J, Cai Z, Fan X. How accurate is the prevalence of overweight and obesity in children and adolescents derived from self-reported data? A meta-analysis. Public Health Nutr 2018 Jul;21(10):1865-1873.

(153) World Health Organization. Global Database on Body Mass Index, BMI classification. 2018; Available at: http://www.assessmentpsychology.com/icbmi.htm. Accessed March/8, 2018.

(154) Mooney SJ. Comparison of anthropometric and body composition measures as predictors of components of the metabolic syndrome in a clinical setting. Obesity research & clinical practice 2013 -01;7(1):e55-e66.

(155) Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000 May 6;320(7244):1240-1243.

(156) Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes 2012 Aug;7(4):284-294.

(157) Votruba-Drzal E. Economic disparities in middle childhood development: does income matter? Dev Psychol 2006 Nov;42(6):1154-1167.

(158) Morgan PJ, Young MD, Lloyd AB, Wang ML, Eather N, Miller A, et al. Involvement of Fathers in Pediatric Obesity Treatment and Prevention Trials: A Systematic Review. Pediatrics 2017 Feb;139(2):10.1542/peds.2016-2635.

(159) Park AL, Fuhrer R, Quesnel-Vallée A. Parents' education and the risk of major depression in early adulthood. Social Psychiatry and Psychiatric Epidemiology 2013 Nov 2013;48(11):1829-1839.

(160) Goodman E, Adler NE, Kawachi I, Frazier AL, Huang B, Colditz GA. Adolescents' perceptions of social status: development and evaluation of a new indicator. Pediatrics 2001 Aug;108(2):E31.

(161) Newcomb MD, Huba GJ, Bentler PM. A Multidimensional Assessment of Stressful Life Events among Adolescents: Derivation and Correlates. J Health Soc Behav 1981;22(4):400-415.

(162) Turner RJ, Wheaton. Checklist measurement of stressful life events. Measuring stress : a guide for health and social scientists: Oxford University Press; 1997. p. 29.

(163) Glasscock DJ, Andersen JH, Labriola M, Rasmussen K, Hansen CD. Can negative life events and coping style help explain socioeconomic differences in perceived stress among adolescents? A cross-sectional study based on the West Jutland cohort study. BMC Public Health 2013 Jun 2;13:532-2458-13-532.

(164) Winding TN, Andersen JH. Do negative childhood conditions increase the risk of somatic symptoms in adolescence? - a prospective cohort study. BMC Public Health 2019 Jun 26;19(1):828-019-7198-y.

(165) Epstein N, Baldwin L, Bishop D. The McMaster family assessment device. Journal of Marital and Family Therapy 1983;9(2):171.

(166) Ware JE,Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992 Jun;30(6):473-483.

(167) Turner RJ, Lloyd DA, Roszell P. Personal resources and the social distribution of depression. Am J Community Psychol 1999 Oct;27(5):643-672.

(168) Carver CS. You want to measure coping but your protocol's too long: consider the brief COPE. Int J Behav Med 1997;4(1):92-100.

(169) Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav 1983 Dec;24(4):385-396.

(170) Klarlund B, Andersen L. Fysisk aktivitet. Håndbog om forebyggelse og behandling. 2018.

(171) World Health Organization. Guidelines on physical activity, sedentary behaviour and sleep. For children under 5 years of age. (https://apps.who.int/iris/bitstream/handle/10665/311664/9789241550536-eng.pdf?sequence=1&isAllowed=yhttps://www.sst.dk/da/Viden/Fysisk-aktivitet/Anbefalinger-om-fysisk-aktivitet/Boern-mellem-5-og-17-aar). 2019.

(172) Morgen CS, Andersen PK, Mortensen LH, Howe LD, Rasmussen M, Due P, et al. Socioeconomic disparities in birth weight and body mass index during infancy through age 7 years: a study within the Danish National Birth Cohort. BMJ Open 2017 Jan 20;7(1):e011781-2016-011781.

(173) Stansfeld SA, Clark C, Rodgers B, Caldwell T, Power C. Childhood and adulthood socio-economic position and midlife depressive and anxiety disorders. Br J Psychiatry 2008 Feb;192(2):152-153.

(174) Dunn EC, Soare TW, Raffeld MR, Busso DS, Crawford KM, Davis KA, et al. What life course theoretical models best explain the relationship between exposure to childhood adversity and psychopathology symptoms: recency, accumulation, or sensitive periods? Psychol Med 2018 Nov;48(15):2562-2572.

(175) Ben-Shlomo Y, Cooper R, Kuh D. The last two decades of life course epidemiology, and its relevance for research on ageing. Int J Epidemiol 2016 Aug;45(4):973-988.

(176) Melchior M, Touchette E, Prokofyeva E, Chollet A, Fombonne E, Elidemir G, et al. Negative events in childhood predict trajectories of internalizing symptoms up to young adulthood: an 18-year longitudinal study. PLoS One 2014 Dec 8;9(12):e114526.

(177) Hughes K, Bellis MA, Hardcastle KA, Sethi D, Butchart A, Mikton C, et al. The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. Lancet Public Health 2017 Aug;2(8):e356-e366.

(178) Pryor L, Strandberg-Larsen K, Nybo Andersen AM, Hulvej Rod N, Melchior M. Trajectories of family poverty and children's mental health: Results from the Danish National Birth Cohort. Soc Sci Med 2019 Jan;220:371-378.

(179) Heinrich CJ. Parents' employment and children's wellbeing. Future Child 2014 Spring;24(1):121-146.

(180) Walsh D, McCartney G, Smith M, Armour G. Relationship between childhood socioeconomic position and adverse childhood experiences (ACEs): a systematic review. J Epidemiol Community Health 2019 Dec;73(12):1087-1093.

(181) Lunau T, Siegrist J, Dragano N, Wahrendorf M. The association between education and work stress: does the policy context matter? PLoS One 2015 Mar 26;10(3):e0121573.

(182) McLaughlin KA, Breslau J, Green JG, Lakoma MD, Sampson NA, Zaslavsky AM, et al. Childhood socio-economic status and the onset, persistence, and severity of DSM-IV mental disorders in a US national sample. Soc Sci Med 2011 Oct;73(7):1088-1096.

(183) Francisco R, Loios S, Pedro M. Family Functioning and Adolescent Psychological Maladjustment: The Mediating Role of Coping Strategies. Child Psychiatry Hum Dev 2016 Oct;47(5):759-770.

(184) Due P, Krolner R, Rasmussen M, Andersen A, Trab Damsgaard M, Graham H, et al. Pathways and mechanisms in adolescence contribute to adult health inequalities. Scand J Public Health 2011 Mar;39(6 Suppl):62-78.

(185) Matthiessen J, Stockmarr A, Fagt S, Knudsen VK, Biltoft-Jensen A. Danish children born to parents with lower levels of education are more likely to become overweight. Acta Paediatr 2014 Oct;103(10):1083-1088.

(186) Klesges RC. Relationship between psychosocial functioning and body fat in preschool children: a longitudinal investigation. J Consult Clin Psychol 1992 -10;60(5):793-796.

(187) Sulkowski ML, Dempsey J, Dempsey AG. Effects of stress and coping on binge eating in female college students. Eat Behav 2011 Aug;12(3):188-191.

(188) Greenberg RS, Daniels SR, Flanders W, Eley JW, Boring III JR. Medical Epidemiology. 4th ed. United States of America: Lange Medical Books/McGraw-Hill, Medical Publishing Division; 2005.

(189) Juul S, Bech B, Dahm C, Rytter D. Epidemiologi og evidens. 3. udgave, 1. oplag ed. København: Munksgaard; 2017.

(190) Winding TN, Andersen JH, Labriola M, Nohr EA. Initial non-participation and loss to follow-up in a Danish youth cohort: implications for relative risk estimates. J Epidemiol Community Health 2014 Feb;68(2):137-144.

(191) Howe CJ. Selection Bias Due to Loss to Follow Up in Cohort Studies. Epidemiology 2016 -01;27(1):91-97.

(192) Stapelfeldt CM. Validation of sick leave measures: self-reported sick leave and sickness benefit data from a Danish national register compared to multiple workplace-registered sick leave spells in a Danish municipality. BMC Public Health 2012 -08;12(1):661.

(193) Vukojevic M, Zovko A, Talic I, Tanovic M, Resic B, Vrdoljak I, et al. Parental Socioeconomic Status as a Predictor of Physical and Mental Health Outcomes in Children - Literature Review. Acta Clin Croat 2017 Dec;56(4):742-748.

(194) Zhou Q, Fan L, Yin Z. Association between family socioeconomic status and depressive symptoms among Chinese adolescents: Evidence from a national household survey. Psychiatry Res 2017 Sep 28;259:81-88.

(195) Wang Z, Patterson CM, Hills AP. A comparison of self-reported and measured height, weight and BMI in Australian adolescents. Aust N Z J Public Health 2002 Oct;26(5):473-478.

(196) Aasvee K, Rasmussen M, Kelly C, Kurvinen E, Giacchi MV, Ahluwalia N. Validity of self-reported height and weight for estimating prevalence of overweight among Estonian adolescents: the Health Behaviour in School-aged Children study. BMC Res Notes 2015 Oct 26;8:606-015-1587-9.

(197) Clarke P, Sastry N, Duffy D, Ailshire J. Accuracy of self-reported versus measured weight over adolescence and young adulthood: findings from the national longitudinal study of adolescent health, 1996-2008. Am J Epidemiol 2014 Jul 15;180(2):153-159.

(198) Perez A, Gabriel K, Nehme EK, Mandell DJ, Hoelscher DM. Measuring the bias, precision, accuracy, and validity of self-reported height and weight in assessing overweight and obesity status among adolescents using a surveillance system. Int J Behav Nutr Phys Act 2015 Jul 27;12 Suppl 1:S2-5868-12-S1-S2. Epub 2015 Jul 27.

(199) van Roode T, Sharples K, Dickson N, Paul C. Life-Course Relationship between Socioeconomic Circumstances and Timing of First Birth in a Birth Cohort. PLoS One 2017 Jan 13;12(1):e0170170.

(200) Rothman K, Greenland S, Lash T. Modern Epidemiology. 3rd ed. USA: Wolters Kluwer, Lippincott Williams & Wilkins; 2008.

(201) Organisation for Economic Co-operation and Development. OECD statistics. Available at https://stats.oecd.org/ (Health, health status). 2019.

Paper I

The influences of childhood family factors on depressive symptoms in adolescence and early adulthood: a Danish longitudinal study.

Authors: Poulsen, PH[1]; Biering, K[1]; Winding[1], TN; Nohr[2], EA; Andersen, JH[1]

Affiliation: [1]Danish Ramazzini Centre, Department of Occupational Medicine, Regional Hospital West Jutland – University Research Clinic, Herning, Denmark. [2]Institute of Clinical Research, University of Southern Denmark, Denmark.

Abstract

Aims: To examine the timing of family socioeconomic factors during early (0—8 years) and late childhood (9—14 years), as well as psychosocial variables in relation to depressive symptoms at age 15, 18 and 21.

Methods: This prospective cohort study included 3,014 young people from western Denmark. Exposure variables were equivalised household income (income), mother's educational level and mother's labour market participation (LMP), derived from registers and self-reported variables family functioning, subjective social status and negative life events. The outcome variable was depressive symptoms.

Associations were analysed using logistic regression, adjusted for other exposure variables and gender.

Results: Early childhood: Mother's low LMP increased the risk of depressive symptoms at age 15 whereas mother's low educational level and lower income increased the risk of depressive symptoms at age 21. Late childhood: Lower income, mother's low educational level and mother's low LMP increased the risk of depressive symptoms at ages 15 and 21. Poorer family functioning was associated with depressive symptoms at age 15-21 with estimates ranging from 1.8 to 2.6. Reporting two or more negative life events were associated with depressive symptoms at age 15 and 18.

Conclusions: Timing of low income, mother's low educational level and mother's low LMP during childhood in relation to future depressive symptoms in the offspring appears to be of some importance in this Danish Youth cohort. Family functioning and negative life events were the most

stable risk factors for depressive symptoms. Results should however be interpreted with caution due to the risk of reverse causality.

Background

Depression is a major contributor to the overall burden of disease. Globally, WHO (World Health Organisation) has estimated that more than 300 million people suffer from depression [1]. According to the latest Danish National Health Profile almost 24% and 13% of young Danish women and men aged 16 to 24 year old reported poor mental health, with a more than five per cent increase since 2013 among females [2]. This increase is an important health issue, as mental health problems may develop into mental disease later in life [3].

The importance of socioeconomic conditions for health is widely recognized and research has provided evidence for a socioeconomic gradient in health, indicating that the higher the level of e.g. household income the lower the risk of health problems [4-6]. Denmark is a welfare state and characterised by a low grade of socioeconomic inequality, despite this; inequality in health exists among children and adolescents [2].

Prolonged or chronic exposure to lower socioeconomic position (SEP) in childhood (defined by parental educational level, parental occupation or household income) or adverse childhood conditions in terms of e.g. parental mental health problems or negative life events have often served as a proxy for social adversity in childhood or adverse childhood experiences. In this paper we refer to childhood social adversity as a broad concept including both socioeconomic and psychosocial factors.

Some studies point towards an association between childhood lower SEP and depressive symptoms [7-10], negative life events or family function and depressive symptoms [11, 12], or the combined effect of lower SEP and negative life events on mental health [13].

Research has shown that accumulated stress mechanisms may account for much of the difference in health outcomes between children from lower and higher socioeconomic conditions [14]. It has been argued that the influence of the family environment in the years, where the children grow up and develop their personality may be crucial for future mental health problems among the socioeconomic disadvantageous children [15, 16]. Growing up in a disadvantaged family environment caused by e.g. lower income, parents being unemployed or a family which is poorly functioning may increase stress in children [9]. Exposure to social adversity in early childhood (0—5 years) has been recognised as a critical period in time in relation to future mental health problems, however, the childhood period (5—12 year) may also be a sensitive period due to development and behaviour problems [17, 18]. Childhood and adolescence are years characterised by complexity and variability both physiological and psychosocial and time-periods where the future pattern of adult health is established [19, 20]. The timing of exposure to childhood social adversity may therefore be of relevance in relation to future mental health problems. Previous research examining the issue of timing has primarily focused on more severe childhood social adversities in relation to later mental health problems [21] or psychiatric disorders [22, 23]. To our knowledge, few studies [10, 16, 24] have examined the timing of childhood low SEP in relation to later depressive symptoms in adolescence and early adulthood. Boe et al. investigated the timing of exposure to low family income in late childhood and mental health problems among Norwegian adolescents aged 16-19 [10]. They did not find strong suggestion of any timing effect when examining the exposure of relative poverty. Findings by Bjorkenstam et al. support the long-term negative impact of childhood adversity on adolescent depressive symptoms; however, the timing of childhood exposure appeared to have little effect on

the risk of depressive symptoms. Their study was, however, conducted in the US with a different society structure, which makes it difficult to transfer results to a Danish welfare society.

We aimed to examine the timing of early (age 0—8 years) and late childhood (age 9—14 years) family socioeconomic factors in relation to depressive symptoms in adolescence and early adulthood; including the psychosocial factors family functioning, negative life events in childhood and subjective social status in society (SSS). These subjective factors have previously been linked to later mental health problems [11, 12, 25] and may therefore contribute with valuable knowledge regarding the family environment and the experienced social adversity in late childhood, which may not be captured by the socioeconomic exposures. The cut for the early and late childhood periods was pragmatic because of inconsistences in the literature.

Methods

Design and population

The study was a prospective cohort study as part of the West Jutland Cohort Study (VestLiv), which is an on-going longitudinal study following a complete regional cohort of young people born in 1989 and residing in the former county of Ringkoebing in the Western part of Denmark in 2004. The aim of the West Jutland Cohort Study is to examine inequality in health in a life course perspective. The source population comprised 3,681 young people aged 15. Recruitment of participants in 2004 took place at the schools within the county when the participants were approximately 15 years old. A baseline questionnaire was completed during school hours and those pupils not a school on this particular day of collection received the questionnaire by mail. Of the potential 3,681 responders, 3,054 (83%) responded to the baseline questionnaire. All the potential responders in 2004 were re-invited to participate at the latter waves. Further information on recruitment and data collection is described elsewhere [26].

Participants were included in this current study if they had responded to questions about depressive symptoms in at least one of three questionnaire waves (year 2004, 2007 and 2010). This was the case for 3,014 young people (age 15) at baseline, 2,373 at the first follow up (age 18) and 1,968 at the second follow up (age 21). Attrition and missing data reduced the sample as shown in Figure 1.

“[insert Figure 1.]"

Data

Data comprised a combination of questionnaire data and data from registers. In Denmark, every citizen is provided with a CPR-number (Civil Registration Number) at birth (or upon entry for immigrants). The CPR-number allowed us to link each child to parental information from registers [27].

Information on annual equivalised disposable household income was from the Danish register on personal income and transfer payments [28], and mother's highest education level was derived from different educational registers [29]. Information about mother's labour market participation (LMP) was derived from the DREAM register, which provides information on social benefits and payments related to e.g. unemployment benefits, sickness absence compensation, and disability pension on a weekly basis [30].

Definition of outcome

The primary outcome measure was depressive symptoms derived from three questionnaire waves.

Depressive symptoms were measured by an abbreviated version of the Center for Epidemiologic Studies Depression Scale for Children (CES-DC), which is designed to measure current levels of depressive symptoms in the general population [31]. The scale has been translated into Danish and is validated [31]. It consists of four items asking about one´s mental state over the past week. There are four categories of answers to each question ranging from ''not at all'' to ''a lot''. The answers are awarded scores of 0—3, where high values correspond to having depressive

symptoms. We applied single item imputation if one item was missing for the scale. The four items summed up to a score between 0 and 12. The definition of depressive symptoms was obtained by using the cut-off point of three and above as recommended for the short scale by Fendrich et al. [31]. The CES-DC scale was also applied in its continuous form.

Definition of exposure

The main exposure variables were a range of socioeconomic and subjective psychosocial factors. We applied subjective (self-reported) factors from the baseline questionnaire in 2004 to the late childhood exposures, because we wanted to include the young people's own perception of the childhood social adversity and the family environment, which may not be captured by the socioeconomic factors.

Socioeconomic factors:

Both equivalised income and mother's LMP can be fluctuating parameters over time, whereas mother's highest educational level is more likely to be stable or has only the ability to increase. To consider this fluctuating element, we calculated a mean for each of the two variables for the early childhood (age 0—8 years) and the late childhood (age 9—14 years), respectively.

Equivalised income was a continuous variable collected each year from 1990 to 2003 (14 years). Information about income had to be available for at least four years in one of the two childhood periods to calculate a mean value for the early or late childhood. Equivalised income was

categorized into low, medium and high income, grouped by 33.3rd and 66.6th percentiles for each childhood period. Equivalised income was also applied as a continuous variable.

Information about mother's highest educational level was included when the child was 8 (1997) and 14 years of age (2003), and the variable was divided into three categories: ≤10, 11-13, >13 years of school/education. If information on this variable was missing for the current year, information from previous years was used (last observation carried forward).

Mother's LMP was defined according to the degree of time on social benefits within each year from second half of 1991 until 2003. When we defined LMP, we omitted payments due to receiving maternity leave benefits or state educational grants. LMP was a continuous variable in the range from 0—100 and calculated as a yearly mean LMP score. We then calculated a mean score in each childhood period and dichotomized the variable into "high LMP" and "low LMP", respectively, with a pragmatic cut-off value of 0.80 and above indicating high LMP.

Psychosocial factors:

Family functioning was a categorical variable based on the general functioning subscale of the McMaster Family Assessment Device (FAD), developed by Epstein et al. The FAD consists of seven subscales where General Functioning assesses the overall health/pathology of the family with questions about how the family handles e.g. crisis or other family issues [32]. It consists of 12 items with four response categories ranging from ''strongly agree'' to ''strongly disagree'' (scores of 1—4), where high values indicated poor family functioning. We then calculated a mean value for the 12 items and did not allow for missing values to occur. The variable was applied as a

continuous exposure variable. When we present the distribution of the variable in relation to the outcome we chose to dichotomise the variable at the 75th percentile of the mean value indicating poor family functioning at ≥2.08, which lies between the mean value for the nonclinical and clinical samples on General Functioning [32].

Subjective social status in society (SSS) was measured by the youth version of the MacArthur Scale of Subjective Social Status [33] using a Danish translated version. This instrument is a 10-rung ladder with the following instruction: "Imagine that this ladder pictures how the Danish society is set up". The participants were then asked to place an X on the ladder representing where their family would be in relation to income, education and prestigious jobs. The scale was categorized into three groups composed of the three lowest rungs (low SSS in society), the three highest rungs (high SSS in society) and the four in the middle (average SSS in society).

Negative life events were measured by six items taken from Newcomb et al. 's [34] measure and the Social Stress Indicator [35]. The questions were according to parental divorce, parental death and abuse during the childhood. The exact wording of the questions has been explained elsewhere [36]. We dichotomized the variable at two and more negative life events.

Statistical methods

We tabulated each exposure variable in early and late childhood in relation to the outcome at age 15, 18 and 21. We examined the associations between early and late childhood family factors and depressive symptoms at age 15, 18 and 21 by using logistic regression models and estimates are shown as odds ratios (OR) with 95% confidence intervals (CI). We also carried out supplementary analyses using linear regression models.

Correlation analyses were carried out for all the exposure variables by Spearman's rank correlation test (matrix not shown). The correlation between equivalised income in early and late childhood was Spearman's rho=0.68 and for mother's LMP in early and late childhood, Spearman's rho=0.50. No strong correlation was seen between any of the other exposure variables; the strongest correlation was between equivalised income in late childhood and SSS, Spearman's rho=0.3024. Other coefficients were lower.

Since none of the socioeconomic exposure variables were strongly correlated, we mutual adjusted the associations between early childhood exposures and depressive symptoms for the other socioeconomic exposure variables in the same childhood period and gender.

For the late childhood exposures in relation to depressive symptoms, we made mutual adjustments for all the other late childhood exposures and gender. To take the effect of the early childhood socioeconomic exposure into account, we also included an adjustment for the early childhood exposure, when we examined the associations between equivalised income and depressive symptoms. The same procedure was applied when examining mother's LMP and mother´s educational level in late childhood. We tested each association for interaction with gender, however, no significant interactions were found (results not shown). In sub-analyses, we explored whether non-participants at baseline were different from participants with respect to socioeconomic position (tables not shown). We furthermore carried out a sensitivity analysis using a multiple imputation chained model with 100 imputations (results not shown).

Data analyses were performed using Stata, statistical software version 14.2 (Stata Corporation, College Station, Texas, USA).

Ethics

Use of the data was carried out under the same conditions and with the same purpose as when originally collected and based on approval from the Danish Data Protection Agency and their rules of data protection. According to Danish law, approval by the Ethics Committee and written informed consent was not required when data collection was carried out. Additional information is available at The National Committee on Health Research Ethics' webpage in the "Act on Research Ethics Review of Health Research Projects" § 14,2. Available from http://www.nvk.dk/english/act-on-research.

Results

When studying the family socioeconomic factors in early childhood in relation to the outcome at age 15, 18 and 21, we did not find any remarkable differences in the proportions of participants with depressive symptoms across the levels of exposure variables (Table 1). “[insert Table 1.]"

For late childhood exposures, we observed a higher proportion of depressive symptoms at all three time points among those, who grew up in lower equivalised income families or with a mother of low LMP or lower educational level, and among those who reported poor family functioning, lower SSS or had experienced two or more negative life events (Table 1).

Table 2 and Table 3 presents unadjusted and adjusted estimates for the associations between family socioeconomic and psychosocial factors in early and late childhood and depressive symptoms at age 15, 18 and 21. For simplicity, only the adjusted results are shown with 95% confidence intervals. “[insert Table 2 and Table 3.]"

Lower equivalised income in early childhood was associated with increased risk of depressive symptoms at age 21, (AOR=1.4 (1.1—1.8)). Children, who grew up with a mother having low LMP in early childhood, had increased risk of depressive symptoms at age 15, (AOR=1.3 (1.1—1.5)). Moreover, mother’s low educational level in early childhood was associated with increased risk of depressive symptoms at especially age 21, (AOR=1.3 (1.0—1.7)).

Children from low equivalised income families during late childhood had slightly increased risk of depressive symptoms at age 15, (AOR=1.2 (0.9—1. 5)). Mother’s low LMP in late childhood was associated with increased risk of depressive symptoms at age 21, (AOR=1.4 (1.0—1.8)).

Furthermore, mother's low educational level in late childhood was associated with depressive symptoms at age 15. With regard to the psychosocial exposures results showed that for each unit increase in family functioning depressive symptoms increased by AOR=2.6 (2.2—3.1) at age 15, by AOR=1.8 (1.5—2.2) at age 18 and by AOR=1.9 (1.6—2.4) at age 21. Reporting lower subjective social status showed a clear association with depressive symptoms at all three ages, however, the association vanished after adjustments. Reporting two or more negative life events was associated with increased risk of depressive symptoms at age 15 and 18, (AOR=1.7 (1.3—2.2)), AOR=1.4 (0.9—1.9)), in that order.

The results from linear regression models confirmed the findings from the logistic regression models and can be seen in supplementary material (Table 2a).

Discussion

We aimed to examine if the timing of family socioeconomic factors in early and late childhood was associated with later depressive symptoms. Furthermore, we supplemented the late childhood exposures with the self-reported psychosocial variables family functioning, subjective social status in society and negative life events in childhood. We observed that the family factors in both early and late childhood were associated with increased risk of depressive symptoms in adolescence and early adulthood. Regarding the timing of exposure, it appeared that the early childhood equivalised income had a somewhat delayed influence at age 21, whereas the late childhood equivalised income was associated with depressive symptoms at age 15, despite some wide confidence intervals. This picture was similar when we examined mother's low educational level. We furthermore observed that mother's low LMP in early childhood was associated with increased risk of depressive symptoms at age 15, whereas mother's low LMP in late childhood showed a delayed effect at age 21. We found that the subjective exposure variables in late childhood in terms of family functioning and negative life events showed stable associations with depressive symptoms in adolescence and early adulthood.

To our knowledge, this is the first study to describe how the timing of several socioeconomic family factors during the entire childhood, supplemented with subjective psychosocial factors relates to depressive symptoms at ages 15, 18 and 21 in a Scandinavian egalitarian Society.

The fact that children, who grow up in families where they experience social adversity in terms of financial problems or parental unemployment, have increased risk of later depressive symptoms have been found in previous Scandinavian studies. Our results, however, indicate that the timing of low income, mother's low educational level and mother's low LMP in early and late childhood

may be of relevance in relation to later depressive symptoms in this cohort since these variables showed their influence at different ages, depending of the exposure period.

Boe et al. found that exposure to low family income in late childhood/adolescence was associated with later mental health problems, however, they did not find strong suggestion of any timing effect [10]. The study examined exposure to relative poverty in relation to symptoms of mental health problems. We did not examine exposure to relative poverty in our study which may have revealed similar results.

Bjorkenstam et al., found that the timing of exposure was less important when they examined the associations between childhood adversities and adolescent depressive symptoms in a US national sample. The difference in findings may be due to the different exposures, the different contexts and a slightly younger US population.

Results from our study showed that mother's low LMP, low equivalised income and mother's low educational level in early childhood were associated with depressive symptoms at age 15 and age 21, respectively. Being unwillingly unemployed or having a low attachment to the labour market may increase maternal stress due to e.g. job- and financial insecurity [37], which may affect the family environment where the children are growing up. During the early childhood developmental period children are primarily influenced by parents and the family environment, so if children are exposed to continuous stress early in life this may track on to adolescence and into young adulthood [38] possibly involving maladaptive coping mechanisms, which may increase risk of poor mental health. Being exposed to maternal low LMP, low equivalised income or mother's low educational level in late childhood was associated with depressive symptoms at age 15 and age 21. During this developmental period with puberty and early adolescence children form increased

attachments to peers and engage in different social contexts. Children are, however, continuously influenced by the family environment which due to financial insecurity and lack of resources may influence children's development and behavior [17]. That maternal low LMP in late childhood exerts a more long-term development of depressive symptoms in the offspring can also be caused by maternal stress, which may decrease social support of the child and thereby increase risk of poorer mental health [39]. In our study, we also observed that reporting poorer family functioning in late childhood was the strongest risk factor for depressive symptoms at ages 15, 18 and 21, which may reflect a disharmonious family environment influenced by parental stress among the socioeconomic disadvantaged families.

Prior research has pointed to the fact that the subjective measure of social status among adolescents showed a clearer association with depressive symptoms than the use of an objective measure of socioeconomic status [25]. This was also the case with SSS in our study, however, the association vanished after adjustments and this was primarily due to adjustment for family functioning. This may indicate that the variable family functioning mediates the associations between low SSS and depressive symptoms [40].

Negative life events in childhood showed clear associations with later depressive symptoms, which is consistent with findings in other studies [11, 41]. In this cohort less than 15% had experienced more than one negative life event during childhood (table not shown). Approximately one in five had experienced parental divorce, 15% had experienced parents being severe ill and between 3 to 7% had experienced negative life-events in terms of abuse, parental alcohol problems or parental death. All of the abovementioned negative life events may individually increase stress in children, where some of the life events may pertain particular to families of lower socioeconomic status.

Being exposed to an increased number of negative life events may likewise increase the risk of later poorer mental health [42].

It is therefore important to address attention to socioeconomic disadvantaged families during the entire childhood to decrease stress in the family environment and prevent the development of poorer mental health among the offspring, which may track into adulthood. Growing up in a social secure and healthy family environment is of outmost importance to prevent future mental health problems related to the family factors.

Strengths and limitations

Design and population

This cohort study covered in total 21 years of follow-up, with the first 14 years of exposure information derived from registers with few missing values. Furthermore, we supplemented with the self-reported exposure variables. Across the following six years, depressive symptoms were measured at three measure points. This longitudinal design is suitable to observe potential changes over time and is considered to be appropriate to study this kind of associations. Also, using register-based exposure variables diminish the risk of differential information bias on the objective variables.

Non-participation can cause selection bias— that is, if non-participation is associated with both the family background factors and the outcome depressive symptoms in this study. We found that non-participants at baseline were more likely to come from lower socioeconomic families, but we had no information about their mental health to investigate if the selection was differential. A

former study by Winding et al. about the potential bias caused by non-participation and drop-outs in the same cohort, found no significant influence on a number of relative risk associations, which is assuring for the results of our study [26]. We conducted a complete case-analysis where we only included participants with complete information on all exposure and outcome variables, due to a different number of participants in each age interval analysis and to embrace that it may be different responders with each survey rounds due to non-participation or missing data. The complete case-analysis did not change the results (results not shown) which we find reassuring for the validity of results presented here. We furthermore conducted a sensitivity analysis using a multiple imputation model (results not shown). These results showed some small deviations of the estimates in both directions, however, the assumptions of missing at random may not be fulfilled with the imputation model as the mechanism behind loss to follow-up in this study is unknown and may be related to unmeasured factors, not included in the model.

Information about the late childhood exposure variables family functioning, SSS and negative life events was collected at the same time as the first outcome measure, which could induce common method bias. Reporting of outcome could have been influenced by the fact that participants, who reported poorer family functioning, lower SSS and more negative life events also may be more likely to report depressive symptoms, which potentially could lead to an overestimation of the associations at age 15.

Another limitation in this study may be that the outcome variable of interest was based on self-reported data, which could induce the risk of information bias. Participants should answer four questions regarding their mental health state during the last four weeks; however, it seems unlikely that participants would answer other than correctly or to the most underestimate their

mental health state. As we find it unlikely that they were aware of the exposures of this study, this would induce a non-differential misclassification and hence bias towards the null-hypothesis. However, applying the self-reported exposure variables at age 15 in relation to later depressive symptoms can be prone to reverse causality. If a person is depressed at the time when he or she fills in the baseline questionnaire this may affect the answers on the applied exposure variables in this study. When we apply these variables as late childhood exposures in relation to the outcome at age 15, 18 and 21, the associations may reflect the fact that the person was depressed when the baseline questionnaire was done. This may lead to an overestimation of the associations.

The CES-DC scale was dichotomised at a cut-off value of three and above, as recommended by Fendrich et al. [31]. In this population-based study the proportion of young people with depressive symptoms seemed high, which could be attributed to the fact that we applied a cut-off value originally derived from an American sample, although it does not differ much from findings in other populations [43, 44]. We explored in supplementary analyses whether applying a cut-off value corresponding to the 90^{th} percentile of the CES-DC mean value would change our conclusions. Results showed similar or stronger associations (results not shown). We also applied the scale in its continuous form and results from linear regression models confirm our results (Table 2a). The plots, however, showed that the residuals were not normally distributed following possible transformations.

It is important to stress, that the high proportion of young people in this cohort presenting with depressive symptoms not necessarily reflect clinical symptoms of depression but rather that adolescence and early adulthood are complicated periods of life, due to starting an adult-life with leaving home, job or educational choice. Furthermore, minor mental health problems seem to be

a part of everyday life for many adolescents and young adults living lives with high levels of competition on several issues in modern society.

We adjusted each of the associations for the other exposure variables in the same childhood period because we wanted to explore the independent effect of each exposure variable. These adjustments overall did not alter the results much.

When examining childhood social conditions in relation to mental health in early adulthood, it would be relevant to include adjustment for the young people's own current financial status [45]. Unfortunately, this was not possible; however, many of the participants in this study have not fully established their own financial status due to still living at home or receiving financial help from their parents to support them during their studies.

Generalisability

An in-depth description of the study setting found that the members of this cohort are similar to young people in other parts of Denmark [36]. Therefore, the results of this study may be transferred to young people with similar social and environmental conditions to this Danish cohort, when taking the aforementioned limitations into account.

Conclusion

In this Danish longitudinal study, we found that family socioeconomic factors in both early and late childhood were associated with increased risk of depressive symptoms in adolescence and early adulthood. Timing of low equivalised income, mother's low educational level and mother's low LMP in early and late childhood showed influence at different ages in relation to future depressive symptoms, which may indicate that the timing of these exposure variables may be of some importance in this Youth cohort. The subjective exposure variables in late childhood; family functioning and negative life events were the most prominent risk factors for depressive symptoms, however, these results should be interpreted with cautious due to risk of reverse causality.

Implications

Even in welfare systems like in Denmark, where rules and regulations aim to reduce social inequality and where school/education is free of charge, poorer family factors in childhood are associated with depressive symptoms in adolescence and early adulthood. It is important to address attention to socioeconomic disadvantaged families to decrease stress in the family environment to prevent mental health problems related to childhood social conditions. It also emphasises that further research in the underlying mechanisms are important to better target relevant support.

References

1. World Health Organization. Depression, http://www.who.int/mediacentre/factsheets/fs369/en/accessed October 12 2017).

2. Rosendahl Jensen HA, Davidsen M, Ekholm O, et al. The Danish National Health Profile 2017, accessed March 6, 2019.

3. Bertha EA and Balazs J. Subthreshold depression in adolescence: a systematic review. Eur Child Adolesc Psychiatry 2013, 22,10:589-603.

4. Adler NE and Stewart J. Health disparities across the lifespan: meaning, methods, and mechanisms. Ann N Y Acad Sci 2010, 1186:5-23.

5. Mackenbach JP, Stirbu I, Roskam AJ, et al. Socioeconomic inequalities in health in 22 European countries. N Engl J Med 2008, 358,23:2468-2481.

6. Reiss F. Socioeconomic inequalities and mental health problems in children and adolescents: a systematic review. Soc Sci Med 2013, 90:24-31.

7. Joinson C, Kounali D and Lewis G. Family socioeconomic position in early life and onset of depressive symptoms and depression: a prospective cohort study. Soc Psychiatry Psychiatr Epidemiol 2017, 52,1:95-103.

8. Elovainio M, Pulkki-Raback L, Jokela M, et al. Socioeconomic status and the development of depressive symptoms from childhood to adulthood: a longitudinal analysis across 27 years of follow-up in the Young Finns study. Soc Sci Med 2012, 74, 6:923-929.

9. Wirback T, Moller J, Larsson JO, et al. Social factors in childhood and risk of depressive symptoms among adolescents--a longitudinal study in Stockholm, Sweden. Int J Equity Health 2014, 13:96-014-0096-0.

10. Boe T, Skogen JC, Sivertsen B, et al. Economic volatility in childhood and subsequent adolescent mental health problems: a longitudinal population-based study of adolescents. BMJ Open 2017, 7, 9:e017030.

11. Melchior M, Touchette E, Prokofyeva E, et al. Negative events in childhood predict trajectories of internalizing symptoms up to young adulthood: an 18-year longitudinal study. PLoS One 2014, 9, 12:e114526.

12. Freed RD, Rubenstein LM, Daryanani I, et al. The relationship between family functioning and adolescent depressive symptoms: The role of emotional clarity. Journal of Youth and Adolescence 2016; 45: 505-519.

13. Boe T, Serlachius AS, Sivertsen B, et al. Cumulative effects of negative life events and family stress on children's mental health: the Bergen Child Study. Soc Psychiatry Psychiatr Epidemiol 2018; 53: 1-9.

14. McLoyd VC. Socioeconomic disadvantage and child development. Am Psychol 1998, 53, 2:185-204.

15. Amone-P'Olak K, Burger H, Ormel J, et al. Socioeconomic position and mental health problems in pre- and early-adolescents: the TRAILS study. Soc Psychiatry Psychiatr Epidemiol 2009, 44, 3:231-238.

16. Bjorkenstam E, Pebley AR, Burstrom B, et al. Childhood social adversity and risk of depressive symptoms in adolescence in a US national sample. J Affect Disord 2017, 212:56-63.

17. Votruba-Drzal E. Economic disparities in middle childhood development: does income matter?. Dev Psychol 2006; 42: 1154-1167.

18. Cohen S, Janicki-Deverts D, Chen E, et al. Childhood socioeconomic status and adult health. Ann N Y Acad Sci 2010, 1186:37-55.

19. Sawyer SM, Afifi RA, Bearinger LH, et al. Adolescence: a foundation for future health. Lancet 2012, 379, 9826:1630-1640.

20. Due P, Krolner R, Rasmussen M, et al. Pathways and mechanisms in adolescence contribute to adult health inequalities. Scand J Public Health 2011, 39, 6 suppl:62-78.

21. Dunn EC, McLaughlin KA, Slopen N, et al. Developmental timing of child maltreatment and symptoms of depression and suicidal ideation in young adulthood: results from the National Longitudinal Study of Adolescent Health. Depress Anxiety 2013, 30, 10:955-964.

22. Bjorkenstam E, Cheng S, Burstrom B, et al. Association between income trajectories in childhood and psychiatric disorder: a Swedish population-based study. J Epidemiol Community Health 2017, 71, 7:648-654.

23. Dahl SK, Larsen JT, Petersen L, et al. Early adversity and risk for moderate to severe unipolar depressive disorder in adolescence and adulthood: A register-based study of 978,647 individuals. J Affect Disord 2017; 214: 122-129.

24. Green MJ, Stritzel H, Smith C, et al. Timing of poverty in childhood and adolescent health: Evidence from the US and UK. Soc Sci Med 2018, 197:136-143.

25. McLaughlin KA, Costello EJ, Leblanc W, et al. Socioeconomic status and adolescent mental disorders. Am J Public Health 2012, 102, 9:1742-1750.

26. Winding TN, Andersen JH, Labriola M, et al. Initial non-participation and loss to follow-up in a Danish youth cohort: implications for relative risk estimates. J Epidemiol Community Health 2014, 68, 2:137-144.

27. Schmidt M, Pedersen L and Sorensen HT. The Danish Civil Registration System as a tool in epidemiology. Eur J Epidemiol 2014, 29, 8:541-549.

28. Baadsgaard M and Quitzau J. Danish registers on personal income and transfer payments. Scand J Public Health 2011, 39, 7 suppl:103-105.

29. Jensen VM and Rasmussen AW. Danish Education Registers. Scand J Public Health 2011, 39, 7 suppl:91-94.

30. Hjollund NH, Larsen FB and Andersen JH. Register-based follow-up of social benefits and other transfer payments: accuracy and degree of completeness in a Danish interdepartmental administrative database compared with a population-based survey. Scand J Public Health 2007, 35, 5:497-502.

31. Fendrich M, Weissman MM and Warner V. Screening for depressive disorder in children and adolescents: validating the Center for Epidemiologic Studies Depression Scale for Children. Am J Epidemiol 1990, 131, 3:538-551.

32. Epstein N, Baldwin L and Bishop D. The McMaster family assessment device. Journal of Marital and Family Therapy 1983; 9: 171.

33. Goodman E, Adler NE, Kawachi I, et al. Adolescents' perceptions of social status: development and evaluation of a new indicator. Pediatrics 2001, 108, 2:E31.

34. Newcomb MD, Huba GJ and Bentler PM. A Multidimensional Assessment of Stressful Life Events among Adolescents: Derivation and Correlates. J Health Soc Behav 1981, 22, 4:400-415.

35. Turner RJ and Wheaton. Checklist measurement of stressful life events. In: Anonymous Measuring stress : a guide for health and social scientists, 1997, p.29.

36. Glasscock DJ, Andersen JH, Labriola M, et al. Can negative life events and coping style help explain socioeconomic differences in perceived stress among adolescents? A cross-sectional study based on the West Jutland cohort study. BMC Public Health 2013, 13:532-2458-13-532.

37. Kim TJ and von dem Knesebeck O. Perceived job insecurity, unemployment and depressive symptoms: a systematic review and meta-analysis of prospective observational studies. Int Arch Occup Environ Health 2016; 89: 561-573.

38. Raposa EB, Hammen CL, Brennan PA, et al. Early adversity and health outcomes in young adulthood: the role of ongoing stress. Health Psychol 2014; 33: 410-418.

39. Rueger SY, Malecki CK, Pyun Y, et al. A meta-analytic review of the association between perceived social support and depression in childhood and adolescence. Psychol Bull 2016; 142: 1017-1067.

40. Devenish B, Hooley M and Mellor D. The Pathways Between Socioeconomic Status and Adolescent Outcomes: A Systematic Review. Am J Community Psychol 2017, 59, 1-2:219-238.

41. Elovainio M, Pulkki-Raback L, Hakulinen C, et al. Childhood and adolescence risk factors and development of depressive symptoms: the 32-year prospective Young Finns follow-up study. J Epidemiol Community Health 2015, 69, 11:1109-1117.

42. Bjorkenstam E, Vinnerljung B and Hjern A. Impact of childhood adversities on depression in early adulthood: A longitudinal cohort study of 478,141 individuals in Sweden. J Affect Disord 2017; 223: 95-100.

43. Wojciech B, Magdalena M, Magdalena K, et al. Socioeconomic determinants of depressive symptoms in a Polish population. Mental Health and Prevention 2015; 3: 152-156.

44. Zhou Q, Fan L and Yin Z. Association between family socioeconomic status and depressive symptoms among Chinese adolescents: Evidence from a national household survey. Psychiatry Res 2017, 259:81-88.

45. Stansfeld SA, Clark C, Rodgers B, et al. Childhood and adulthood socio-economic position and midlife depressive and anxiety disorders. Br J Psychiatry 2008, 192, 2:152-153.

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None

List of abbreviations

Adjusted odds ratio	AOR
Center for Epidemiologic Studies Depression Scale for Children	CES-DC
Confidence interval	CI
Exempli gratia	E.g.
Labour market participation	LMP
Odds ratio	OR
Socioeconomic position	SEP
Subjective social status in society	SSS
Year	Yr

Declarations

Ethics approval and consent to participate

The study was carried out according to the Declaration of Helsinki. According to Danish law, approval by the Ethics Committee and written informed consent is not required in questionnaire-

based and register-based projects. Additional information is available at The National Committee on Health Research Ethics' webpage in the "Act on Research Ethics Review of Health Research Projects" § 14,2. Available from http://www.nvk.dk/english/act-on-research. Use of the data was carried out under the same conditions and with the same purpose as when originally collected and based on approval from the Danish Data Protection Agency and their rules of data protection.

Consent to publish

Not applicable

Availability of data and materials

The data that support the findings of this study are available from Statistics Denmark but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Statistics Denmark.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

PHP designed the study and performed the analyses and wrote the main paper.

KB helped in designing the study and analysing data.

TNW helped in designing the study and analysing data.

EAN helped in designing the study and analysing data.

JHA initiated the study and helped in designing the study and analysing data.

All authors interpreted the results and their implications and commented on the manuscripts at all stages.

All authors read and approved the final manuscript.

Endnotes

[a] Mean equivalised income categorised at 33.3rd; 66.6thpercentile, [b] Mother's mean labour market participation dichotomised ≥0.80 (high score), [c] Mother's highest educational level, [d] Mutual adjusted (adj.) for other early childhood exposures and gender, [e] Subjective social status in society, [f] Mutual adj. for other late childhood exposures, early childhood equivalised income and gender, [g] Mutual adj. for other late childhood exposures, mother's LMP in early childhood and gender, [h]

Mutual adj. for other late childhood exposure variables, mother's education in early childhood and gender, [i] Mutual adj. for other late childhood exposure variables and gender.

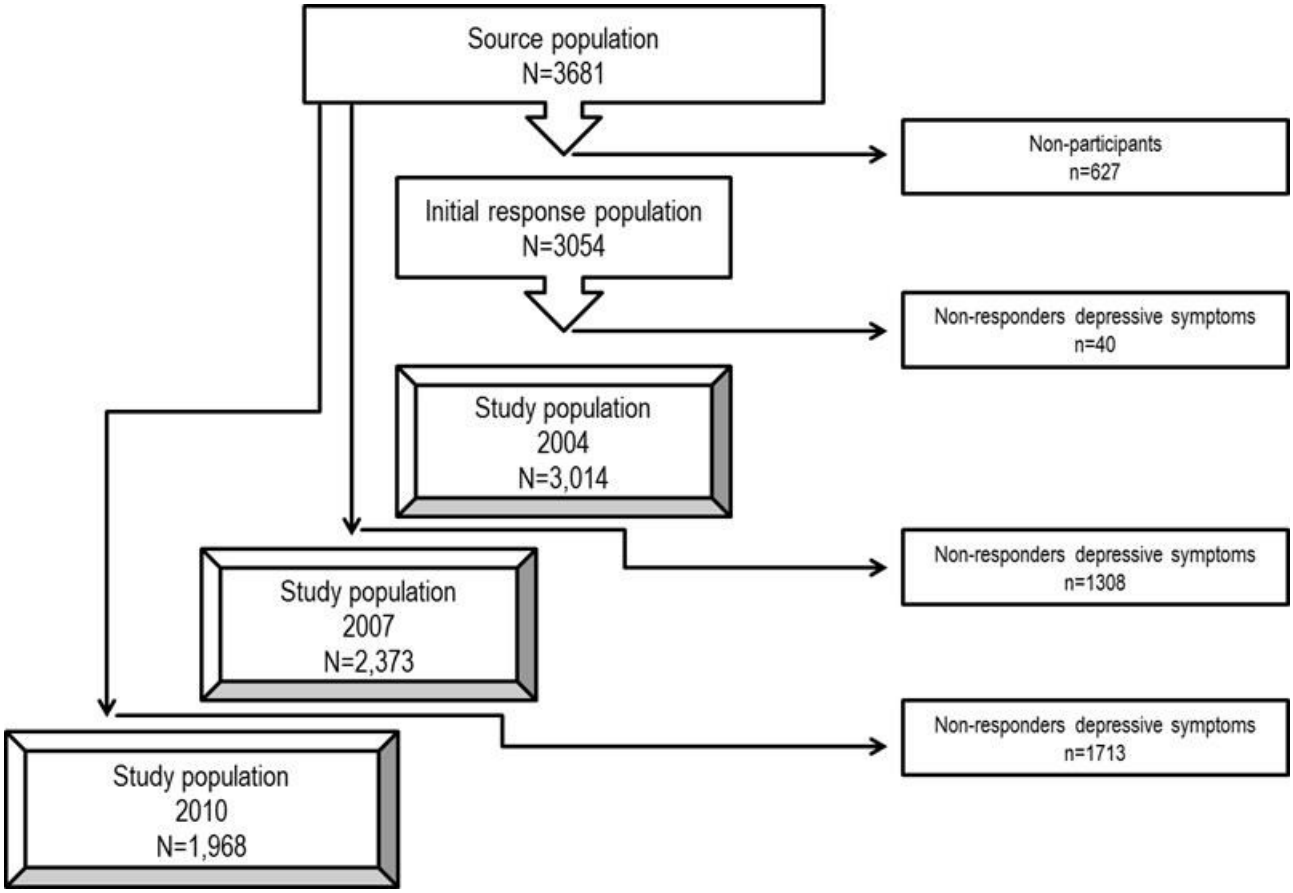

Fig. 1. Baseline participation and participation to follow-ups in 2007 and 2010.

Table 1. Distribution of family factors in early and late childhood in relation to depressive symptoms at age 15, 18 and 21 (N=3014).

Variables	15			18			21		
		Depressive symptoms			Depressive symptoms			Depressive symptoms	
	n	n	n (%)	n	n	n (%)	n	n	n (%)
Gender	3,014			2,373			1,968		
Girls		1,523	594 (39)		1,280	720 (56)		1,104	461 (42)
Boys		1,491	453 (30)		1,093	435 (40)		864	297 (34)
Early childhood									
Income[a]	2,898			2,288			1,915		
High		1,013	350 (35)		847	404 (48)		668	226 (34)
Medium		986	337 (34)		748	370 (49)		645	253 (39)
Low		899	319 (35)		693	340 (49)		602	257 (43)
LMP[b]	2,952			2,370			1,965		
High score		2,057	677 (33)		1,678	812 (48)		1,399	532 (38)
Low score		895	349 (39)		692	341 (49)		566	225 (40)
Mother´s education 1997[c]	2,869			2,307			1,934		
1 (>13 yr)		784	271 (35)		668	338 (51)		572	210 (37)
2 (11-13 yr)		1,292	423 (33)		1,022	473 (46)		855	308 (36)
3 (≤10 yr)		793	293 (37)		617	306 (50)		507	227 (45)
Late childhood									
Income[a]	2,949			2,341			1,940		
High		1,048	328 (31)		864	416 (48)		684	233 (34)
Medium		1,003	357 (36)		814	389 (48)		695	276 (40)
Low		898	327 (36)		663	329 (50)		561	235 (42)
LMP[b]	2,939			2,359			1,957		
High score		2,217	745 (34)		1,828	880 (48)		1,521	557 (37)
Low score		722	277 (38)		531	268 (50)		436	195 (45)
Mother´s education 2003[c]	2,910			2,334			1,948		
1 (>13 yr)		879	303 (34)		742	370 (50)		620	236 (38)
2 (11-13 yr)		1,343	439 (33)		1,063	491 (46)		887	312 (35)
3 (≤10 yr)		688	263 (38)		529	270 (51)		441	204 (46)
Family functioning	2,894			2,071			1,738		
Good (ref.grp)		2,142	607 (28)		1,581	202 (41)		1,320	449 (34)
Poor		752	395 (53)		490	288 (59)		418	210 (50)
Subjective social status[e]	2,935			2,110			1,769		
High		971	284 (29)		693	314 (45)		572	194 (34)
Average		1,917	714 (37)		1,384	697 (50)		1,169	467 (40)
Low		47	24 (51)		33	20 (61)		28	15 (54)
Negative life-events	2,988			2,143			1,790		
<2		2,585	840 (33)		1,910	900 (47)		1,614	590 (37)
≥2		403	198 (49)		233	140 (60)		176	91 (52)

[a]Mean equivalised income categorized at 33.3rd;66.6th percentile

[b]Mother´s mean labour market participation dichotomized ≥0.80 (high score)

[c]Mother´s highest educational level

[e]Subjective social status in society

Table 2. The association between income, mother´s labour market participation (mother´s LMP), mother´s highest education level (mother´s education) in early and late childhood and depressive symptoms at age 15 (N=3,014), 18 (N=2,373) and 21 (N=1,968).

	15			18			21		
	n	OR	n	AOR (95% CI)	n	OR	n	AOR (95% CI)	n	OR	n	AOR (95% CI)
Early childhood												
Income[a]	2,898		2,800		2,288		2,256		1,915		1,898	
High (ref.grp.)		1		1[d]		1		1[d]		1		1[d]
Medium		1.0		1.0 (0.8;1.2)		1.1		1.1 (0.9;1.3)		1.3		1.2 (0.9;1.6)
Low		1.0		1.0 (0.8;1.2)		1.1		1.1 (0.8;1.3)		1.5		1.4 (1.1;1.8)
Mother´s LMP	2,952		2,800		2,370		2,256		1,965		1,898	
High score (ref.grp.)		1		1[d]		1		1[d]		1		1[d]
Low score		1.3		1.3 (1.1;1.5)		1.0		1.1 (0.9;1.3)		1.1		1.0 (0.8;1.3)
Mother´s education	2,869		2,800		2,307		2,256		1,934		1,898	
1 (>13 yr) (ref.grp.)		1		1[d]		1		1[d]		1		1[d]
2 (11-13 yr)		0.9		0.9 (0.7;1.0)		0.8		0.8 (0.7;1.0)		1.0		0.9 (0.7;1.2)
3 (≤10 yr)		1,1		1.0 (0.8;1.2)		1.0		1.0 (0.8;1.2)		1.4		1.3 (1.0;1.7)
Late childhood												
Income[a]	2,949		2,581		2,341		1,919		1,940		1,631	
High (ref.grp.)		1		1[f]		1		1[f]		1		1[f]
Medium		1.2		1.2 (0.9;1.4)		1.0		0.9 (0.8;1.2)		1.3		1.2 (0.9;1.6)
Low		1.3		1.2 (0.9;1.5)		1.1		1.0 (0.8;1.4)		1.4		1.1 (0.8;1.6)
Mother´s LMP	2,939		2,649		2,359		1,961		1,957		1,661	
High score (ref.grp.)		1		1[g]		1		1[g]		1		1[g]
Low score		1.2		1.0 (0.8;1.2)		1.1		1.0 (0.8;1.3)		1.4		1.4 (1.0;1.8)
Mother´s education	2,910		2,637		2,334		1,953		1,948		1,656	
1 (>13 yr) (ref.grp.)		1		1[h]		1		1[h]		1		1[h]
2 (11-13 yr)		0.9		1.1 (0.7;1.9)		0.9		1.1 (0.6;1.9)		0.9		0.5 (0.2;0.9)
3 (≤10 yr)		1.2		1.5 (0.8;2.9)		1.0		1.2 (0.6;2.4)		1.4		0.9 (0.4;2.0)

[a]Mean equivalised income categorized at 33.3rd,66.6th percentile

[d]Mutual adjusted (adj.) for other early childhood exposures and gender

[f]Mutual adj. for other late childhood exposures, early childhood equivalised income and gender

[g]Mutual adj. for other late childhood exposures, mother´s LMP in early childhood and gender

[h]Mutual adj. for other late childhood exposure variables, mother´s education in early childhood and gender

Table 3. The association between family functioning, subjective social status in society, negative life events in late childhood and depressive symptoms at ages 15 (N=3,014), 18 (N=2,373) and 21 years (N=1,968).

	15				18				21			
	n	OR	n	AOR (95% CI)	n	OR	n	AOR (95% CI)	n	OR	n	AOR (95% CI)
Family functioning	2,894		2,649		2,071		1,961		1,738		1,661	
Increase per unit		2.9		2.6 (2.2;3.1)		1.9		1.8 (1.5;2.2)		2.0		1.9 (1.6;2.4)
Subjective social status	2,935		2,649		2,110		1,961		1,769		1,661	
High (ref.grp.)		1		1[i]		1		1[i]		1		1[i]
Average		1.4		1.2 (1.0;1.5)		1.2		1.1 (0.9;1.3)		1.3		1.1 (0.8;1.3)
Low		2.5		1.0 (0.5;2.1)		1.9		0.9 (0.4;2.1)		2.2		0.7 (0.3;1.8)
Negative life events	2,988		2,646		2,143		1,961		1,790		1,661	
<2 (ref.grp.)		1		1[i]		1		1[i]		1		1[i]
≥2		2.0		1.7 (1.3;2.2)		1.7		1.4 (0.9;1.9)		1.9		1.2 (0.8;1.7)

[i]Mutual adj. for other late childhood exposure variables and gender

Table 2a. The association between equivalised income, mother's labour market participation (mother's LMP), mother's highest education level (mother's education) in early and late childhood (family functioning, subjective social status, negative life events) and depressive symptoms at age 15, 18 and 21.

	15				18				21			
	n	β	n	β (95% CI)	n	β	n	β (95% CI)	n	β	n	β (95% CI)
Early childhood												
Equivalised income (low—high)	2,898	-0.18	2,800	-0.03 (-0.38;0.32)[d]	2,288	0.01	2,256	0.09 (-0.33;0.50)[d]	1,915	-0.49	1,898	-0.32 (-0.80;0.15)[d]
Mother's LMP (high—low)	2,952	0.29	2,800	0.23 (0.05;0.42)[d]	2,370	0.11	2,256	0.08 (-0.13;0.30)[d]	1,965	0.18	1,898	0.12 (-0.11;0.36)[d]
Mother's education (high—low)	2,869	0.08	2,800	0.02 (-010;0.13)[d]	2,307	-0.02	2,256	-0.03 (-0.16;0.10)[d]	1,934	0.22	1,898	0.18 (0.04;0.33)[d]
Late childhood												
Equivalised income (low—high)	2,949	-0.10	2,581	0.04 (-0.14;0.23)[f]	2,341	-0.08	1,919	-0.03 (-0.24;0.18)[f]	1,940	-0.31	1,631	-0.19 (-0.45;0.06)[f]
Mother's LMP (high—low)	2,939	0.38	2,649	0.18 (-0.01;0.37)[g]	2,359	0.10	1,961	-0.02 (-0.29;0.24)[g]	1,957	0.43	1,661	0.31 (0.02;0.60)[g]
Mother's education (high—low)	2,910	0.07	2,649	-0.07 (-0.18;0.04)[h]	2,334	0.01	1,953	-0.05 (-0.41;0.32)[h]	1,948	0.21	1,656	0.05 (-0.38;0.47)[h]
Family functioning (good—poor)	2,894	1.44	2,649	1.31 (1.16;1.46)[i]	2,071	1.00	1,961	0.93 (0.74;1.13)[i]	1,738	0.92	1,661	0.82 (0.61;1.04)[i]
Subjective social status (high—low)	2,935	0.48	2,649	0.15 (-0.01;0.31)[i]	2,110	0.40	1,961	0.23 (0.03;0.44)[i]	1,769	0.43	1,661	0.09 (-0.14;0.31)[i]
Negative life events (none—≥2)	2,988	0.87	2,649	0.54 (0.29;0.79)[i]	2,143	0.61	1,961	0.29 (-0.04;0.63)[i]	1,790	0.81	1,661	0.16 (-0.22;0.55)[i]

[d] Mutual adjusted (adj.) for other early childhood exposures and gender

[f] Mutual adj. for other late childhood exposures, early childhood equivalised income and gender

[g] Mutual adj. for other late childhood exposures, mother's LMP in early childhood and gender

[h] Mutual adj. for other late childhood exposure variables, mother's education in early childhood and gender

[i] Mutual adj. for other late childhood exposures and gender

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How does childhood socioeconomic position affect overweight and obesity in adolescence and early adulthood: a longitudinal study

Per Hoegh Poulsen[1*], Karin Biering[1], Trine Nøhr Winding[1], Ellen Aagaard Nohr[2] and Johan Hviid Andersen[1]

Abstract

Background: Childhood socioeconomic position (SEP) has previously been associated with increased risk of overweight among children and adolescents. However, it remains uncertain whether the timing of exposure is important in relation to developing overweight in early adulthood. We aimed to examine how SEP during early (0–8 years) and late childhood (9–14 years) relates to overweight at age 15, 18 and 21.

Methods: Longitudinal study in Western Denmark of 2879 young people (aged 15 in 2004). Exposure variables from registers were yearly household income, parental highest educational level and parental labour market participation (LMP), supplemented with questionnaire information about "family functioning" (age 15). Outcome variables were overweight and obesity, measured at three-time points.
We analyzed the adjusted associations between childhood SEP and overweight and obesity using multinomial logistic regression, stratified on gender.

Results: Early childhood: Parental lower educational level increased girls' risk of overweight and obesity at age 18 and 21 between RR = 1.8 (95% CI 1.0;3.4) and RR = 5.2 (95% CI 1.4;19.3). Girls reporting poor "family functioning" had up to twice the risk of overweight and obesity at age 21. Boys, whose fathers had a lower level of education had up to 2.4 times the risk of obesity at age 21. Parental low LMP increased boys' risk of obesity at age 18 and 21 between RR = 2.2 (95% CI 1.3;3.8) and RR = 2.8 (95% CI 1.3;6.1). Late childhood: Parental lower level of education tripled the risk of overweight and obesity among girls at age 18 and among both genders at age 21.

Conclusion: This study confirmed to some extent that economic, social and psychological insecurity and inequality as measured by lower parental educational level, lower household income, low labour market participation and poor family function during childhood was associated with an increased risk of overweight and especially obesity in adolescence and early adulthood in both genders. Despite some imprecise measures, the direction of the associations pointed to several associations, which all were in the hypothesized direction. Timing of lower household income and parental low LMP in childhood seemed to be gender-specific in some way, but this warrants more studies.

Keywords: Young people, Childhood socioeconomic exposures, Timing of exposure, Overweight, Gender-specific differences

* Correspondence: perhpo@rm.dk
[1]Danish Ramazzini Centre, Department of Occupational Medicine, University Research Clinic, Regional Hospital West Jutland, Gl. Landevej 61, 7400 Herning, Denmark
Full list of author information is available at the end of the article

Background

Prevalence of overweight and obesity has increased worldwide over the last decades [1]. In Denmark, the overall prevalence of overweight and obese children and adolescents appears to be stable or slowly declining [2]. Recent findings show that 26% of young Danes aged 16–24 are overweight and obese. This percentage has been increasing among both genders since 2010, with the highest prevalence among those having primary school as the highest level of education [3].

Overweight and obesity has traditionally been associated with a thermodynamic explanatory model [4] combined with genetics, where preventive initiatives primarily have focused on healthy diet, increased physical activity and lifestyle changes, showing modest associations [5]. In recent years theories about economic, social and psychological insecurity and inequality in relation to obesity has gained ground [6, 7]. The theory which involves social insecurity pursues the hypothesis that obesity could be a healthy active response to an expected future lack of energy [8]. In higher income countries with easily access to energy-dense food, exposure to economic, social and psychological insecurity and inequality in terms of low socioeconomic position (SEP) may induce excessive weight gain [9, 10].

According to SEP and future physical health, Newton et al. concluded that the inverse relationship between low life-course SEP and obesity was consistent for women, not for men [11]. These findings were also reported by a recent review, which concluded that perceived financial hardship before the age of 16 and having an unemployed father were associated with a higher Body Mass Index (BMI) in males. Among females, it was primarily low paternal education level which was associated with a higher BMI [12]. Brisbois et al. found that father's lower employment status as a proxy for childhood SEP appeared to be an early (before the age of 5) marker of obesity among adults in both genders [13].

The health of young people is strongly affected by social factors at a personal, family and societal level. One of the strongest determinants of health is income inequality [14]. In the review by Halliday et al. it was argued that the social factor "family functioning" may be an important risk factor for physical health, hence poor "family functioning" was associated with an increased risk of overweight and obesity among children and adolescents [15]. Family functioning covers a person's perception on e.g. how crisis may be dealt with in the nearest family, thereby adding an individual perspective to the family level.

Previous research has predominantly focused on early childhood in relation to physical health in later childhood and adolescence. However, research using longitudinal datasets to address and explore the pathways and mechanisms by which low income/SEP exerts its long term effect on physical health are needed [16]. Especially the age-period 18–26 years appears to be critical by having profound and long-lasting implications for young people's future health and well-being [17]. Another sensitive period of development appears to be adolescence thereby indicating that the timing of SEP exposure may be an important issue to address in relation to future health problems [18].

How does the timing of several socioeconomic exposures at the family level during the entire span of childhood relate to later risk of overweight and obesity? By including both objective and subjective exposure variables in a longitudinal design we aimed to contribute to the scientific knowledge in this field. Our purpose was to explore the association between SEP during early childhood (0–8 year) and late childhood (9–14 year) and overweight and obesity at age 15, 18 and 21 years.

Methods

Design and population

The study was a prospective cohort study. Data was collected as part of the West Jutland Cohort Study (VestLiv), which is an ongoing Danish longitudinal study following a complete cohort of young people born in 1989 and residing in the former Ringkoebing County in 2004. The source population comprised 3681 young people. Recruitment of participants took place at the schools within the county where a baseline questionnaire was completed during school hours in 2004 when the participants were approximately 15 years old. Those not at school on the day of collection received the questionnaire by mail. Of the potential 3681 responders, 3054 (83%) participated in this study. All the potential responders in 2004 were re-invited to participate at the latter waves.

The project has so far included waves of questionnaires in 2004 (age 15), 2007 (age 18) and 2010 (age 21) (http://www.vestliv.dk), which furthermore have been supplemented with a range of register-based information.

A more thorough information on recruitment and data collection has been presented elsewhere [19].

Participants were included in this current study if they had responded to the questions about weight and height in one of the three questionnaire rounds. This was obtained for 2879 in 2004, 2308 in 2007 and 1974 in 2010. Attrition and missing data reduced the sample as shown in Fig. 1.

Data comprised a combination of both questionnaire data and register data. In Denmark, every citizen is provided with a CPR-number (Civil Registration Number) at birth (or upon entry for immigrants), which allowed the researchers to link the CPR number of each child to parental information from registers [20].

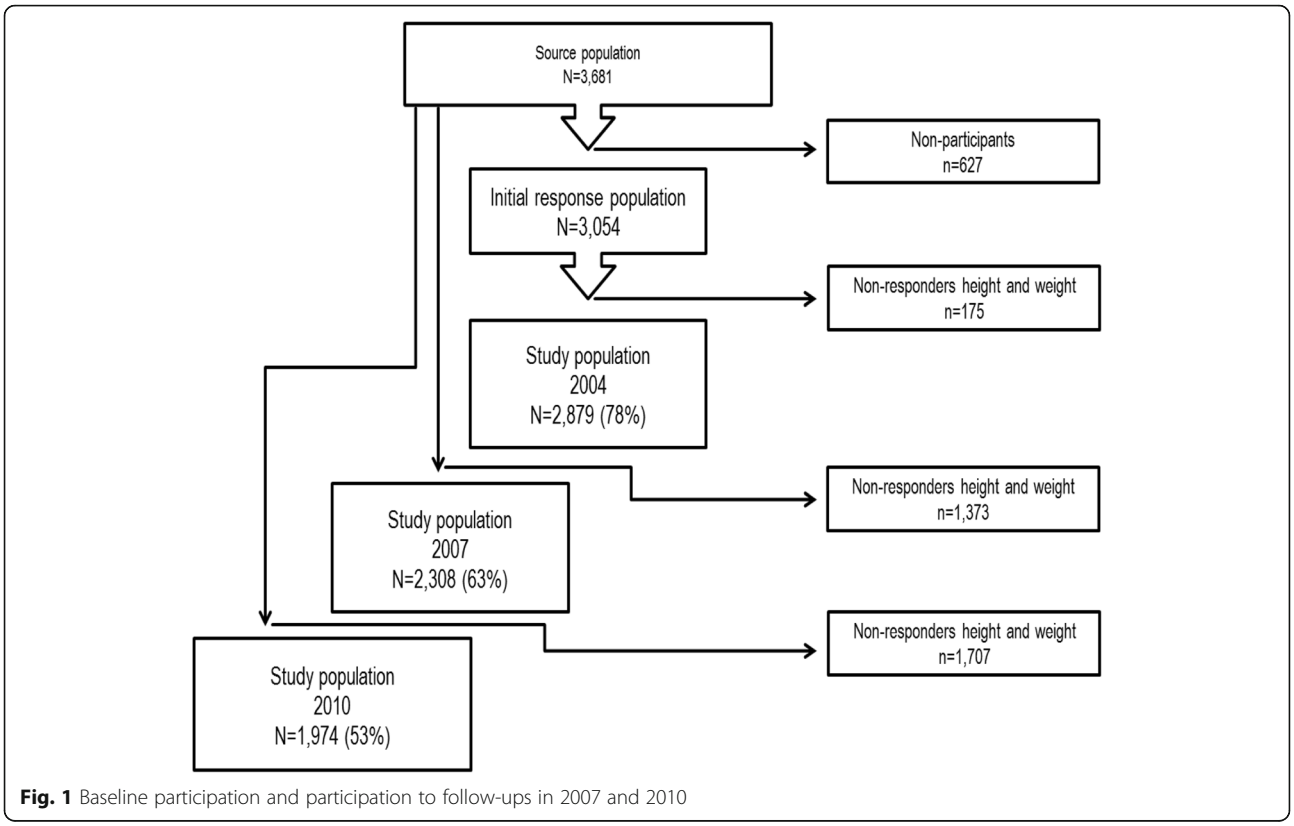

Fig. 1 Baseline participation and participation to follow-ups in 2007 and 2010

Definition of outcome

The outcome measure was overweight and obesity, defined by Body Mass Index (BMI), which was calculated from self-reported weight and height (weight/height^2) collected at all three questionnaire rounds (age 15, 18 and 21).

At 18 and 21 years of age, participants were categorized as "normal weight" (BMI ≤24.99), "overweight" (BMI 25 to 27.49) or "obese" (BMI ≥27.50), due to additional cut-off points from the Global Database on Body Mass Index [21]. Because there were very few 15 year old obese in this cohort, participants were at this age dichotomized into "normal weight" (< 23.29 kg/m^2 for boys and < 23.94 kg/m^2 for girls), and "overweight" (BMI ≥23.29 kg/m^2 for boys and BMI ≥23.94 kg/m^2 for girls) using thresholds for 15 year old girls and boys [22].

Definition of exposures

Childhood SEP was defined by yearly household income, parental highest educational level, parental labour market participation (LMP) and "family functioning" to uncover aspects of both economic and social inequality at the family level. Two age-intervals in childhood was applied; early childhood (0–8 year) and late childhood (9–14 year).

Information on yearly household income was from the Danish register on personal income and transfer payments [23] and parental highest educational level was derived from different educational registers [24]. Parental LMP was derived from the DREAM register [25], which provides information on social benefits and information on payments related to e.g. unemployment benefits and sickness absence compensation on a weekly basis [25].

Yearly household income was a continuous variable collected each year from 1989 (birth of child) and onwards until 2003 (age 14). The variable consisted of information on all residents above 18 years in the household living together with the child. Information about household income had to be available for at least five years in an age-interval in childhood to calculate a mean value. Household income was categorized into low, medium or high income according to the 33.3rd and 66.6th percentile.

Information about parental highest educational level was included for each parent from the year 1989 and year 2003 and was divided into three categories: < 10, 10–13, > 13 years of education. If information on highest educational level was missing for year 2003, information was used from previous years (last observation carried forward).

Parental LMP was defined according to the degree of receiving social benefits within each year from 1991 to 2003. When we defined this variable, we omitted payments due to receiving maternity leave benefits or state educational grants. Information about LMP had to be available for at least four years in an age-interval in

childhood to calculate a mean LMP score [26]. LMP was a continuous variable in the range from 0 to 100 and calculated as a yearly mean LMP score for each parent in each age-interval and dichotomized into "high LMP" and "low LMP" at a cut off value of ≥0.80 indicating high LMP [27].

Information about "family functioning" was obtained from the initial questionnaire and is a categorical variable with 12 items based on the General functioning subscale of the McMaster Family Assessment Device (FAD), developed by Epstein et al. This variable assesses the overall health/pathology of the family. We calculated a mean value for the 12 items and dichotomized the variable at the 75th percentile of the mean value indicating poor "family functioning" at ≥2.08 [28].

Additional variables

High birth-weight and parental marital status have previously been associated with an increased risk of later overweight and obesity [29–32].

Birth-weight was obtained from the Danish Medical Birth Register; a national register which contains information about all births in hospital and home births [33]. We applied the variable split home as a dichotomous variable with yearly information obtained from the CPR register on whether the child lived together with both parents or not. In this study, split home in 1989 (at birth) and split home in 2003 (age 14) was applied for early and late childhood, in that order.

Statistical methods

Multinomial logistic regression models were used to calculate the associations between the exposure variables during early or late childhood and overweight and obesity at age 18 and 21. Results are presented with unadjusted and adjusted relative risks (ARR). The adjusted results are shown with 95% confidence interval (95% CI). At age 15, we applied logistic regression models to calculate the associations between the exposure variables and overweight. Correlation analyses were carried out for all the exposure variables by Spearman's rank correlation coefficient. The correlations between mean yearly household income in early and late childhood and between parental highest educational level in early and late childhood was very high. The correlation between mean yearly household income and mean LMP of the father showed a Spearman's rho = 0.3631. The correlation coefficient between mean LMP of the mother and mother's highest educational level in 1989 was rho = 0.2925 (Additional file 1: Table S1). Since the rest of the correlation coefficients were similar or lower, all analyses were mutually adjusted for all other exposure variables and birth weight as a continuous variable. Furthermore, the variable split home 1989 was applied to early childhood adjustments, whereas the variable split home 2003 was applied to late childhood adjustments. Moreover, when examining the associations between mean yearly household income in late childhood and overweight and obesity in adolescence and early adulthood, we also adjusted the associations for the yearly household income exposure in early childhood. When we did the analyses for parental LMP in late childhood and overweight and obesity, we also adjusted the associations for the same exposure variable in early childhood. These adjustments were applied to take the effect of the early childhood exposure into account.

Sub-analyses explored whether non-participants at baseline were significantly different from participants with respect to SEP (tables not shown). Data-analysis was performed by the statistical package Stata, statistical software version 14.2 (Stata Corporation, College Station, Texas, USA).

Ethics

Use of the data is carried out under the same conditions and with the same purpose as when originally collected and based on approval from the Danish Data Protection Agency and their rules of data protection. According to Danish law, approval by the Ethics Committee and written informed consent was not required in questionnaire-based and register-based project.

Results

Descriptive data of the exposure variables in relation to the outcome at age 18 and 21 are presented for each gender in Table 1.

A higher proportion of overweight and obesity at age 18 and 21 was observed in both genders if they grew up with lower educated parents or if their mothers had a low LMP during their early childhood. Among boys, a higher proportion of obesity at age 18 and 21 was also observed in low income families or if they had a father with low LMP during their early childhood.

A higher proportion of overweight and obesity at age 18 and 21 was likewise observed in both genders, if they grew up with lower educated parents during their late childhood. A higher proportion of obesity was observed among both genders at age 21 in lower income families during their late childhood. Furthermore, among girls, a higher proportion of overweight and obesity at age 18 and 21 was observed if their parent's had low LMP or the girls reported poor "family functioning" during their later childhood.

15-year-old girls had increased risk of overweight, if they reported poor "family functioning"; OR = 1.7, 95% CI 1.1;2.7 (table not shown).

15-year-old boys had an increased risk of overweight, if their fathers had a low LMP or the boys came from

Table 1 Distribution of exposure variables in relation to normal weight, overweight and obesity at age 18 and 21 ($N = 2308$)

Variables	Girls								Boys							
	18				21				18				21			
		Normal	Overweight	Obesity		Normal	Overweight	Obesity		Normal	Overweight	Obesity		Normal	Overweight	Obesity
Early childhood	n	n (%)	n (%)	n (%)	n	n (%)	n (%)	n (%)	n	n (%)	n (%)	n (%)	n	n (%)	n (%)	n (%)
Income[a]	1200				1060				1030				861			
High		392 (88)	30 (7)	22 (5)		291 (78)	41 (11)	40 (11)		319 (82)	42 (11)	27 (7)		241 (74)	57 (17)	30 (9)
Medium		354 (83)	42 (10)	29 (7)		274 (72)	46 (12)	61 (16)		310 (83)	33 (9)	29 (8)		224 (72)	47 (15)	42 (13)
Low		284 (86)	29 (9)	18 (5)		227 (74)	33 (11)	47 (15)		209 (77)	29 (11)	32 (12)		156 (71)	30 (14)	34 (15)
LMP[b] (mother)	1239				1085				1066				883			
High score		756 (88)	61 (7)	47 (5)		590 (78)	71 (9)	99 (13)		637 (82)	77 (10)	58 (8)		490 (77)	86 (13)	62 (10)
Low score		312 (83)	40 (11)	23 (6)		228 (70)	48 (15)	49 (15)		231 (78)	32 (11)	31 (11)		152 (62)	48 (20)	45 (18)
LMP[b] (father)	1228				1074				1062				881			
High score		928 (86)	85 (8)	63 (6)		715 (75)	105 (11)	130 (14)		778 (82)	93 (10)	73 (8)		576 (73)	124 (15)	93 (12)
Low score		131 (86)	15 (10)	6 (4)		94 (76)	14 (11)	16 (13)		87 (74)	15 (13)	16 (13)		64 (73)	10 (11)	14 (16)
Highest educational level (mother) 1989	1165				1034				1001				841			
1 (> 13 yr)		242 (90)	17 (6)	10 (4)		197 (83)	17 (7)	23 (10)		228 (86)	22 (8)	17 (6)		191 (80)	27 (11)	21 (9)
2 (10–13 yr)		480 (88)	42 (8)	23 (4)		390 (79)	47 (9)	59 (12)		347 (83)	46 (11)	27 (6)		243 (72)	62 (18)	34 (10)
3 (< 10 yr)		279 (79)	38 (11)	34 (10)		187 (62)	52 (17)	62 (21)		238 (76)	34 (11)	42 (13)		174 (66)	43 (16)	46 (18)
Highest educational level (father) 1989	1119				984				965				801			
1 (> 13 yr)		225 (92)	15 (6)	4 (2)		177 (85)	12 (6)	19 (9)		189 (84)	20 (9)	15 (7)		163 (81)	25 (12)	13 (7)
2 (10–13 yr)		493 (84)	56 (9)	39 (7)		375 (73)	59 (12)	78 (15)		401 (82)	49 (10)	38 (8)		274 (71)	63 (17)	47 (12)
3 (< 10 yr)		241 (84)	25 (9)	21 (7)		180 (68)	41 (16)	43 (16)		195 (77)	26 (10)	32 (13)		142 (66)	40 (18)	34 (16)
Late childhood																
Income[a]	1222				1072				1053				876			
High		408 (88)	34 (8)	20 (4)		303 (78)	46 (12)	39 (10)		325 (83)	42 (11)	26 (6)		238 (72)	60 (18)	33 (10)
Medium		365 (84)	36 (8)	32 (8)		293 (75)	37 (10)	60 (15)		308 (82)	33 (9)	34 (9)		229 (73)	48 (15)	39 (12)
Low		277 (85)	32 (10)	18 (5)		210 (71)	36 (12)	49 (17)		225 (79)	31 (11)	29 (10)		170 (74)	26 (11)	33 (15)
LMP[b] (mother)	1228				1076				1059				879			
High score		827 (88)	67 (7)	47 (5)		633 (77)	83 (10)	106 (13)		685 (82)	84 (10)	68 (8)		511 (73)	107 (15)	83 (12)
Low score		230 (80)	34 (12)	23 (8)		177 (69)	36 (14)	42 (17)		178 (80)	23 (10)	21 (10)		129 (72)	25 (14)	24 (14)
LMP[b] (father)	1213				1057				1049				868			
High score		921 (87)	87 (8)	56 (5)		718 (76)	100 (11)	119 (13)		777 (82)	99 (10)	75 (8)		564 (71)	130 (17)	95 (12)

Table 1 Distribution of exposure variables in relation to normal weight, overweight and obesity at age 18 and 21 (*N* = 2308) *(Continued)*

Variables	Girls								Boys							
	18				21				18				21			
		Normal	Overweight	Obesity		Normal	Overweight	Obesity		Normal	Overweight	Obesity		Normal	Overweight	Obesity
Low score		126 (84)	13 (9)	10 (7)		80 (67)	18 (15)	22 (18)		77 (79)	9 (9)	12 (12)		66 (83)	3 (4)	10 (13)
Highest educational level (mother) 2003	1225				1076				1048				876			
1 (> 13 yr)		338 (91)	22 (6)	13 (3)		269 (84)	24 (7)	29 (9)		296 (84)	32 (9)	24 (7)		241 (79)	38 (12)	27 (9)
2 (10–13 yr)		494 (87)	48 (8)	28 (5)		392 (76)	55 (11)	70 (13)		378 (82)	53 (12)	29 (6)		258 (71)	64 (17)	43 (12)
3 (< 10 yr)		224 (79)	30 (11)	28 (10)		152 (64)	39 (17)	46 (19)		181 (77)	21 (9)	34 (14)		139 (68)	32 (16)	34 (16)
Highest educational level (father) 2003	1171				1026				1025				847			
1 (> 13 yr)		276 (92)	19 (6)	5 (2)		215 (85)	16 (6)	23 (9)		224 (83)	26 (10)	20 (7)		194 (81)	31 (13)	15 (6)
2 (10–13 yr)		496 (84)	54 (9)	41 (7)		384 (74)	58 (11)	77 (15)		418 (83)	52 (10)	37 (7)		284 (72)	62 (16)	50 (12)
3 (< 10 yr)		235 (84)	24 (9)	21 (7)		172 (68)	40 (16)	41 (16)		195 (78)	24 (10)	29 (12)		138 (65)	39 (19)	34 (16)
Family functioning[c]	1088				967				932				773			
Good		728 (87)	63 (8)	44 (5)		567 (78)	76 (10)	87 (12)		573 (81)	71 (10)	63 (9)		419 (71)	91 (16)	79 (13)
Poor		208 (82)	29 (12)	16 (6)		158 (67)	30 (12)	49 (21)		186 (83)	26 (11)	13 (6)		136 (74)	29 (16)	19 (10)

[a]Yearly household income categorized at 33.3rd;66.6th percentile
[b]Labour market participation dichotomized ≥0.80 (high score)
[c]Family functioning, measured at age 15

families with parents having a low level of education during their early childhood, with estimates ranging from OR = 1.6, 95% CI 0.9;2.9 to OR = 2.2, 95% CI 1.2;3.8. Parental low educational level during their late childhood almost doubled boys' risk of overweight at 15 years of age, OR = 1.9, 95% CI 1.1;3.3. It also gave the impression that boys who grew up in low income families had some increased risk of overweight at age 15, although this being imprecise results (OR = 1.7, 95% CI 0.9;3.1) (table not shown).

Girls, whose mother had a lower educational level in their early childhood, had increased risk of overweight and obesity at age 21, RR = 1.9, 95% CI 1.0;3.8 and RR = 2.1, 95% CI 1.1;3.9, respectively. This tendency was also seen with father's lower educational level, which increased the risk of overweight and obesity at both age 18 and 21, with estimates ranging from RR = 1.8, 95% CI 1.0;3.4 to RR = 5.2, 95% CI 1.4;19.3. Likewise, reporting poor "family functioning" increased girls' risk of overweight at the age of 18 and obesity at the age of 21 between 1.6 and 2 times (Table 2).

Boys, whose mother had low LMP during their early childhood, had about twice the risk of overweight and obesity at the age of 21 (RR = 2.0, 95% CI 1.2;3.2, RR = 2.2, 95% CI 1.3;3.8). Boys, whose father had a lower level of education during their early childhood, had up to 2.4 times increased risk of obesity at age 21 (RR = 2.4, 95% CI 1.1;5.4). Furthermore, father's low LMP during early childhood increased boys' risk of obesity at the age of 18, RR = 2.8, 95% CI (1.3;6.11) (Table 2).

Girls, whose mother had a low level of education during their late childhood, had between 2 and 2.2 times increased risk of obesity at age 18 and 21. Father's lower level of education in late childhood almost increased girls' risk of obesity 4-fold at age 18 (RR = 3.7, 95% CI 1.2;11.9) and more than doubled the risk of overweight at age 21 (RR = 2.5, 95% CI 1.2;5.2). Reporting poor "family functioning" also increased girls' risk of obesity at age 21, RR = 1.7, 95% CI 1.1;2.7. It seemed that girls who grew up in lower income families or experienced their parent's having low LMP during their later childhood had increased risk of obesity at age 18 and 21 though the estimates were inaccurate (Table 3).

Boys, whose mother had a lower level of education during their late childhood, appeared to have some increased risk of obesity at the ages of 18 and 21, although the estimates were imprecise; (RR = 1.8, 95% CI 0.9;3.6, RR = 1.6, 95% CI 0.9;3.1). Father's lower level of education in late childhood almost tripled boys' risk of overweight and obesity at age 21, RR = 1.9, 95% CI 1.0;3.6, RR = 2.9, 95% CI 1.4;6.4, respectively (Table 3).

Discussion

This study showed that growing up in families with parent's having a low level of education in early or late childhood increased the risk of overweight and obesity at age 18 and 21 in both genders, where especially father's low level of education appeared to be a quite strong risk factor in both genders, despite somewhat wide confidence intervals. We also found that girls, who reported poor "family functioning" in early or late childhood had increased risk of overweight and obesity at age 18 and 21, which was not seen among boys. Among boys, results showed that growing up in families with parent's having low LMP during early childhood increased their risk of overweight and obesity at age 18 and 21.

To our knowledge, this is the first study to examine how childhood SEP relates to overweight and obesity, using a longitudinal study-design with 14 years of register-based exposure information. Furthermore, this was supplemented with the social factor "family functioning" to facilitate the subjective perception of childhood social conditions on the family level, which is not captured by the objective SEP measures.

Our results were in line with findings from the study by Kestila et al., who examined the association between childhood social circumstances and overweight and obesity in early adulthood in a cross-sectional design. The authors found a strong inverse association between parental educational level and obesity in both genders [34]. These results are also supported by Mathiessen et al., who found that educational level of the parents was inversely associated with their off-spring being overweight [35]. Morgen et al. found that 14–16-year-old girls of lower parental SEP had more than four times the risk of developing overweight/obesity at age 21, compared to girls of higher parental SEP [36]. In our study, we found that parental lower educational level in early or late childhood may increase the risk of overweight and obesity at age 18 and 21 up between 1.8 and 3-fold among both genders.

Al-Emranie et al. examined the association between five-year weight gain among adults and SEP in childhood and adulthood. They found a significant association between childhood SEP and obesity among males aged 29–39, thereby suggesting that the socioeconomic gradient is even more prominent in relation to obesity [37]. Results from our study showed that parental low LMP in early childhood was associated with increased risk of overweight and obesity in primarily boys, with a more than 2-fold increased risk of obesity at the age of 18 and 21.

Bann et al. examined how childhood and adult SEP relates to BMI across adulthood in three national British birth cohorts. They found that father's occupational class at age 10/11 was associated with higher adult BMI in both genders [38]. These findings are partly supported by results from our study concerning girls showing that low parental LMP in late childhood was associated with increased risk of overweight and obesity at age 18, although the findings were inaccurate. Among boys our

Table 2 The association between yearly household income (income), labour market participation (LMP), parental highest educational level (highest edu) and family functioning (family func) in early childhood and overweight and obesity at age 18 or 21

Early Childhood	Girls											
	18						21					
	n	RR		n	ARR[d] (95% CI)		n	RR		n	ARR[d] (95% CI)	
		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity
Income[a]	1200			970			1060			864		
High (ref.grp.)		1	1		1	1		1	1		1	1
Medium		1.6	1.5		1.5 (0.9;2.6)	1.4 (0.7;2.9)		1.2	1.6		0.7 (0.4;1.2)	1.4 (0.9;2.4)
Low		1.3	1.1		0.9 (0.5;1.9)	0.9 (0.4;2.1)		1.0	1.5		0.5 (0.3;1.0)	1.1 (0.6;1.9)
LMP[b] (mother)	1239			970			1085			864		
High score (ref.grp.)		1	1		1	1		1	1		1	1
Low score		1.6	1.2		1.3 (0.8;2.1)	1.0 (0.6;2.0)		1.7	1.3		1.6 (1.0;2.6)	1.2 (0.8;1.8)
LMP[b] (father)	1228			970			1074			864		
High score (ref.grp.)		1	1		1	1		1	1		1	1
Low score		1.3	0.7		1.4 (0.7;2.9)	0.8 (0.3;2.2)		1.0	0.9		0.7 (0.3;1.5)	0.8 (0.4;1.6)
Highest edu[e] (mother)1989	1165			970			1034			864		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.2	1.2		0.8 (0.4;1.6)	0.7 (0.3;1.7)		1.4	1.3		0.9 (0.5;1.7)	1.0 (0.5;1.7)
3 (< 10 yr)		1.9	2.9		1.4 (0.7;2.7)	1.9 (0.8;4.7)		3.2	2.8		1.9 (1.0;3.8)	2.1 (1.1;3.9)
Highest edu[e] (father) 1989	1119			970			984			864		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.7	4.4		2.1 (1.0;4.3)	4.5 (1.3;15.7)		2.3	1.9		2.5 (1.2;5.1)	1.8 (1.0;3.4)
3 (< 10 yr)		1.6	4.9		1.4 (0.6;3.2)	5.2 (1.4;19.3)		3.4	2.2		2.6 (1.2;5.8)	1.8 (0.9;3.6)
Family func[c]	1088			970			967			864		
Good (ref.grp.)		1	1		1	1		1	1		1	1
Poor		1.6	1.3		1.6 (1.0;2.7)	1.2 (0.6;2.3)		1.4	2.0		1.5 (0.9;2.5)	2.0 (1.3;3.1)

[a]Yearly household income categorized at 33.3rd and 66.6th percentile[b]Labour market participation dichotomized ≥0.80 (high score)[c]Family functioning, measured at age 15[d]Mutual adjusted for other exposure variables, birthweight and split home 1989[e]Highest educational level

Table 2 The association between yearly household income (income), labour market participation (LMP), parental highest educational level (highest edu) and family functioning (family func) in early childhood and overweight and obesity at age 18 or 21 *(Continued)*

Early Childhood	Boys											
	18						21					
	n	RR		n	ARR[d] (95% CI)		n	RR		n	ARR[d] (95% CI)	
		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity
Income[a]	1030			840			861			698		
High (ref.grp.)		1	1		1	1		1	1		1	1
Medium		0.8	1.1		0.7 (0.4;1.1)	1.0 (0.5;1.9)		0.9	1.5		0.7 (0.4;1.1)	1.1 (0.6;2.0)
Low		1.1	1.8		0.7 (0.3;1.4)	1.2 (0.6;2.4)		0.8	1.8		0.5 (0.3;1.0)	0.9 (0.5;1.9)
LMP[b] (mother)	1066			840			883			698		
High score (ref.grp.)		1	1		1	1		1	1		1	1
Low score		1.1	1.5		1.1 (0.6;2.0)	1.3 (0.7;2.3)		1.8	2.3		2.0 (1.2;3.2)	2.2 (1.3;3.8)
LMP[b] (father)	1062			840			881			698		
High score (ref.grp.)		1	1		1	1		1	1		1	1
Low score		1.4	2.0		1.1 (0.4;2.8)	2.8 (1.3;6.1)		0.7	1.4		0.7 (0.3;2.1)	1.6 (0.7;4.1)
Highest edu[e] (mother)1989	1001			840			841			698		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.4	1.0		1.4 (0.7;2.5)	0.8 (0.4;1.6)		1.8	1.3		1.7 (1.0;3.0)	0.7 (0.4;1.4)
3 (< 10 yr)		1.5	2.4		1.4 (0.7;2.8)	1.5 (0.7;3.2)		1.7	2.4		1.4 (0.7;2.7)	1.3 (0.7;2.6)
Highest edu[e] (father) 1989	965			840			801			698		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.2	1.2		1.1 (0.6;1.9)	1.0 (0.5;2.0)		1.5	2.2		1.6 (0.9;2.8)	1.9 (0.9;4.0)
3 (< 10 yr)		1.3	2.1		1.1 (0.5;2.2)	1.6 (0.8;3.5)		1.8	3.0		1.8 (0.9;3.4)	2.4 (1.1;5.4)
Family func[c]	932			840			773			698		
Good (ref.grp.)		1	1		1	1		1	1		1	1
Poor		1.1	0.6		1.1 (0.6;1.9)	0.5 (0.3;1.0)		1.0	0.7		0.9 (0.5;1.5)	0.5 (0.3;1.0)

Table 3 The association between yearly household income (income), parental labour market participation (LMP), parental highest educational level (highest edu) and family functioning in late childhood and overweight or obesity at age 18 or 21

Late Childhood	Girls											
	18						21					
	n	RR		n	ARR[f] (95% CI)		n	RR		n	ARR[f] (95% CI)	
		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity
Income[a]	1222			970			1072			862		
High (ref.grp.)		1	1		1[g]	1[g]		1	1		1[g]	1[g]
Medium		1.2	1.8		0.8 (0.4;1.4)	2.1 (0.9;5.0)		0.8	1.6		0.6 (0.4;1.2)	1.3 (0.7;2.3)
Low		1.4	1.3		0.7 (0.3;1.5)	2.0 (0.7;5.9)		1.1	1.8		1.0 (0.5;2.0)	1.8 (0.9;3.5)
LMP[b] (mother)	1228			972			1076			862		
High score (ref.grp.)		1	1		1[h]	1[h]		1	1		1[h]	1[h]
Low score		1.8	1.8		1.6 (0.9;2.8)	1.6 (0.8;3.2)		1.5	1.4		1.1 (0.6;2.0)	1.3 (0.8;2.1)
LMP[b] (father)	1213			972			1057			862		
High score (ref.grp.)		1	1		1[i]	1[i]		1	1		1[i]	1[i]
Low score		1.1	1.3		1.3 (0.6;2.8)	2.0 (0.8;5.1)		1.6	1.7		1.5 (0.7;3.2)	1.6 (0.8;3.1)
Highest edu[d] (mother) 2003	1225			972			1076			862		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.5	1.5		1.2 (0.7;2.2)	1.1 (0.5;2.4)		1.6	1.7		1.3 (0.7;2.3)	1.4 (0.8;2.3)
3 (< 10 yr)		2.1	3.3		1.8 (0.9;3.5)	2.2 (0.9;5.2)		2.9	2.8		1.8 (0.9;3.4)	2.0 (1.1;3.7)
Highest edu[d] (father) 2003	1171			972			1026			862		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.6	4.6		1.5 (0.8;2.8)	3.1 (1.0;9.3)		2.0	1.9		2.1 (1.1;4.0)	1.4 (0.8;2.4)
3 (< 10 yr)		1.5	4.9		1.1 (0.5;2.4)	3.7 (1.2;11.9)		3.1	2.2		2.5 (1.2;5.2)	1.5 (0.8;2.9)
Family Func[c]	1088			972			967			862		
Good (ref.grp.)		1	1		1	1		1	1		1	1
Poor		1.6	1.3		1.5 (0.9;2.5)	1.0 (0.5;2.0)		1.4	2.0		1.3 (0.8;2.1)	1.7 (1.1;2.7)

[a]Yearly household income categorized at 33.3rd and 66.6th percentile[b]Labour market participation dichotomized ≥0.80 (high score)[c]Family functioning, measured at age 15[d]Highest educational level[f]Mutual adjusted for other exposure variables, birth-weight and split home 2003[g]Mutual adjusted for other exposure variables, birth-weight, split home 2003 and early childhood income[h]Mutual adjusted for other exposure variables, birth-weight, split home 2003 and mother's LMP in early childhood[i]Mutual adjusted for other exposure variables, birth-weight, split home 2003 and father's LMP in early childhood

Table 3 The association between yearly household income (income), parental labour market participation (LMP), parental highest educational level (highest edu) and family functioning in late childhood and overweight or obesity at age 18 or 21 *(Continued)*

Late Childhood	Boys											
	18						21					
	n	RR		n	ARR[f] (95% CI)		n	RR		n	ARR[f] (95% CI)	
		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity		Overweight	Obesity
Income[a]	1053			837			876			697		
High (ref.grp.)		1	1		1[g]	1[g]		1	1		1[g]	1[g]
Medium		0.8	1.4		0.9 (0.5;1.6)	1.5 (0.7;3.0)		0.8	1.2		0.8 (0.4;1.3)	0.8 (0.4;1.5)
Low		1.1	1.6		0.9 (0.4;2.0)	1.3 (0.5;3.3)		0.6	1.4		0.6 (0.3;1.4)	1.0 (0.4;2.2)
LMP[b] (mother)	1059			838			879			698		
High score (ref.grp.)		1	1		1[h]	1[h]		1	1		1[h]	1[h]
Low score		1.1	1.2		1.1 (0.6;2.1)	0.6 (0.3;1.3)		0.9	1.1		1.1 (0.6;2.0)	0.9 (0.5;1.8)
LMP[b] (father)	1049			838			868			698		
High score (ref.grp.)		1	1		1[i]	1[i]		1	1		1[i]	1[i]
Low score		0.9	1.6		0.6 (0.2:1.9)	1.0 (0.4;2.8)		0.2	0.9		0.1 (0.0;0.9)	0.7 (0.3;2.2)
Highest edu[d] (mother) 2003	1048			838			876			698		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.3	0.9		1.3 (0.8;2.2)	0.9 (0.5;1.6)		1.6	1.5		1.6 (1.0;2.7)	1.0 (0.6;1.8)
3 (< 10 yr)		1.1	2.3		0.9 (0.4;1.8)	1.8 (0.9;3.6)		1.5	2.2		1.6 (0.9;3.0)	1.6 (0.9;3.1)
Highest edu[d] (father) 2003	1025			838			847			698		
1 (> 13 yr) (ref.grp.)		1	1		1	1		1	1		1	1
2 (10–13 yr)		1.1	1.0		1.2 (0.7;2.2)	0.9 (0.4;1.7)		1.4	2.3		1.5 (0.9;2.6)	2.5 (1.3;5.0)
3 (< 10 yr)		1.1	1.7		1.2 (0.6;2.4)	1.3 (0.6;2.8)		1.8	3.2		1.9 (1.0;3.6)	2.9 (1.4;6.4)
Family Func[c]	932			838			773			698		
Good (ref.grp.)		1	1		1	1		1	1		1	1
Poor		1.1	0.6		1.1 (0.6;1.9)	0.5 (0.3;1.1)		1.0	0.7		1.1 (0.7;1.8)	0.6 (0.3;1.2)

results indicated that parental LMP in late childhood may be less important for boys' risk of later overweight and obesity.

Overall, our findings indicate that childhood low SEP at the family level is associated with increased risk of overweight and obesity in adolescence and early adulthood. As mentioned in the background, a recent theory suggests that obesity may be a healthy active response to a future lack of energy caused by the sense of e.g. social insecurity in the family [8]. This could be a plausible explanation for a possible pathway between low childhood SEP and the development of obesity in a well-fare society with easy accessibility to rich calories-dense food. We did not find strong associations between low household income in childhood and later overweight/obesity, which may be due to this population living in a well-fare society, where a family may have a reasonable living despite a rather low income. However, we saw a tendency towards an increased risk of obesity at age 18 and 21 among girls, who grew up in low income families in late childhood, when the associations were adjusted for the early childhood income indicating that the timing of this exposure may be relevant among girls, but not boys.

Parental lower educational level(s) during early and late childhood were quite consistent risk factors for overweight and obesity in both genders in this youth cohort. Parental low LMP in early childhood was primarily a risk factor for boys, and for girls there was a tendency in late childhood to influence girls' future risk of overweight and obesity. Parental lower educational level and parental low LMP may negatively affect the psychosocial security experienced in families due to e.g. job insecurity, living in poorer residential area and perhaps also an unhealthy life style, which may affect the children. Due to role modeling, children reflect themselves in their parents, so when boys experience their father having low LMP during early childhood, this may increase boys' feeling of perceived social insecurity in daily life, which may be translated into psychological processes with possible future biological consequences [8]. Lower educated parent's and parent's with low LMP are perhaps also more likely to pass on poorer eating habits to the children [39], which combined with increasing sedentary behavior and risk behavior may tract into adolescence and adulthood and thereby also contribute to an enhanced risk of overweight and obesity.

A recent review conducted primarily on cross sectional studies concluded, that poor "family functioning" was associated with increased risk of overweight and obesity among children and adolescent aged 3–17 [15]. We observed gender differences in our study, where reporting poor "family functioning" at age 15 was a risk factor for overweight and obesity in adolescence and early adulthood in girls, but not among boys. Perhaps weight-gaining in boys during adolescence and early adulthood are less affected by how the nearest family function, compared to girls due to e.g. different coping strategies or life styles [40].

This cohort study had several strengths. The initial study response rate was 78%, which somewhat declined at the latter rounds. The study covered up to 21 years of follow up and used register-based information to define most of the exposure variables, which resulted in few missing values. The exposure variable "family functioning" was applied to uncover the child's experiences of the social conditions in the family during childhood. By adding the subjective perspective in terms of this social factor, we emphasize the importance of this influence on the physical health of young people.

The prospective design is suitable to observe potential changes over time and we consider this to be an appropriate way of studying this kind of associations. Also, applying register-based exposure variables diminishes the risk of differential information bias on these variables.

Participating in surveys may be prone to selection bias; that is if non-participation is associated with both exposures and outcomes. In this cohort, we found non-participants to be significantly different from participants with respect to the exposure variables, however, we do not have any information on height and weight from the non-participants, so it is not possible to disentangle whether any selection was differential. Non-participation and drop-outs in the same cohort was examined in a previous study by Winding et al. and results showed that neither non-participation nor drop-outs influenced significantly on the size of the measured associations [19].

The main limitation of the study was that the outcome was based on self-reported height and weight and consequently prone to misclassification. Participants, who are overweight, are probably more likely to underestimate their weight [41], which may be most pronounced in girls [42]. This increases the risk of underestimating the associations between the exposures and the outcome and hence bias towards the null-hypothesis. We believe that due to the study design the risk of differential misclassification of the outcome was small. We applied the self-reported variable "family functioning" along with the outcome reported from the baseline questionnaire at age 15 and we are aware that these findings are cross-sectional and cannot tell us anything about causality.

We decided to imply the additional cut-offs for obesity from the Global database on BMI due to a relatively low prevalence of obese participants in this cohort according to conventional World Health Organization-guidelines. We believe that applying the additional cut-off seems reasonable in this young healthy population.

All the associations in the study were mutually adjusted for the other exposure variables, but these adjustments did not alter the results much. We did not find strong correlations between e.g. household income and highest

educational level in this study. This may be explained by the fact that household income in Denmark not necessarily reflects a person's level of education. An unskilled worker in a factory often earns a rather high salary compared to e.g. health care workers with a short or medium long education. For the early childhood adjustment's we applied split home 1989, however we repeated the analyses with split home 1991 instead, because the first couple of years after the birth of a child may be a difficult time for the parents' relationship and one could suspect that more families may split up during these years. Applying split home 1991 did not change the estimates.

A previous examination of the study setting concluded that the participants of this youth cohort are comparable to young people in other parts of Denmark [43]. Therefore, the results of this study may be transferred to young people with similar environmental and social conditions to this Danish cohort, when taking the above-mentioned limitations into account.

Conclusion

In this study, we found that parental lower educational level during childhood was associated with an increased risk of overweight and obesity in adolescence and early adulthood in both genders. Father's lower educational levels during early or late childhood were the strongest risk factors for overweight and obesity at age 18 and 21 with as much as fivefold increased risks.

Parental low LMP during early childhood was a risk factor for overweight and obesity at age 18 and 21 in primarily boys, where reporting poor "family functioning" was a risk factor for overweight and obesity in girls only. The timing of SEP in childhood appears to be gender-specific according to some of the parental socioeconomic exposure variables; girls seems to be primarily influenced by the later childhood lower income and parent's low LMP, where it appeared to be parent's low LMP in the earlier part of the childhood which may influence boys' risk of future overweight and obesity the most. The results should, however, be interpreted with caution due to imprecise estimates with wide confidence intervals.

Lower SEP in childhood is associated with overweight and obesity in adolescence and early adulthood in Denmark despite this being a well-fare society, where rules and regulations aim to reduce inequality. Further research is required to disentangle some of the underlying mechanisms and to be able to target relevant support to prevent overweight and obesity related to childhood conditions.

Additional file

Additional file 1: Table S1. Spearman's rank correlation matrix of exposure variables in early (0–8 years) and late childhood (9–14 years). (DOCX 30 kb)

Abbreviations

ARR: Adjusted Relative Risks; BMI: Body Mass Index; CI: Confidence interval; CPR: Civil Registration Number; E.g.: Exempli gratia; LMP: Labour market participation; SEP: Socioeconomic position; Yr: Year

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Availability of data and materials

The data that support the findings of this study are available from Statistics Denmark but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Statistics Denmark.

Authors' contributions

PHP designed the study and performed the analyses and wrote the main paper. KB helped in designing the study and analyzing data. TNW helped in designing the study and analyzing data. EAN helped in designing the study and analyzing data. JHA initiated the study and helped in designing the study and analyzing data. All authors interpreted the results and their implications and commented on the manuscripts at all stages. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was carried out according to the Declaration of Helsinki. According to Danish law, approval by the Ethics Committee and written informed consent was not required in questionnaire-based and register-based projects. Additional information is available at The National Committee on Health Research Ethics' webpage in the "Act on Research Ethics Review of Health Research Projects" § 14,2. Available from http://www.nvk.dk/english/act-on-research. Use of the data was carried out under the same conditions and with the same purpose as when originally collected and based on approval from the Danish Data Protection Agency and their rules of data protection.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author details

[1]Danish Ramazzini Centre, Department of Occupational Medicine, University Research Clinic, Regional Hospital West Jutland, Gl. Landevej 61, 7400 Herning, Denmark. [2]Institute of Clinical Research, Department of Obstetrics & Gynecology, Odense University Hospital, University of Southern Denmark, Odense, Denmark.

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References

1. [http://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight]. Accessed 12 Mar 2018.
2. Schmidt Morgen C, Rokholm B, Sjoberg Brixval C, Schou Andersen C, Geisler Andersen L, Rasmussen M, Nybo Andersen AM, Due P, Sorensen TI. Trends in prevalence of overweight and obesity in Danish infants, children and adolescents--are we still on a plateau? PLoS One. 2013;8(7):e69860.
3. Rosendahl Jensen HA, Davidsen M, Ekholm O, Christensen AI: The Danish National Health Profile 2017. 2018.
4. Hall KD, Sacks G, Chandramohan D, Chow CC, Wang YC, Gortmaker SL, Swinburn BA. Quantification of the effect of energy imbalance on bodyweight. Lancet. 2011;378(9793):826–37.

5. Al-Khudairy L, Loveman E, Colquitt JL, Mead E, Johnson RE, Fraser H, Olajide J, Murphy M, Velho RM, O'Malley C, Azevedo LB, Ells LJ, Metzendorf MI, Rees K. Diet, physical activity and behavioural interventions for the treatment of overweight or obese adolescents aged 12 to 17 years. Cochrane Database Syst Rev. 2017;6:CD012691.
6. Ulijaszek SJ. Socio-economic status, forms of capital and obesity. J Gastrointest Cancer. 2012;43(1):3–7.
7. Offer A, Pechey R, Ulijaszek S. Obesity under affluence varies by welfare regimes: the effect of fast food, insecurity, and inequality. Econ Hum Biol. 2010;8(3):297–308.
8. Sorensen TI. Is obesity a healthy active response to an expected future lack of energy rather than a passive storage of surplus energy? Obes Facts. 2012; 5(3):431–5.
9. Dhurandhar EJ. The food-insecurity obesity paradox: a resource scarcity hypothesis. Physiol Behav. 2016;162:88–92.
10. Nettle D, Andrews C, Bateson M. Food insecurity as a driver of obesity in humans: the insurance hypothesis. Behav Brain Sci. 2017;40:e105.
11. Newton S, Braithwaite D, Akinyemiju TF. Socio-economic status over the life course and obesity: systematic review and meta-analysis. PLoS One. 2017; 12(5):e0177151.
12. Pavela G. Is childhood socioeconomic status independently associated with adult bmi after accounting for adult and neighborhood socioeconomic status? PLoS One. 2017;12(1):e0168481.
13. Brisbois TD, Farmer AP, McCargar LJ. Early markers of adult obesity: a review. Obes Rev. 2012;13(4):347–67.
14. Viner RM, Ozer EM, Denny S, Marmot M, Resnick M, Fatusi A, Currie C. Adolescence and the social determinants of health. Lancet. 2012;379(9826): 1641–52.
15. Halliday JA, Palma CL, Mellor D, Green J, Renzaho AM. The relationship between family functioning and child and adolescent overweight and obesity: a systematic review. Int J Obes. 2014;38(4):480–93.
16. Spencer N, Thanh TM, Louise S. Low income/socio-economic status in early childhood and physical health in later childhood/adolescence: a systematic review. Matern Child Health J. 2013;17(3):424–31.
17. Bonnie RJ, Stroud C, Breiner H, National Research Council (U.S.). Committee on improving the health, Safety, and well-being of young adults, Investing in the health and well-being of young adults. Washington, D.C.: Naitonal Academies Press; 2014.
18. Cohen S, Janicki-Deverts D, Chen E, Matthews KA. Childhood socioeconomic status and adult health. Ann N Y Acad Sci. 2010;1186:37–55.
19. Winding TN, Andersen JH, Labriola M, Nohr EA. Initial non-participation and loss to follow-up in a Danish youth cohort: implications for relative risk estimates. J Epidemiol Community Health. 2014;68(2):137–44.
20. Schmidt M, Pedersen L, Sorensen HT. The Danish civil registration system as a tool in epidemiology. Eur J Epidemiol. 2014;29(8):541–9.
21. [http://www.assessmentpsychology.com/icbmi.htm]. Accessed 12 Mar 2018.
22. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000; 320(7244):1240–3.
23. Baadsgaard M, Quitzau J. Danish registers on personal income and transfer payments. Scand J Public Health. 2011;39(7 Suppl):103–5.
24. Jensen VM, Rasmussen AW. Danish education registers. Scand J Public Health. 2011;39(7 Suppl):91–4.
25. Hjollund NH, Larsen FB, Andersen JH. Register-based follow-up of social benefits and other transfer payments: accuracy and degree of completeness in a Danish interdepartmental administrative database compared with a population-based survey. Scand J Public Health. 2007;35(5):497–502.
26. Biering K, Hjollund NH, Lund T. Methods in measuring return to work: a comparison of measures of return to work following treatment of coronary heart disease. J Occup Rehabil. 2013;23(3):400–5.
27. Lund T, Andersen JH, Winding TN, Biering K, Labriola M. Negative life events in childhood as risk indicators of labour market participation in young adulthood: a prospective birth cohort study. PLoS One. 2013;8(9):e75860.
28. Epstein N, Baldwin L, Bishop D. The McMaster family assessment device. J Marital Fam Ther. 1983;9(2):171–80.
29. Schellong K, Schulz S, Harder T, Plagemann A. Birth weight and long-term overweight risk: systematic review and a meta-analysis including 643,902 persons from 66 studies and 26 countries globally. PLoS One. 2012;7(10): e47776.
30. Zhao Y, Wang SF, Mu M, Sheng J. Birth weight and overweight/obesity in adults: a meta-analysis. Eur J Pediatr. 2012;171(12):1737–46.
31. Biehl A, Hovengen R, Groholt EK, Hjelmesaeth J, Strand BH, Meyer HE. Parental marital status and childhood overweight and obesity in Norway: a nationally representative cross-sectional study. BMJ Open. 2014;4(6):e004502. https://doi.org/10.1136/bmjopen-2013-004502.
32. Hohwu L, Zhu JL, Graversen L, Li J, Sorensen TI, Obel C. Prenatal parental separation and body weight, including development of overweight and obesity later in childhood. PLoS One. 2015;10(3):e0119138.
33. Knudsen LB, Olsen J. The Danish medical birth registry. Dan Med Bull. 1998; 45(3):320–3.
34. Kestila L, Rahkonen O, Martelin T, Lahti-Koski M, Koskinen S. Do childhood social circumstances affect overweight and obesity in early adulthood? Scand J Public Health. 2009;37(2):206–19.
35. Matthiessen J, Stockmarr A, Fagt S, Knudsen VK, Biltoft-Jensen A. Danish children born to parents with lower levels of education are more likely to become overweight. Acta Paediatr. 2014;103(10):1083–8.
36. Morgen CS, Mortensen LH, Rasmussen M, Andersen AM, Sorensen TI, Due P. Parental socioeconomic position and development of overweight in adolescence: longitudinal study of Danish adolescents. BMC Public Health. 2010;10:520. https://doi.org/10.1186/1471-2458-10-520.
37. Al-Emrani F, Stafstrom M, Ostergren PO. The influences of childhood and adult socioeconomic position on body mass index: a longitudinal Swedish cohort study. Scand J Public Health. 2013;41(5):463–9.
38. Bann D, Johnson W, Li L, Kuh D, Hardy R. Socioeconomic inequalities in body mass index across adulthood: coordinated analyses of individual participant data from three British birth cohort studies initiated in 1946, 1958 and 1970. PLoS Med. 2017;14(1):e1002214.
39. Cribb VL, Jones LR, Rogers IS, Ness AR, Emmett PM. Is maternal education level associated with diet in 10-year-old children? Public Health Nutr. 2011; 14(11):2037–48.
40. Hoegh Poulsen P, Biering K, Andersen JH: The association between leisure time physical activity in adolescence and poor mental health in early adulthood: a prospective cohort study. BMC Public Health 2016, 16:3–015–2658-5.
41. Elgar FJ, Roberts C, Tudor-Smith C, Moore L. Validity of self-reported height and weight and predictors of bias in adolescents. J Adolesc Health. 2005; 37(5):371–5.
42. Clarke P, Sastry N, Duffy D, Ailshire J. Accuracy of self-reported versus measured weight over adolescence and young adulthood: findings from the national longitudinal study of adolescent health, 1996-2008. Am J Epidemiol. 2014;180(2):153–9.
43. Glasscock DJ, Andersen JH, Labriola M, Rasmussen K, Hansen CD. Can negative life events and coping style help explain socioeconomic differences in perceived stress among adolescents? A cross-sectional study based on the West Jutland cohort study. BMC Public Health. 2013;13:532. https://doi.org/10.1186/1471-2458-13-532.

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How does psychosocial stress affect the relationship between socioeconomic disadvantage and overweight and obesity? Examining Hemmingsson's model with data from a Danish longitudinal study

Per Hoegh Poulsen[1*], Karin Biering[1], Trine Nøhr Winding[1], Ellen Aagaard Nohr[2], Liselotte Vogdrup Petersen[3], Stanley J. Ulijaszek[4] and Johan Hviid Andersen[1]

Abstract

Background: Chronic stress in childhood may increase the risk of overweight and obesity in young people. Erik Hemmingsson has suggested a new obesity causation model which focuses on psychosocial stress.
The aim was to examine the associations between socioeconomic disadvantage and overweight and obesity and examine if these associations attenuate, when the effect of the different domains from Eric Hemmingsson's obesity causation model were taken into account.

Methods: A longitudinal study using data from The West Jutland Cohort Study (N = 2879). Outcome was overweight and obesity combined derived from self-reported weight and height at age 15, 18, 21 and 28 years. Exposure variables were equivalised household income, educational level and labour market participation of the mother derived from registers and psychosocial variables derived from questionnaires. A three-step adjustment model using logistic regression and stratified by gender was applied.

Results: Mother's low educational level was associated with a 3-fold increased odds of obesity in 18 year-old-girls, which attenuated when adjusting for the domains adult distress, disharmonious family environment and offspring distress. In 28 year-old girls, a 2.5-fold increased odds of obesity was observed, which attenuated when mutual adjusted for other socioeconomic variables and attenuated even further when adjusting for all the domains. In 18-year-old boys, a 3-fold increased odds of obesity was observed which attenuated after adjustments for adult distress, disharmonious family environment and offspring distress. In 21-year old boys, a four-fold increased odds of obesity was observed that attenuated after adjustments. At age 28 years, a three-fold increased odds of obesity was observed, which vanished in the fully adjusted model.

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* Correspondence: perhpo@rm.dk
[1]Danish Ramazzini Centre, Department of Occupational Medicine, University Research Clinic, Regional Hospital West Jutland, Gl. Landevej 61, 7400 Herning, Denmark
Full list of author information is available at the end of the article

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Conclusions: Our study confirms to some extent that the associations between socioeconomic disadvantage and overweight and obesity can be explained by the domains included in Erik Hemmingsson's model, although our results should be interpreted with caution. Adult distress, disharmonious family environment and offspring distress accounted for some of the association in girls, whereas in boys it was primarily offspring distress, which had the greatest impact. Young people's educational attainment can act as a buffer in the relationship between mother's lower educational level and obesity at age 28 years.

Keywords: Socioeconomic disadvantage, Overweight and obesity, Psychosocial stress

Background

In western high-income countries, the prevalence of overweight and obesity has increased dramatically over the last three decades [1]. Despite a possible levelling-off among children and adolescents from more affluent families, a continued increase has been observed among lower socioeconomic classes, indicating increasing socioeconomic inequalities in overweight and obesity [2, 3]. A recent meta-analysis by Wardle et al. showed a small, yet persistent, association between perceived psychosocial stress and an increased risk of obesity in adults [4]. Among children and adolescents, overweight and obesity may have other psychosocial and social pathways than in adults. In a review by Gundersen et al., individual psychosocial stressors along with psychosocial stressors in the household were associated with an increased risk of childhood overweight and obesity [5].

The concept of stress can be defined in different ways. In the bio-physiological area, "stress" is often referred to as "the non-specific response of the body to any factors that overwhelms or threatens to overwhelm the body's ability to maintain homeostasis" [6]. In the psychological literature, the word "stress" is often defined as "a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being" [7]. The experience of stress can be caused by different types of emotional challenge (e.g. unemployment or conflict) or by physiological challenges (e.g. illness) [8]. Stress can be divided into acute or chronic stress. The experience of acute stress can be related to one's personal safety which may activate the "fight and flight" mechanism [6] and may also be associated with the inhibition of appetite/loss of appetite [9]. Chronic stress can occur in response to a prolonged exposure to psychological stressors (e.g. job pressures) as well as exposure to adverse events in childhood [10], where stress mechanisms may manifest themselves in the individual expressing a preference for high energy-dense foods [11, 12], which may contribute to weight gain and future overweight and obesity [13], especially for example among women [14].

Being obese as a child or during adolescence is a major risk factor for being obese as an adult and obesity is a major risk factor for later morbidity [15]. Obese people are often stigmatized in society which may result in severe psychological problems for the individual [16, 17]. Therefore, to shape and to help initiate future preventive initiatives against overweight and obesity in children and young people, it is important to identify psychosocial and environmental risk factors during upbringing that facilitate the experience of chronic stress in the individual.

Erik Hemmingsson recently introduced a new causal conceptual model as a possible way of rethinking preventive initiatives against obesity. The model explores the underlying reasons behind the association between low socioeconomic status (SES) and obesity with an emphasis on the psychological and emotional stress factors experienced by parents and children [18]. It is a step-by-step model of obesity causation which highlights the many steps in the lifecourse for an individual in which predisposing factors can influence the onset of weight gain. These steps are presented as domains with a wide array of psychosocial factors, where the model attempts to disentangle the possible negative effects of growing up in a socioeconomic disadvantaged environment, which eventually may lead to psychological and emotional overload in an individual and possible disrupted energy balance homeostasis, resulting in weight gain and obesity. This approach suggests that the psychosocial factors encompassed in the different domains may act as mediators for the association between socioeconomic disadvantage and obesity.

The proposed obesity causation model is primarily based on literature from the United States (US) and the United Kingdom (UK), which are countries with neoliberal political systems and high levels of inequality and insecurity at the national level, which could influence the experience of chronic stress in the population. In the US, according to the American Psychology Association, 75% of adults reported that they had experienced moderate to high levels in stress within the last month [19]. Among Americans aged 18–21 years who participated in

the annual "Stress in America Survey", 58% reported common symptoms of stress [20]. In Denmark, 40% of young women and 23% of young men aged 16–24 years reported higher levels of perceived stress according to the latest Danish National Health Profile 2017 [21] and approximately 20% of Danish children and young people aged 10–24 years reported often feeling stressed in a report, published by "The Council on Health and Disease" [22].

These reports indicate very different levels of experienced stress across countries, and perhaps stress emerges in a different way in Denmark than in the US and the UK due to a more egalitarian society with low levels of income inequality and job insecurity. The proposed step-by-step model holds promise as a new approach to understand obesity causation, and it is important to examine whether this model can be applied empirically. To examine the Erik Hemmingsson model in an empirical context, it is necessary to use longitudinal data, and to the best of our knowledge, no such examination with the use of longitudinal data has yet been performed.

Our aim was therefore to explore the associations between socioeconomic disadvantage and overweight and obesity and examine if these associations attenuate, when the effects of the domains: adult distress, disharmonious family environment, offspring distress, psychological and emotional overload and homeostasis disrupted from Eric Hemmingsson's model were taken into account.

Methods

Design and population

This is a longitudinal study using data from the West Jutland Cohort Study (VestLiv), an on-going Danish study following a complete regional cohort of young people who were born in 1989 and lived in the western part of Denmark (former Ringkoebing County) in 2004. The county had a total of 275,000 inhabitants when the cohort was established in 2004.

The main purpose of this youth cohort is to study the relationship between social inequality and health from a life course perspective. The project has so far included four waves of questionnaires, in 2004, 2007, 2010 and 2017 [23], which have been supplemented with a range of register-based information. Furthermore, in 2004, the parents completed a questionnaire about the child's health during upbringing, as well as about their own psychosocial health.

The source population comprised 3681 young people at the age of 15 years. Detailed information on recruitment and data collection has been described elsewhere [24]. Participants were included in this study if they had responded to questions about reported height and weight in 2004, 2007, 2010 or 2017 to determine rates of overweight and obesity. Depending on the research question, attrition and missing data reduced the sample as shown in Fig. 1. Women who were more than 3 months pregnant when they completed the questionnaire were excluded from the analyses related to this specific survey wave, due to temporally higher BMI. These exclusions are displayed in Fig. 1.

Data for this study comprised a combination of questionnaire data from both children and parents and data from registers. In Denmark, every citizen is provided with a CPR-number (Central Office of Civil Registration) at birth (or upon entry for immigrants). This is a key component for register linkages [25] and allowed us to link the CPR number of each child to parental information from registers.

Definition of outcome

The primary outcome measure was overweight and obesity combined, defined by Body Mass Index (BMI) at age 15, 18, 21 and 28 years. Weight and height were derived from questionnaires and BMI was calculated as weight in kilograms divided by height in meters squared. At age 18–28 years, participants were categorized according to the International Classification of adult obesity (BMI ≥ 30 kg/m^2) [26, 27]. However, at age 15 years, participants were categorized into "normal weight" (< 23.29 kg/m^2 for boys and < 23.94 kg/m^2 for girls), and "overweight" (BMI ≥23.29 kg/m^2 for boys and BMI ≥23.94 kg/m^2 for girls) using thresholds for 15 year old girls and boys [28] because of few obese at this age (21 girls and 23 boys).

Definition of exposure domains

We generated proxy variables from registers and questionnaires for the six domains in Hemmingsson's causation model: socioeconomic disadvantage, adult distress, disharmonious family environment, offspring distress, psychological and emotional overload, and homeostasis disrupted: start of weight gain (hereafter referred to as homeostasis disrupted). These domains are adapted from Fig. 1 in [18], presented in Fig. 2, and explained in detail below.

Socioeconomic disadvantage was measured as mother's highest educational level, equivalised disposable household income and mother's labour market participation. Information on mother's highest educational level in 2003 was derived from different educational registers [29]. The variable was divided into three categories: ≤10 years (primary school), 11–13 years (secondary school) and > 13 years of education (tertiary school). If information was missing for year 2003, information from previous years was applied (last observation carried forward).

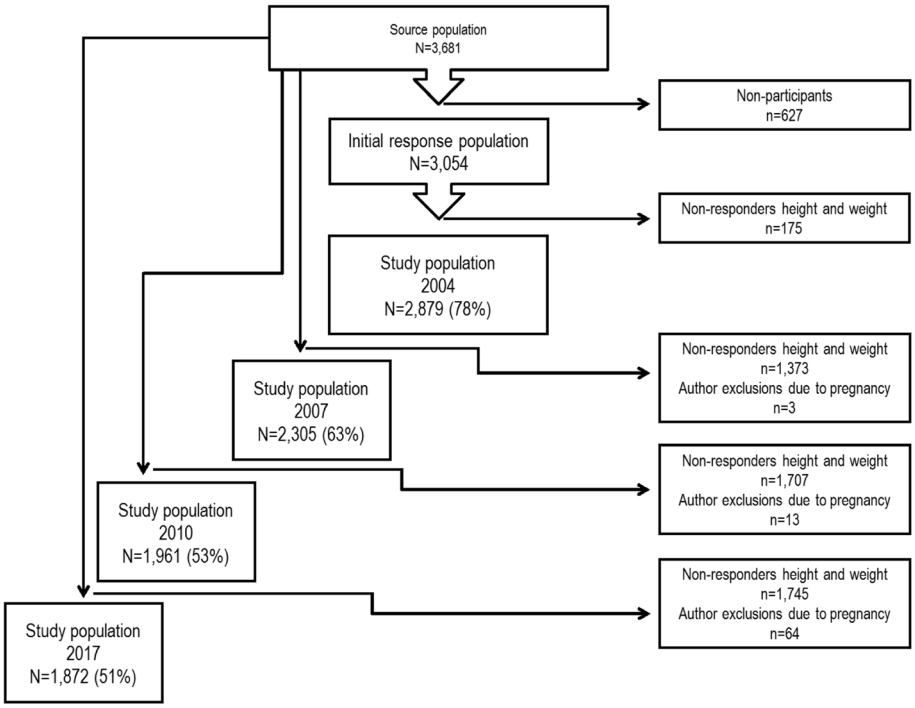

Fig. 1 Distribution of participants and non-participants in 2004, 2007, 2010 and 2017

Annual equivalised disposable household income (equivalised income) was included as it informs about the inequality in wealth distribution among Danish families independent of family size and age distribution in the family. Equivalent disposable income is a weighted value which uses an equivalence scale that takes into account that a family of two adults consumes more, but does not need twice the income as a family with only one adult. The scale also reflects that children do not need as much income as adults to achieve the same standard of living. Information about equivalised income in Danish Kronor (DKK) was derived from the Danish register on Personal Income and Transfer Payments [30] and we applied information from 1990 to 1997 (8 years). We calculated a mean value for this early childhood period and categorized the variable into low, medium and high equivalised income, grouped by the 33.3rd and 66.6th percentiles. Information on mother's labour market participation (LMP) was derived from the Danish Register for Evaluation of Marginalization (referred to as the DREAM Register) which provides information on public transfer incomes on a weekly basis [31]. Mother's LMP was defined according to the degree of receiving social benefits (e.g. sickness absence compensation or unemployment benefits) within each year from the second half of 1991 to 1997. When we defined this variable, we omitted maternity leave benefits or state educational grants. LMP was a continuous variable in the range from 0 to 100 and calculated as a mean LMP score between 0 and 1 for the entire period and categorized into "high LMP" and "low LMP" at a cut-off value of ≥0.80 indicating high LMP.

Adult distress was measured as parental self-rated health (2004). Information was provided by the parents in the parental questionnaire in 2004 and measured using a single item from the SF-36 on general health (GH-1) [32]. The question was: "In general, would you say your health is …" with five response options ranging from "excellent" to "poor", which was subsequently dichotomised to indicate "good" (excellent, very good) versus "poor" (good/less good/poor) self-rated health.

Disharmonious family environment was measured as family functioning. Information on family functioning came from the baseline questionnaire in 2004, when the participants were 15 years of age. Family functioning was a categorical variable based on the general functioning subscale of the McMaster Family Assessment Device (FAD), developed by Epstein et al. [33]. The FAD consists of seven subscales where General Functioning assesses the overall health/pathology of the family with questions about how the family handles such things as crisis and other family issues. It consists of 12 items with four response categories ranging from "strongly agree" to "strongly disagree" (scores of 1–4), where higher values indicate poorer family functioning. We calculated a mean value for the 12 items. A pragmatic decision was made by the authors to include participants with 8 and more answers to enhance the number of participants,

Domain	Factors (selected)	Proxy variables to cover the different domains (this study)
Socioeconomic disadvantage		
	Low education	Mothers highest educational level (retrived from Danish educational registers in year 2003)
	Income inequality	Equivalised disposable household income (1990-1997, retrived from Danish register on Personal Income and Transfer payments)
	Social insecurity	Mothers labour market participation (1990-1997, retrived from the Danish Register for Evaluation of Marginalization)
	Unemployment	
	Job insecurity	
Adult distress		
	Low self-esteem	Parental self-rated health (parental questionnaire completed in 2004)
	Low self-worth	
	Powerlessness and apathy	
	Depression	
Disharmonious family environment		
	Parent frustrations	Family functioning (from questionnaire completed at age 15 years)
	Negative belief systems	
	Harsh upbringing methods	
	Lack of support	
	Neglect and abuse	
	Low resilience and coping	
Offspring distress		
	Low self-esteem	Self-esteem (from questionnaire completed at age 15 years)
	Depression	Depressive symptoms (from questionnaire completed at age 15 years)
	Negative self-belief	Self-rated health (from questionnaire completed at age 15 years)
	Powerlessness	
	Increased stress sensitivity	
Psychological and emotional overload		
	Maladaptive coping behaviours	Avoidance coping (from questionnaires completed at ages 15, 18, 21 years)
	Increased stress	Perceived stress (from questionnaires completed at ages 15, 18, 21 years)
	Overreactive emotional response	Smoking (from questionnaires completed at ages 15, 18, 21 years)
	Increased inflammation	
	Increased vulnerability	
Homeostasis disrupted: start of weight gain		
	Reduced energy expenditure	Physical activity (from questionnaires completed at ages 15, 18, 21 years)
		Computer time (from questionniares completed at ages 15, 18, 21 years)
	Emotional eating	
	High intake of comfort foods	
	Appetite up-regulated	
	Weight gain as protection	

Fig. 2 presents the domains from Hemmingsson's model with the chosen proxy variables in this study (adapted from Fig. 1, Hemmingsson 2014)

despite missing items. The variable was dichotomised at the 75th percentile of the mean value indicating poor family functioning at ≥2.08, which lies between the mean value for the non-clinical and clinical samples on General Functioning [33]. This cut-off value has been applied in previous studies on the same cohort.

Offspring distress was measured as participant's self-rated health, self-esteem and depressive symptoms. From the baseline questionnaire, we used information about self-rated health, self-esteem and depressive symptoms.

Self-rated health was measured using a single item from SF-36 on general health (GH-1) and the response categories were dichotomised into two groups: "good" self-rated health (excellent/very good), and"poor" self-rated health (good/less good/poor) as described above with the domain adult distress [32]. Self-esteem was

measured using six items from the Rosenberg self-esteem scale with scores from 1 to 4 and a total score between 6 and 24 [34]. Scores were reversed so higher scores indicated lower self-esteem. The variable was dichotomised at the 75th percentile into "high" and "low" self-esteem. Depressive symptoms were measured using the abbreviated 4-item validated version of "The Center for Epidemiologic Studies Depression Scale for Children" (CES-DC) [35]. It consists of four items asking about one's mental state over the past week. There are four categories of answers to each question ranging from "not at all" to "a lot". The answers are awarded scores of 0–3, where high values correspond to having depressive symptoms. We applied single item imputation if one item was missing for the scale by adding the mean of the other items. The four items summed up to a score between 0 and 12. The definition of depressive symptoms was obtained by using the cut-off point of 3 and above indicating depressive symptoms as recommended for the short scale by Fendrich et al. [35].

Psychological and emotional overload was measured as avoidance coping, perceived stress and smoking status. Information about avoidance coping, perceived stress and smoking status was collected from the 2004, 2007 and 2010 questionnaires. Avoidance coping was measured using three subscales of two items each from the BRIEF COPE Scale [36]. The three subscales employed in this study were "self-distraction", "substance use" and "behavioural disengagement". Each item had 4 response categories yielding scores between 1 and 4, with higher scores indicating a higher level of avoidance coping. The avoidance coping scale was created by the mean of the item scores. The distribution of avoidance coping for this population was skewed to the right, so we decided to dichotomise the avoidance coping scale into low and high avoidance coping at the 75th percentile, respectively.

Perceived stress was measured using a Danish 4 item version of the Perceived Stress Scale (PSS), which was originally developed by Cohen et al. [37]. The 4 items ask about the responder's experience of being in control of their life during the last month. Each item has a score of between 0 ("never") and 4 ("very often"). The total scale ranged from 0 to 16 points where higher values indicated higher levels of perceived stress. PSS has no clinical cut points, so the variable was dichotomised into low and high PSS at the 75th percentile, respectively.

Smoking status was a categorical variable with four possible answers that were dichotomised into smoking ("yes, but not every week", "yes, but not every day", "yes, daily") and not smoking ("no, I do not smoke").

Homeostasis disrupted was measured as physical activity and computer time. Information about physical activity and computer time was collected from questionnaires in 2004, 2007 and 2010.

Physical activity (PA) was a categorical variable with six possible answers where each participant was asked in a single item, "How many hours a week during leisure time do you usually exercise or play sports where you are out of breath or sweating?". The answer categories of PA were respectively: none, ½ hour, 1 h, 2–3 h, 4–6 h, and 7 h or more. The variable was dichotomised according to the recommendation on PA given by the Danish Health Authorities for adolescents (60 min/day) and young adults (30 min/day) [38]. At age 15 years, the variable was dichotomised into: "Low level of PA" (≤2–3 h/week); "high level of PA" (≥4–6 h/week) assuming 2 h of compulsory physical education classes at school. At age 18 and 21 years, the variable was dichotomised into: "Low level of PA" (≤1 h/week); "high level of PA" (≥2–3 h/week).

Computer time (CT) was a categorical variable with 7 possible answers where each participant was asked in a single item, "On an average (school) day, how many hours of your leisure time do you spend in front of a computer?". The answer categories of CT were in the range of "I am not using the computer" to "Approximately five hours or more per day". Since we do not have any official Danish recommendations for children's and young people's computer use, the authors made a pragmatic decision to dichotomise the variable at the 75th percentile, which resulted in slightly different cut-offs. At age 15, the variable was categorised into "low level of CT" (≤2 h/day) and "high level of CT" (≥3 h/day). At age 18 and 21 the variable was categorised into "low level of CT" (≤3 h/day) and "high level of CT" (≥4 h/day).

Additional variables

Birth-weight and highest educational level at age 28 years.

Birth-weight was included in the analyses because high birth-weight has previously been associated with later overweight and obesity [39]. Information on birth-weight was obtained from the Danish Medical Birth Register, which is a national register with information about all hospital and home births [40].

As a proxy for the participant's own socioeconomic position at age 28 years, we obtained information on highest educational level from educational registers [29]. The variable was divided into three categories: ≤10 years, 11–13 years and > 13 years of education.

Statistical analyses

We calculated proportions on each variable from the six domains in relation to the outcome at age 15–28 years, stratified by gender. Logistic regression models were used to calculate the associations between each of the three main exposures (socioeconomic disadvantage

domain) and overweight and obesity at age 15–28 years. Estimates are presented as odds ratios (OR) with 95% confidence intervals (95% CI). We also examined each of the variables from the remaining 5 domains individually with the outcome at age 15–28 years using logistic regression.

In the main regression analyses it was decided á priori to include variables from the other domains as potential confounders in a three-step adjustment model. We examined the correlations between variables within each domain using Spearman's Rank correlation coefficient to ensure that we did not apply highly correlated variables from the same domains to the models, which could increase the risk of over-adjustments. Self-esteem, depressive symptoms and self-rated health (offspring distress) were correlated with Spearman's rho = 0.28 and 0.37. Perceived stress and avoidance coping (psychological and emotional overload) were correlated with Spearman's rho = 0.40. The rest of the correlations between proxies within domains were similar or smaller (correlation matrix not shown).

In the first model (crude), we examined the association between each of the three socioeconomic variables (socioeconomic disadvantage) and overweight and obesity at age 15–28 years (Model I). In the second model, we mutually adjusted for the other SES variables, because we wanted to examine the independent effect of each SES variable in relation to overweight and obesity (Model II). In the third model (Model III), we adjusted for Model II variables and the domains: *adult distress*, *disharmonious family environment* and *offspring distress*. In the fourth and fully adjusted model (Model IV), we adjusted for Model II + Model III and the domains: *psychological and emotional overload* and *homeostasis disrupted*. We included the exposure variables for the two domains *psychological and emotional overload* and *homeostasis disrupted* at age 15, 18 and 21 years ensuring that exposures were measured before the outcome at age 18–28 years. Thus, when we examined the outcome at age 18 years, the exposures were measured at age 15 years.

At age 28 years, we also included an adjustment for the young people's highest educational level. Additionally, we adjusted for birth-weight as a continuous variable in model III-IV at all four time-points.

We assumed that there was no interaction between the variables from the socioeconomic disadvantage domain and the proxy variables from the other domains.

We explored the adjusted effect of the individual proxies in the association between the socioeconomic disadvantage domain and the outcome at all four time-points in supplementary analyses (tables not shown).

All analyses were stratified by gender.

Data-analysis was performed by the statistical package Stata, statistical software version 14.2 (Stata Corporation, College Station, Texas, USA).

Ethics

Use of the data was carried out under the same conditions and with the same purpose as when originally collected and based on approval from the Danish Data Protection Agency and their rules for data protection. According to Danish law at the time of data collection, approval by the Ethics Committee and written informed consent were not required for questionnaire-based and register-based projects.

Results

Tables 1 and 2 present the proportion of overweight and obese girls and boys at age 15, 18, 21 and 28 years in relation to the proxies in each domain.

A higher proportion of overweight and obese girls were observed at ages 15, 18, 21 and 28 years if they grew up having a mother with a low level of education. At all four time points, a higher proportion of overweight and obese girls were also observed if they reported poor family functioning, lower self-esteem, poor self-rated health, high avoidance coping, perceived stress, low level of PA, or a high amount of CT. Furthermore, a higher proportion of obese girls at ages 21 and 28 years were smokers.

A higher proportion of overweight and obese boys were observed at age 15, 18, 21 and 28 years if they grew up having a mother with a low level of education or their mothers had a low labour market participation. A higher proportion of overweight and obese boys was also observed at all 4 time points if they reported poor self-rated health, higher levels of perceived stress, were a smoker, had low level of PA or a high amount of CT.

Additional file 1: Table S1 and Additional file 2: Table S2 present the crude estimates for the assocation between proxy variables for the domains *adult distress* to *homeostasis disrupted* and overweight and obesity at age 15–28 years in girls and boys, respectively.

Parental poor self-rated health (adult distress) was associated with overweight and obesity at age 18–28 years in girls and at age 15–18 years in boys. Poor family functioning (disharmonious family environment) was associated with overweight and obesity at age 15, 18 and 28 years in girls, but not boys. Low self-esteem, depressive symptoms and poor self-rated health (offspring distress) were associated with overweight and obesity at age 15–28 years in girls, in boys merely poor self-rated health was associated with overweight and obesity at age 15–28 years. High avoidance coping, perceived stress and smoking (psychological and emotional overload) among girls were associated with overweight and obesity at ages 15–18, 18–21 and 21–28 years, respectively. High perceived stress was in boys primarily associated with obesity at age 18 years, where smoking showed increased

Table 1 Distribution of proxy variables from the domains (Hemmingsson:2014) in relation to the outcome at ages 15 and 18, stratified by gender

	age=15 (N=2,879)						age=18 (N=2,305)					
	Girls			Boys			Girls			Boys		
Domains	Overweight and obesity			Overweight and obesity			Obesity			Obesity		
	N	n	n (%)	N	n	n (%)	N	n	n (%)	N	n	n (%)
Socioeconomic disadvantage												
Mother´s education	1,387			1,389			1,222			1,048		
>13 years		405	31 (8)		444	40 (9)		373	7 (2)		352	8 (2)
11-13 years		641	47 (7)		634	82 (13)		569	12 (2)		460	14 (3)
≤10 years		341	39 (11)		311	50 (16)		280	14 (5)		236	15 (6)
Mother´s labour market participation	1,403			1,416			1,236			1,067		
High		969	87 (9)		993	113 (11)		862	25 (3)		772	24 (3)
Low		434	33 (8)		423	66 (16)		374	8 (2)		295	14 (5)
Equivalised income	1,380			1,387			1,195			1,026		
High		474	34 (7)		499	59 (12)		445	8 (2)		386	14 (4)
Medium		470	47 (10)		468	56 (12)		406	12 (3)		316	6 (2)
Low		436	39 (9)		420	60 (14)		344	12 (3)		324	18 (6)
Adult distress												
Parental self-rated health	1,206			1,199			1,010			857		
Good		803	63 (8)		806	86 (11)		688	14 (2)		577	15 (3)
Poor		403	36 (9)		393	60 (15)		322	15 (5)		280	12 (4)
Disharmonious family environment												
Family functioning	1,426			1,424			1,128			955		
Good		1,059	72 (7)		1,054	129 (12)		867	20 (2)		725	25 (3)
Poor		367	52 (14)		370	52 (14)		261	12 (5)		230	7 (3)
Offspring distress (15 years)												
Self-esteem	1,429			1,434			1,128			960		
High		1,099	84 (8)		1,212	148 (12)		879	20 (2)		826	25 (3)
Low		330	39 (12)		222	34 (15)		249	12 (5)		134	7 (5)
Depressive symptoms	1,427			1,418			1,129			954		
No		878	60 (7)		988	117 (12)		705	15 (2)		664	19 (3)
Yes		549	63 (11)		430	60 (14)		424	16 (4)		290	13 (4)
Self-rated health	1,435			1,435			1,133			958		
Good		1,004	64 (6)		1,153	122 (11)		814	15 (2)		781	15 (2)
Poor		431	60 (14)		282	59 (21)		319	17 (5)		177	16 (9)
Psychological and emotional overload (ages 15,18)												
Avoidance coping	1,428			1,425			1,132			954		
Low		1,133	85 (8)		1,137	143 (13)		919	23 (3)		767	27 (4)
High		295	38 (13)		288	37 (13)		213	9 (4)		187	5 (3)
Perceived stress	1,410			1,421			1,121			956		
Low		1,100	88 (8)		1,103	135 (12)		887	21 (2)		763	19 (2)
High		310	34 (11)		318	45 (14)		234	11 (5)		193	12 (6)
Smoking status	1,435			1,436			1,134			961		
Not smoking		1,224	107 (9)		1,279	155 (12)		999	27 (3)		872	28 (3)
Smoking		211	17 (8)		157	26 (17)		135	5 (4)		89	4 (4)
Homeostasis disrupted: start of weight gain (ages 15,18)												
Physical activity	1,425			1,435			1,125			958		
High		747	44 (6)		899	97 (11)		617	12 (2)		611	16 (3)
Low		678	78 (12)		536	84 (16)		508	20 (4)		347	16 (5)
Computer time	1,437			1,434			1,137			959		
Low		1,314	111 (8)		971	109 (11)		1,043	27 (3)		663	21 (3)
High		123	13 (11)		463	71 (15)		94	5 (5)		296	11 (4)

Table 2 Distribution of proxy variables from the domains (Hemmingsson:2014) in relation to the outcome at ages 21 and 28, stratified by gender

	age=21 (N=1,961)						age=28 (N=1,872)					
	Girls			Boys			Girls			Boys		
Domains		Obesity			Obesity			Obesity			Obesity	
	N	n	n (%)	N	n	n (%)	N	n	n (%)	N	n	n (%)
Socioeconomic disadvantage												
Mother´s education	1,063			876			1,019			800		
>13 years		319	10 (3)		306	8 (3)		296	23 (8)		270	22 (8)
11-13 years		510	33 (6)		365	23 (6)		479	73 (15)		334	54 (16)
≤10 years		234	27 (12)		205	22 (11)		244	44 (18)		196	43 (22)
Mother´s labour market participation	1,072			884			1,025			813		
High		753	48 (6)		638	30 (5)		719	86 (12)		587	75 (13)
Low		319	22 (7)		246	24 (10)		306	55 (18)		226	50 (22)
Equivalised income	1,045			857			1,007			799		
High		364	20 (5)		300	20 (7)		336	45 (13)		281	36 (13)
Medium		364	29 (8)		278	16 (6)		349	49 (14)		272	39 (14)
Low		317	22 (7)		279	18 (6)		322	50 (16)		246	45 (18)
Adult distress												
Parental self-rated health	875			707			825			621		
Good		579	33 (6)		489	29 (6)		563	64 (11)		425	61 (14)
Poor		296	28 (9)		218	15 (7)		262	46 (18)		196	27 (14)
Disharmonious family environment												
Family functioning	985			796			947			699		
Good		748	48 (6)		605	36 (6)		698	84 (12)		532	77 (14)
Poor		237	20 (8)		191	14 (7)		249	45 (18)		167	22 (13)
Offspring distress (15 years)												
Self-esteem	987			799			947			708		
High		753	40 (5)		677	42 (6)		731	82 (11)		615	87 (14)
Low		234	26 (11)		122	8 (7)		216	45 (21)		93	15 (16)
Depressive symptoms	991			793			946			700		
No		618	37 (6)		570	35 (6)		576	68 (12)		511	69 (14)
Yes		373	31 (8)		223	15 (7)		370	16 (16)		189	30 (16)
Self-rated health	990			793			948			705		
Good		711	32 (5)		645	34 (5)		666	65 (10)		577	70 (12)
Poor		279	36 (13)		148	16 (11)		282	64 (23)		128	32 (25)
Psychological and emotional overload (ages 18,21)												
Avoidance coping	922			705			734			497		
Low		698	44 (6)		556	41 (7)		569	82 (14)		395	50 (13)
High		224	18 (8)		149	6 (4)		165	27 (16)		102	19 (19)
Perceived stress	922			706			764			504		
Low		729	42 (6)		550	33 (6)		572	79 (14)		418	55 (13)
High		193	20 (10)		156	14 (9)		192	32 (17)		86	13 (15)
Smoking status	929			702			757			503		
Not smoking		718	41 (6)		519	31 (6)		555	68 (12)		339	39 (12)
Smoking		211	21 (10)		183	16 (9)		202	42 (21)		164	31 (19)
Homeostasis disrupted: start of weight gain (ages 18,21)												
Physical activity	935			720			753			502		
High		705	42 (6)		566	33 (6)		547	66 (12)		379	48 (13)
Low		230	20 (9)		154	14 (9)		206	44 (21)		123	22 (18)
Computer time	932			715			755			501		
Low		648	41 (6)		438	22 (5)		501	62 (12)		302	35 (12)
High		284	21 (7)		277	25 (9)		254	48 (19)		199	35 (18)

odds of obesity at age 28 years. In girls, PA (homeostasis disrupted) was associated with overweight and obesity at all four time-points, where CT was associated with obesity at age 28 years. In boys, this picture was similar to the girls for the domain.

Socioeconomic disadvantage and overweight and obesity (Table 3, girls)

When we examined the association between mother's educational level and overweight and obesity in 15 year-old girls, our results only revealed a tendency towards an association which was not influenced by any adjustment. At age 18 years, an almost three-fold increased odds for obesity was observed among girls with lower educated mothers, compared to girls with higher educated mothers. This attenuated primarily in Model III, whereas further adjustment in Model IV did not alter the estimates. At age 21 years, odds of obesity were four-fold greater, and this was not influenced by income or mother's LMP (Model II). When we included the variables from the domains in Model III, the estimates increased and showed a more than 5-fold increased odds for obesity, which did not change in the fully adjusted model. At age 28 years, we observed a more than 2.5-fold increased odds for obesity in girls with lower or medium educated mothers, which attenuated slightly by adding equivalised income and mother's LMP in Model II. When we included variables from the domains in Model III estimates increased slightly. Adding further to the model in terms of variables included in Model IV attenuated the association considerably in girls with lower educated mothers.

We did not find consistent associations between mother's low LMP and overweight and obesity at age 15, 18 and 21 years. At age 28 years there was 1.6-fold increased odds of obesity, which attenuated by adding variables included in Model II + III. Estimates did not change in the fully adjusted model. When we examined the associations between low equivalised income and overweight and obesity at ages 15 to 28 years, the majority of the associations showed small and inconsistent results. However, at age 18 years results showed 2-fold increased odds for obesity, which attenuated when adding variables included in Model II + III. The fully adjusted model did not change the estimates.

Socioeconomic disadvantage and overweight and obesity (Table 4, boys)

When we examined the association between mother's educational level and overweight and obesity in 15 year-old boys, we observed a 1.9-fold increased odds of overweight and obesity in boys with lower educated mothers, compared to boys with higher educated mothers.

Table 3 Unadjusted and adjusted estimates for the association between the socioeconomic disadvantage domain and overweight and obesity at age 15, 18, 21 and 28 years (girls)

	age=15 (N=1,438)								age=18 (N=1,238)							
	Model I		Model II[a]		Model III[b]		Model IV[c]		Model I		Model II[a]		Model III[b]		Model IV[c]	
Socioeconomic disadvantage	n	OR	n	AOR	n	AOR	n	AOR	n	OR	n	AOR	n	AOR	n	AOR
Mother's education	1,387		1,333		1,120		1,089		1,222		1,181		943		920	
>13 years (ref.gr.)		1		1		1		1		1		1		1		1
11-13 years		1.0 (0.6;1.5)		1.0 (0.6;1.6)		1.1 (0.7;2.0)		1.2 (0.7;2.0)		1.1 (0.4;2.9)		1.3 (0.5;3.6)		1.1 (0.4;3.2)		1.1 (0.4;3.2)
≤10 years		1.6 (0.9;2.6)		1.6 (0.9;2.8)		1.8 (0.9;3.3)		1.8 (0.9;3.4)		2.8 (1.1;6.9)		3.1 (1.1;8.4)		2.5 (0.8;7.3)		2.6 (0.9;7.8)
Mother's labour market participation	1,403		1,333		1,120		1,089		1,236		1,181		943		920	
High (ref.gr.)		1		1		1		1		1		1		1		1
Low		0.8 (0.5;1.3)		0.7 (0.5;1.1)		0.7 (0.4;1.2)		0.7 (0.4;1.1)		0.7 (0.3;1.6)		0.6 (0.3;1.4)		0.4 (0.2;1.2)		0.4 (0.1;1.2)
Equivalised income	1,380		1,333		1,120		1,089		1,195		1,181		943		920	
High (ref.gr.)		1		1		1		1		1		1		1		1
Medium		1.4 (0.9;2.3)		1.7 (1.0;2.7)		1.1 (0.7;1.9)		1.0 (0.6;1.8)		1.7 (0.7;4.1)		1.7 (0.7;4.2)		1.8 (0.6;5.0)		1.7 (0.6;4.8)
Low		1.3 (0.8;2.1)		1.2 (0.7;2.0)		0.8 (0.5;1.5)		0.7 (0.4;1.4)		2.0 (0.8;4.9)		1.7 (0.7;4.4)		1.5 (0.5;4.7)		1.5 (0.5;4.6)

	age=21 (N=1,075)								age=28 (N=1,045)							
	Model I		Model II[a]		Model III[b]		Model IV[c]		Model I		Model II[a]		Model III[b]		Model IV[d]	
Socioeconomic disadvantage	n	OR	n	AOR	n	AOR	n	AOR	n	OR	n	AOR	n	AOR	n	AOR
Mother's education	1,063		1,035		824		730		1,019		984		783		583	
>13 years (ref.gr.)		1		1		1		1		1		1		1		1
11-13 years		2.1 (1.0;4.4)		2.1 (1.0;4.3)		2.8 (1.2;6.7)		2.5 (1.0;6.0)		2.1 (1.3;3.5)		1.9 (1.1;3.1)		2.5 (1.4;4.5)		2.1 (1.1;4.1)
≤10 years		4.0 (1.9;8.5)		3.9 (1.8;8.5)		5.2 (2.1;12.9)		5.2 (2.1;13.2)		2.6 (1.5;4.5)		2.3 (1.3;4.1)		2.5 (1.3;4.9)		1.6 (0.7;3.5)
Mother's labour market participation	1,072		1,035		824		730		1,025		984		783		583	
High (ref.gr.)		1		1		1		1		1		1		1		1
Low		1.1 (0.6;1.8)		0.9 (0.5;1.5)		1.0 (0.5;1.9)		1.0 (0.5;2.0)		1.6 (1.1;2.3)		1.4 (0.9;2.0)		1.2 (0.7;1.9)		1.3 (0.8;2.3)
Equivalised income	1,045		1,035		824		730		1,007		984		783		583	
High (ref.gr.)		1		1		1		1		1		1		1		1
Medium		1.5 (0.8;2.7)		1.5 (0.8;2.7)		1.4 (0.7;2.7)		1.5 (0.7;3.1)		1.1 (0.7;1.6)		0.9 (0.6;1.4)		0.8 (0.5;1.4)		0.8 (0.5;1.5)
Low		1.3 (0.7;2.4)		1.1 (0.6;2.2)		0.9 (0.4;2.0)		1.0 (0.4;2.2)		1.2 (0.8;1.8)		0.9 (0.6;1.4)		0.6 (0.4;1.1)		0.5 (0.2;0.9)

a Mutual adjustments (adj.) for other SES variables
b Adj. for Model II + adult distress, disharmonious family environment and offspring distress, birth-weight
c Adj. for Model II + III, psychological and emotional overload, homeostasis disrupted, birth-weight
d Adj. for Model II + III, psychological and emotional overload, homeostasis disrupted, birth-weight, young people's own education (age 28)

Estimates did not change much when we added equivalised income and mother's LMP to the second model, and adding variables in Model III + IV did not reveal further changes. Among 18-year-old boys, we observed a 3-fold increased odds of obesity, which attenuated with the inclusion of equivalised income and mother's LMP in the second model. Adding the domains adult distress, disharmonious family environment and offspring distress to the third model attenuated the associations even further. In the fully adjusted Model IV, the estimate increased slightly. At age 21 years, we observed a more than four-fold increased odds for obesity in boys having a mother with low level of education and it was primarily by adding equivalised income and mother's LMP to the second model that attenuated the associations. When applying the fully adjusted model, estimates attenuated slightly more. At age 28 years, we observed a more than 3-fold increased odds for obesity, the associations being primarily attenuated in Model III by adding equivalised income, mother's LMP and variables from the domains adult distress, disharmonious family environment and offspring distress. When we applied the fully adjusted model the association between mother's low educational level and obesity vanished.

When we examined the associations between mother's low LMP and overweight and obesity in boys it appeared that the association at age 15 years to some extent attenuated when all variables from the different domains were included in the fully adjusted model. This tendency was also seen at age 21 years. At ages 18 and 28 years it was primarily by adding mother's LMP, equivalised income and the variables from the domains adult distress, disharmonious family environment and offspring distress which attenuated the associations.

Discussion

The aim of this study was to explore the associations between socioeconomic disadvantage and overweight and obesity and to examine if these associations attenuate, when the different domains from Eric Hemmingsson's obesity causation model were taken into account. Our results showed that mother's lower educational level as proxy for the socioeconomic disadvantage domain was by far the strongest and most consistent risk factor for overweight and obesity at ages 15 to 28 years in both genders with an up to 4-fold increased odds for overweight and obesity. Mother's low LMP was a consistent risk factor in relation to overweight and obesity in boys only.

For both genders, controlling for the different domains when examining the association between mother's low educational level and overweight and obesity did not

Table 4 Unadjusted and adjusted estimates for the association between the socioeconomic disadvantage domain and overweight and obesity at age 15, 18, 21 and 28 years (boys)

	age=15 (N=1,441)								age=18 (N=1,067)							
	Model I		Model II[a]		Model III[b]		Model IV[c]		Model I		Model II[a]		Model III[b]		Model IV[c]	
Socioeconomic disadvantage	n	OR	n	AOR	n	AOR	n	AOR	n	OR	n	AOR	n	AOR	n	AOR
Mother's education	1,389		1,344		1,098		1,077		1,048		1,014		786		769	
>13 years (ref. gr.)		1		1		1		1		1		1		1		1
11-13 years		1.5 (1.0;2.2)		1.4 (0.9;2.1)		1.5 (0.9;2.3)		1.5 (0.9;2.4)		1.3 (0.6;3.3)		1.3 (0.5;3.1)		1.3 (0.5;3.4)		1.8 (0.6;5.4)
≤10 years		1.9 (1.2;3.0)		1.8 (1.1;2.8)		1.8 (1.0;3.0)		1.8 (1.0;3.1)		2.9 (1.2;7.0)		2.5 (1.0;6.1)		1.7 (0.6;5.2)		2.2 (0.7;7.2)
Mother's labour market participation	1,416		1,344		1,098		1,077		1,067		1,014		786		769	
High (ref.gr.)		1		1		1		1		1		1		1		1
Low		1.4 (1.0;2.0)		1.3 (0.9;1.8)		1.3 (0.8;1.9)		1.2 (0.8;1.9)		1.6 (0.8;3.0)		1.2 (0.6;2.5)		1.0 (0.4;2.4)		1.0 (0.4;2.5)
Equivalised income	1,387		1,344		1,098		1,077		1,026		1,014		786		769	
High (ref.gr.)		1		1		1		1		1		1		1		1
Medium		1.0 (0.7;1.5)		0.9 (0.6;1.4)		0.9 (0.5;1.4)		0.8 (0.5;1.3)		0.5 (0.2;1.4)		0.5 (0.2;1.2)		0.6 (0.2;1.7)		0.4 (0.1;1.5)
Low		1.2 (0.8;1.8)		1.1 (0.7;1.7)		1.2 (0.7;2.0)		1.2 (0.7;1.9)		1.6 (0.8;3.2)		1.2 (0.6;2.6)		1.5 (0.6;3.9)		1.7 (0.6;4.4)

	age=21 (N=886)								age=28 (N=827)							
	Model I		Model II[a]		Model III[b]		Model IV[c]		Model I		Model II[a]		Model III[b]		Model IV[c]	
Socioeconomic disadvantage	n	OR	n	AOR	n	AOR	n	AOR	n	OR	n	AOR	n	AOR	n	AOR
Mother's education	876		851		658		551		800		776		572		390	
>13 years (ref.gr.)		1		1		1		1		1		1		1		1
11-13 years		2.5 (1.1;5.7)		2.3 (0.9;5.2)		2.7 (1.1;6.6)		2.5 (0.9;6.3)		2.2 (1.3;3.7)		1.9 (1.1;3.3)		1.9 (1.0;3.4)		1.7 (0.8;3.4)
≤10 years		4.5 (2.0;10.3)		3.8 (1.6;9.0)		3.9 (1.5;10.4)		3.6 (1.3;10.2)		3.2 (1.8;5.5)		2.6 (1.5;4.6)		2.0 (0.9;3.9)		0.9 (0.3;2.6)
Mother's labour market participation	884		851		658		551		813		776		572		390	
High (ref.gr.)		1		1		1		1		1		1		1		1
Low		2.2 (1.3;3.8)		1.8 (0.9;3.2)		1.7 (0.9;3.4)		1.4 (0.7;3.1)		1.9 (1.3;2.9)		1.6 (1.0;2.4)		1.5 (0.9;2.6)		1.5 (0.7;3.0)
Equivalised income	857		851		658		551		799		776		572		390	
High (ref.gr.)		1		1		1		1		1		1		1		1
Medium		0.9 (0.4;1.7)		0.7 (0.3;1.3)		0.6 (0.3;1.3)		0.6 (0.2;1.3)		1.1 (0.7;1.9)		0.9 (0.6;1.5)		0.8 (0.5;1.5)		0.7 (0.3;1.5)
Low		1.0 (0.5;1.9)		0.6 (0.3;1.3)		0.6 (0.3;1.4)		0.4 (0.2;1.1)		1.5 (0.9;2.5)		1.2 (0.7;2.0)		1.2 (0.6;2.1)		1.1 (0.5;2.4)

a Mutual adjustments (adj.) for other SES variables

b Adj. for Model II + adult distress, disharmonious family environment and offspring distress, birth-weight

c Adj. for Model II + III, psychological and emotional overload, homeostasis disrupted, birth-weight

d Adj. for Model II + III, psychological and emotional overload, homeostasis disrupted, birth-weight, young people's own education (age 28)

influence the associations much at age 15 years, while at age 21 years, some gender-differences became apparent. In the analysis with the outcome in 18-year-old girls and boys it appeared that adjusting for especially the variables included in the domains adult distress, disharmonious family environment and offspring distress attenuated the associations to some degree. At age 21 years, however, adjustments increased the association in girls, whereas in boys the association attenuated. At age 28 years the estimates attenuated considerably in both genders when we added all the variables in the fully adjusted model. For both girls and especially boys it appeared that the introduction of their own educational level in the models substantially decreased the ORs for the association between mother's low educational level and obesity, which points to a potential strong buffering effect of education for the development of overweight and obesity in adulthood [41].

Our study showed that the associations between socioeconomic disadvantage and overweight and obesity to some degree attenuated when the domains from Erik Hemmingsson's obesity causation model were taken into account. This may, to some extent, confirm that the proposed obesity causation model can be used as a model to understand overweight and obesity among young people living in a more egalitarian society. Our choice of proxies for the different domains may, however, have influenced our findings and makes it difficult to examine the model in full; this will be discussed in further details under analytic approach and limitations.

When we examined the associations between low equivalised income and overweight and obesity we found no association. The Danish well-fare society is well organized and individuals have the opportunity of receiving social benefits in case of long-term unemployment or sick leave which may, to some degree, decrease the risk of chronic stress related to financial difficulties compared to the US and the UK. Danish parents have furthermore the opportunity to stay on parental leave for a longer period than in most other countries, which perhaps decreases the risk of parental distress experienced during this stressful period of starting up a family. Our data showed that boys who grew up in families with a mother having a low LMP in early childhood had some increased odds of overweight and obesity. In girls, the tendency was opposite, and we have no good explanation for this difference. The results in boys may reflect that mother's with low LMP or being unemployed in early childhood have less surplus to, for example, prepare healthy nutritious food which along with increased sedentary behaviour, unhealthy eating habits [42] and disturbed sleep pattern [43] in adolescent boys may increase the risk of overweight and obesity.

Our analyses showed that mother's low educational level as a proxy for the socioeconomic disadvantage domain was the most stable and consistent risk factor for overweight and obesity in both genders. This may add attention to the different forms of social and cultural capital [44] which may be passed on from parent's to children, due to the fact that children from families of lower socioeconomic status may carry much less capital compared to peers from families of higher socioeconomic status [45]. In this Danish context, cultural capital may be very important, since children who grow up in families with parents having a low level of education more often end up with a lower educational attainment [46], which may increase risks of unhealthy habits related to lifestyle and health. Our results revealed a quite strong role of own education in mitigating the relationships between maternal lower educational level and young people's obesity at age 28 years. It seems therefore essential to address the importance of young people's educational attainment since this, at least to some extent, may prevent overweight and obesity.

Our analyses showed that the associations between mother's low educational level and obesity at age 18 years attenuated primarily when we added the variables from the domains adult distress, disharmonious family environment and offspring distress. Self-rated health of the participants (offspring distress) was a robust and consistent risk factor for overweight and obesity at all four ages in both genders, which could indicate that this variable may account for some of the effect. This is supported by the findings from supplementary analyses (results not shown) where we did adjustments for the individual proxies which showed that participant's poor self-rated health attenuated the associations substantially, especially in boys. In girls, however, the variables parental poor self-rated health (adult distress) and poor family functioning (disharmonious family environment) also attenuated the associations to some degree.

It is important to address the fact that every fifth child or young person aged between 10 and 24 years reported often feeling stressed [22] and further disentangle whether this is related to family conflict, well-being in schools or increased job demands, which may have the potential of evolving to chronic stress with negative health consequences.

Our results have shown that especially mother's lower educational level was associated with later overweight and obesity in both genders. It is therefore important to increase the support to socioeconomically disadvantaged families during childhood to help decrease stress in parents which may influence the family environment where the child is living. Likewise it is important to address the attention to children and young people's report of poor self-rated health since this may act as an important marker of later overweight and obesity. It therefore also

seems relevant to include a greater use of self-report from children and adolescents due to its value to get more good surveillance data to be able to better target preventive initiatives within overweight and obesity.

Obesity in children and young people is a very complex issue which makes it difficult to be specific in relation to preventive initiatives. However, being stressed due to e.g. poorer family function or/ and having a poor self-rated health as a child or adolescent may increase the risk of applying maladaptive coping mechanisms and induce risky behaviours which may track into adulthood and increase the risk of poorer health later on. It is therefore important to address these issues at the family and school level since they appear to be important steps on the pathway between socioeconomic disadvantage and obesity, at least in a Danish context.

Analytic approach

We applied proxy variables for all the domains which were available from surveys and registers. It may be debatable whether these proxies were sufficient and robust enough to capture the content of the domains presented in Erik Hemmingsson's model and perhaps less suited to be applied to both genders. As presented under the results several of the proxies appeared to pertain primarily to girls which may have influenced our results.

The overall avoidance scale included items about substance use. Previous studies have found an association between maladaptive coping mechanisms and obesity [47]. It can be speculated that if a person applied this type of maladaptive coping mechanism for chronic stress, perhaps overeating as well could be implied in this kind of substance use, especially among girls [48].

We did not have the opportunity to include information about more severe childhood adversities such as parental neglect in childhood, which has shown to be an important risk factor for later obesity [49], nor about childhood abuse [50], which may severely increase psychosocial distress in children. Including information on parental divorce or single-mother background could be relevant since being a single mother may increase distress which can potentially influence the family environment and induce increased psychosocial distress in children and hence lead to an increase in weight [51].

Our analytic approach was a three-step model with adjustments for the proxy variables in the different domains as potential confounders. Since some of the proxy variables within offspring distress and within psychological and emotional overload to some extent were correlated we did a supplementary analysis for both genders, where we only included the overall strongest proxies in each domain in relation to the outcome. This did, however, not change the estimates radically (results not shown).

We included adjustments for birth weight in Model III + IV, and it is debatable whether the attenuation of the estimates may be due to this adjustment or to the included variables in the different domains. We did supplementary analyses between the different exposures and the outcome, adjusting solely for birth weight; this did, however, not change the estimates much, so the attenuation of estimates is likely due to the other included variables and not birth weight (results not shown).

Strengths and limitations

To our knowledge, this is the first study to examine this Hemmingsson obesity causation model using longitudinal data to disentangle the associations between socioeconomic disadvantage during childhood and overweight and obesity in adolescence and early adulthood.

A major strength of this study was the fact that it was a prospective cohort study using data from four survey waves in the West Jutland Cohort Study, supplemented with register information on the three socioeconomic exposure variables, resulting in few missing values on the main exposures.

One of the main limitations of the study was that the main outcome was based on self-reported weight and height and several of the applied proxies was also based on self-reported information, which is prone to misclassification. Participants in surveys, who are overweight or obese, are probably more likely to underestimate weight, especially girls [52] which may increase the risk of differential misclassification. This increases the risk of overestimating a potential association and hence bias away from the null hypothesis. We acknowledge the fact that the measured associations at age 15 years were cross-sectional and cannot tell us anything about the direction of associations. We did not find the model suitable to explain the associations between mother's low educational level and overweight and obesity at age 15 years. This may, however, be attributed to the fact that we applied the BMI limits for overweight and not obesity due to very few obese subjects at this age. As mentioned in the section about the analytic approach our chosen proxies may not fully cover the different domains in Hemmingsson's model which limits the ability to examine the model in full. However, we have included available variables which we believe may act as proxies for the different domains. Unfortunately, we did not have information on food intake for the domain regarding homeostasis disrupted which may have influenced our results. It may also be debatable whether applying smoking status as a proxy for the psychological and emotional overload domain seems reasonable, however, we believe that smoking may reflect a maladaptive coping mechanism which was not covered by the questions regarding substance use.

The cut-off for high level of PA in adults was set below the recommended limit for weekly PA, which is due to the response categories and also to ensure that we did not get any rendered results because there were quite few 21 year olds having a PA level of ≥4 h per week.

We chose to dichotomise many of the continuous and categorical proxy variables to facilitate comprehensibility of the results although dichotomising a variable will result in loss of information [53].

A previous examination of the study setting concluded that the participants of this youth cohort do not differ from young people in other parts of Denmark [54]. The results from this study with the abovementioned limitations may therefore be generalizable to other young people experiencing environmental and social conditions similar to this Danish youth cohort.

Conclusion

Our study confirms to some extent that the associations between socioeconomic disadvantage and overweight and obesity can be disentangled by the domains included in Erik Hemmingsson's proposed obesity causation model. Our results showed that mother's low educational level as a proxy for socioeconomic disadvantage was clearly associated with overweight and obesity in both gender with an up to four-fold increased odds, whereas mother's low LMP was associated with overweight and obesity in boys only. Poor parental self-rated health (adult distress), poor family function (disharmonious family environment) and poor self-rated health (offspring distress) of the participant's appeared to account for some of the effect in girls, in boys this was merely poor self-rated health (offspring distress). Young people's own educational attainment may act as a buffer of the association between mother's low educational level and obesity at age 28. The main results should be interpreted with caution due to the risk of information bias related to the outcome and due to the fact that some of the chosen proxies for the different domains may pertain primarily to girls and may not fully cover the domains of Hemmingsson's model.

Future research should focus on other proxy variables which may pertain to earlier stages in childhood to further explain the associations between socioeconomic disadvantage and overweight and obesity in the offspring and to further investigate whether the gender differences found in our study may be due to the chosen proxies or the included ages of outcome. It seems important to include information about e.g. parental neglect and childhood abuse in future studies because of their strong associations with later obesity. To prevent overweight and obesity in children and young people, it is important that societies address the experience of stress among especially socioeconomic disadvantaged families. It also seems essential to address the importance of young people's educational attainment given the potential important mitigating role of own education in the relationship between maternal low education and later overweight and obesity.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12889-019-7699-8.

Additional file 1: Table S1. Unadjusted estimates for the association between the individual proxies from the 5 domains (Hemmingsson:2014) and overweight and obesity at age 15, 18, 21 and 28 years (girls).

Additional file 2: Table S2. Unadjusted estimates for the association between the individual proxies from the 5 domains (Hemmingsson:2014) and overweight and obesity at age 15, 18, 21 and 28 years (boys).

Abbreviations

AOR: Adjusted Odds Ratio; BMI: Body Mass Index; CES-DC: Center for Epidemiologic Studies Depression Scale for Children; CI: Confidence interval; CT: Computer time; E.g.: Exempli gratia; FAD: McMaster Family Assessment Device; LMP: Labour market participation; OR: Odds ratio; PA: Physical activity; PSS: Perceived Stress Scale; SES: Socioeconomic status; UK: United Kingdom; US: United States

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None.

Authors' contributions

PHP designed the study and performed the analyses, and wrote the main paper. KB helped in designing the study and analysing data. TNW helped in designing the study and analysing data. EAN helped in designing the study and analysing data. LVP helped in designing the study and analysing data. SJU helped in designing the study and analysing data. JHA initiated the study and helped in designing the study and analysing data. All authors interpreted the results and their implications and commented on the manuscripts at all stages. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available from Statistics Denmark but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Statistics Denmark.

Ethics approval and consent to participate

The study was appoved by the Danish Data Protection Agency. According to Danish Law (Act on Research Ethics Review of Health Research Projects), questionnaire and register-based studies require neither approval by ethical or scientific committees nor informed consent [55].

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Danish Ramazzini Centre, Department of Occupational Medicine, University Research Clinic, Regional Hospital West Jutland, Gl. Landevej 61, 7400

Herning, Denmark. [2]Institute of Clinical Research, Department of Obstetrics & Gynecology, University of Southern Denmark, Odense University Hospital, Odense, Denmark. [3]National Center for Register-Based Research, Aarhus University, Fuglesangs Allé 26, 8210 Aarhus V, Denmark. [4]Unit for Biocultural Variation and Obesity, Institute of Social and Cultural Anthropology, University of Oxford, Oxford, UK.

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References

1. World Health Organization, Europe. Data and statistics. http://www.euro.who.int/en/health-topics/noncommunicable-diseases/obesity/data-and-statistics. Accessed 15 May 2019.
2. Magnusson M, Sorensen TI, Olafsdottir S, Lehtinen-Jacks S, Holmen TL, Heitmann BL, Lissner L. Social inequalities in obesity persist in the nordic region despite its relative affluence and equity. Curr Obes Rep. 2014;3:1–15.
3. Chung A, Backholer K, Wong E, Palermo C, Keating C, Peeters A. Trends in child and adolescent obesity prevalence in economically advanced countries according to socioeconomic position: a systematic review. Obes Rev. 2016;17(3):276–95.
4. Wardle J, Chida Y, Gibson EL, Whitaker KL, Steptoe A. Stress and adiposity: a meta-analysis of longitudinal studies. Obesity (Silver Spring). 2011;19(4):771–8.
5. Gundersen C, Mahatmya D, Garasky S, Lohman B. Linking psychosocial stressors and childhood obesity. Obes Rev. 2011;12(5):e54–63.
6. Sherwood L. Human Physiology From Cells to Systems: 4th ed. California: Brooks/Cole; 2001.
7. Lazarus R, Folkman S. The Concept of Stress. In stress, appraisal, and coping. Edited by Anonymous. New York: Springer Publishing Company, Inc; 1984. p. 11–9.
8. Yau YH, Potenza MN. Stress and eating behaviors. Minerva Endocrinol. 2013;38(3):255–67.
9. Charmandari E, Tsigos C, Chrousos G. Endocrinology of the stress response. Annu Rev Physiol. 2005;67:259–84.
10. Evans GW, Kim P. Childhood poverty, chronic stress, self-regulation, and coping. Child Dev Perspect. 2013;7(1):43–8.
11. Adam TC, Epel ES. Stress, eating and the reward system. Physiol Behav. 2007;91(4):449–58.
12. Tryon MS, Carter CS, Decant R, Laugero KD. Chronic stress exposure may affect the brain's response to high calorie food cues and predispose to obesogenic eating habits. Physiol Behav. 2013;120:233–42.
13. Torres SJ, Nowson CA. Relationship between stress, eating behavior, and obesity. Nutrition. 2007;23(11–12):887–94.
14. De Vriendt T, Clays E, Maes L, De Bourdeaudhuij I, Vicente-Rodriguez G, Moreno LA, et al. HELENA Study Group: European adolescents' level of perceived stress and its relationship with body adiposity--the HELENA study. Eur J Pub Health. 2012;22(4):519–24.
15. Biro FM, Wien M. Childhood obesity and adult morbidities. Am J Clin Nutr. 2010;91(5):1499S–505S.
16. Hayward LE, Vartanian LR, Pinkus RT. Weight stigma predicts poorer psychological well-being through internalized weight bias and maladaptive coping responses. Obesity (Silver Spring). 2018;26(4):755–61.
17. Pont SJ, Puhl R, Cook SR, Slusser W. Section on obesity, obesity society: Stigma experienced by children and adolescents with obesity. Pediatrics. 2017;140(6). https://doi.org/10.1542/peds.2017-3034 Epub 2017 Nov 20.
18. Hemmingsson E. A new model of the role of psychological and emotional distress in promoting obesity: conceptual review with implications for treatment and prevention. Obes Rev. 2014;15(9):769–79.
19. Global organization for stress. Stress facts. Available at http://www.gostress.com/stress-facts/. Accessed 15 May 2019.
20. American Psychological Association: Stress in America Generation Z: Stress in America TM Survey. 2018, october.
21. Rosendahl Jensen HA, Davidsen M, Ekholm O, Christensen AI. The Danish National Health Profile 2017; 2018.
22. Due P, Diderichsen F, Meilstrup C, Nordentoft M, Obel C, Sandbæk A. Børn og unges mentale helbred. Forekomst af psykiske symptomer og lidelser og mulige forebyggelsesindsatser; 2014.
23. VestLiv [http://www.vestliv.dk/dk/sprgeskema/tidligere-sprgeskemaer]. Accessed 15 May 2019.
24. Winding TN, Andersen JH, Labriola M, Nohr EA. Initial non-participation and loss to follow-up in a Danish youth cohort: implications for relative risk estimates. J Epidemiol Community Health. 2014;68(2):137–44.
25. Schmidt M, Pedersen L, Sorensen HT. The Danish civil registration system as a tool in epidemiology. Eur J Epidemiol. 2014;29(8):541–9.
26. World Health Organisation, Global database on body mass index available at http://apps.who.int/bmi/index.jsp?introPage=intro_3.html. Accessed 15 May 2019.
27. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7(4):284–94.
28. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000;320(7244):1240–3.
29. Jensen VM, Rasmussen AW. Danish education registers. Scand J Public Health. 2011;39(7 Suppl):91–4.
30. Baadsgaard M, Quitzau J. Danish registers on personal income and transfer payments. Scand J Public Health. 2011;39(7 Suppl):103–5.
31. Hjollund NH, Larsen FB, Andersen JH. Register-based follow-up of social benefits and other transfer payments: accuracy and degree of completeness in a Danish interdepartmental administrative database compared with a population-based survey. Scand J Public Health. 2007;35(5):497–502.
32. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care. 1992;30(6):473–83.
33. Epstein N, Baldwin L, Bishop D. The McMaster family assessment device. J Marital Fam Ther. 1983;9(2):171.
34. Turner RJ, Lloyd DA, Roszell P. Personal resources and the social distribution of depression. Am J Community Psychol. 1999;27(5):643–72.
35. Fendrich M, Weissman MM, Warner V. Screening for depressive disorder in children and adolescents: validating the Center for Epidemiologic Studies Depression Scale for children. Am J Epidemiol. 1990;131(3):538–51.
36. Carver CS. You want to measure coping but your protocol's too long: consider the brief COPE. Int J Behav Med. 1997;4(1):92–100.
37. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav. 1983;24(4):385–96.
38. Klarlund B, Andersen L. Fysisk aktivitet. Håndbog om forebyggelse og behandling; 2018.
39. Zhao Y, Wang SF, Mu M, Sheng J. Birth weight and overweight/obesity in adults: a meta-analysis. Eur J Pediatr. 2012;171(12):1737–46.
40. Knudsen LB, Olsen J. The Danish medical birth registry. Dan Med Bull. 1998;45(3):320–3.
41. Kuntz B, Lampert T. Intergenerational educational mobility and obesity in adolescence: findings from the cross-sectional German KiGGS study. J Public Health. 2013;21:49–56.
42. Santaliestra-Pasias AM, Mouratidou T, Verbestel V, Huybrechts I, Gottrand F, Le Donne C, et al. Healthy lifestyle in Europe by nutrition in adolescence cross-sectional study group: food consumption and screen-based sedentary behaviors in European adolescents: the HELENA study. Arch Pediatr Adolesc Med. 2012;166(11):1010–20.
43. Miller MA, Kruisbrink M, Wallace J, Ji C, Cappuccio FP. Sleep duration and incidence of obesity in infants, children, and adolescents: a systematic review and meta-analysis of prospective studies. Sleep. 2018;41(4). https://doi.org/10.1093/sleep/zsy018.
44. Ulijaszek SJ. Inequalities. In: Models of Obesity From ecology to complexity in science and policy. 1st ed. Edited by. Anonymous United Kingdom: Cambridge University Press; 2017. p. 71–93.
45. Ulijaszek SJ. Socio-economic status, forms of capital and obesity. J Gastrointest Cancer. 2012;43(1):3–7.
46. Tverborgvik T, Clausen LB, Thorsted BL, Mikkelsen S, Lynge E. Intergenerational educational mobility in Denmark. Scand J Educ Res. 2013;57(5):544–60.
47. Young D, Limbers CA. Avoidant coping moderates the relationship between stress and depressive emotional eating in adolescents. Eat Weight Disord. 2017;22(4):683–91.
48. Sulkowski ML, Dempsey J, Dempsey AG. Effects of stress and coping on binge eating in female college students. Eat Behav. 2011;12(3):188–91.
49. Lissau I, Sorensen TI. Parental neglect during childhood and increased risk of obesity in young adulthood. Lancet. 1994;343(8893):324–7.
50. Hemmingsson E, Johansson K, Reynisdottir S. Effects of childhood abuse on adult obesity: a systematic review and meta-analysis. Obes Rev. 2014;15(11):882–93.
51. Mikkonen HM, Salonen MK, Hakkinen A, Olkkola M, Pesonen AK, Raikkonen K, et al. The lifelong socioeconomic disadvantage of single-mother

background - the Helsinki Birth Cohort study 1934–1944. BMC Public Health. 2016;16(1):817. https://doi.org/10.1186/s12889-016-3485-z.
52. Clarke P, Sastry N, Duffy D, Ailshire J. Accuracy of self-reported versus measured weight over adolescence and young adulthood: findings from the national longitudinal study of adolescent health, 1996-2008. Am J Epidemiol. 2014;180(2):153–9.
53. Juul S. Epidemiology and evidence: 2nd ed. Viborg: Munksgaard, Copenhagen; 2012.
54. Glasscock DJ, Andersen JH, Labriola M, Rasmussen K, Hansen CD. Can negative life events and coping style help explain socioeconomic differences in perceived stress among adolescents? A cross-sectional study based on the West Jutland cohort study. BMC Public Health. 2013;13:532. https://doi.org/10.1186/1471-2458-13-532.
55. Danish National Committee on Biomedical Research Ethics: Act on research ethics review of health research projects. 2013.

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Full name of the PhD student: Per Høgh Poulsen

This declaration concerns the following article/manuscript:

Title:	The influences of childhood family factors on depressive symptoms in adolescence and early adulthood: a Danish longitudinal study
Authors:	Poulsen, PH; Biering, Karin; Winding, TN; Nohr, EA; Andersen, JH

The article/manuscript is: Published ☐ Accepted X☐ Submitted: In preparation ☐

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Element	Extent (A-F)
1. Formulation/identification of the scientific problem	B
2. Development of the method	B
3. Planning of the experiments and methodology design and development	B
4. Involvement in the experimental work/clinical studies/data collection/obtaining access to data	E
5. Development of analysis plan and preparation of data for analysis	B
6. Planning and conducting the analysis of data	B
7. Interpretation of the results	B
8. Writing of the first draft of the manuscript	A
9. Finalization of the manuscript and submission	A

Signatures of first- and last author, and main supervisor

Date	Name	Signature
9/12-2019	Per Høgh Poulsen	Per Høgh Poulsen
9/12-2019	Johan Hviid Andersen	Johan Hviid Andersen

AARHUS
UNIVERSITY

Date: 9/12-2019

Per Hoegh

Signature of the PhD student

AARHUS UNIVERSITY

Declaration of co-authorship concerning article for PhD dissertations

Full name of the PhD student: Per Høgh Poulsen

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Title:	How does childhood socioeconomic position affect overweight and obesity in adolescence and early adulthood: a longitudinal study
Authors:	Poulsen, PH; Biering, K; Winding, TN; Nohr, EA; Andersen, JH

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Element	Extent (A-F)
1. Formulation/identification of the scientific problem	B
2. Development of the method	B
3. Planning of the experiments and methodology design and development	B
4. Involvement in the experimental work/clinical studies/data collection/obtaining access to data	E
5. Development of analysis plan and preparation of data for analysis	B
6. Planning and conducting the analysis of data	B
7. Interpretation of the results	B
8. Writing of the first draft of the manuscript	A
9. Finalization of the manuscript and submission	A

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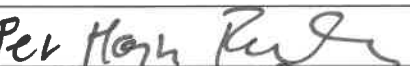
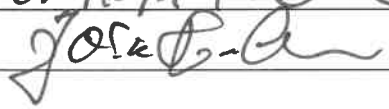
Date	Name	Signature
17/6-19	Per Høgh Poulsen	
17/6-19	Johan Hviid Andersen	

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Date: 17/6-2019

Per Høgh Poulsen

Signature of the PhD student

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Declaration of co-authorship concerning article for PhD dissertations

Full name of the PhD student: Per Høgh Poulsen

This declaration concerns the following article/manuscript:

Title:	How does psychosocial stress affect the relationship between socioeconomic disadvantage and overweight and obesity? Examining Hemmingsson´s model with data from a Danish longitudinal
Authors:	Poulsen, PH; Biering, K; Winding, TN; Nohr, EA; Petersen, LV; Ulijaszek, SJ; Andersen, JH

The article/manuscript is: Published X☐ Accepted ☐ Submitted: In preparation ☐

If published, state full reference: 2019;19:1475

If accepted or submitted, state journal: BMC Public Health

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No: X Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

A. Has essentially done all the work
B. Has done most of the work (67-90 %)
C. Has contributed considerably (34-66 %)
D. Has contributed (10-33 %)
E. No or little contribution
F. N/A

Element	Extent (A-F)
1. Formulation/identification of the scientific problem	B
2. Development of the method	B
3. Planning of the experiments and methodology design and development	B
4. Involvement in the experimental work/clinical studies/data collection/obtaining access to data	E
5. Development of analysis plan and preparation of data for analysis	B
6. Planning and conducting the analysis of data	B
7. Interpretation of the results	B
8. Writing of the first draft of the manuscript	A
9. Finalization of the manuscript and submission	A

Signatures of first- and last author, and main supervisor

Date	Name	Signature
9/12-19	Per Høgh Poulsen	Per Høgh Poulsen

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9/12-19	Johan Hviid Andersen	

Date: 9/12-2019

Signature of the PhD student