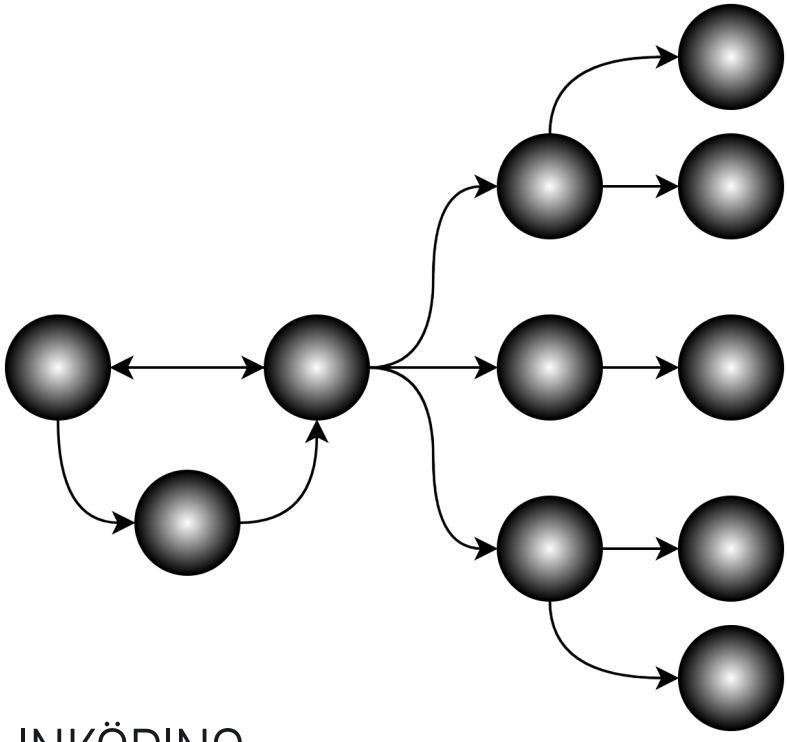
Linköping University Medical Dissertation No. 1885

Social Inequalities in Child Health

Type 1 Diabetes, Obesity, Cardiovascular Risk Factors and the Role of Self-control

Pär Andersson White



LINKÖPING UNIVERSITY

Linköping University Medical Dissertations No. 1885

Social Inequalities in Child Health

Type 1 Diabetes, Obesity, Cardiovascular Risk Factors and the Role of Self-control

Pär Andersson White

Department of Health, Medicine and Caring Science
Linköping University, Sweden
Linköping 2024

Cover: Pär Andersson White

Published articles have been reprinted with the permission of the copyright holder.

Printed in Sweden by LiU-Tryck, Linköping, Sweden, 2024

ISBN 978-91-8075-416-3 (print)
ISBN 978-91-8075-417-0 (PDF)
ISSN 0345-0082

To Edith, Siri, and Maria

"Medicine is a social science, and politics
nothing but medicine at a larger scale."
- Rudolf Virchow (nov, 1848)

CONTENTS

ABSTRACT

The Swedish Commission on Health Inequality defined health inequality as systematic differences in health between groups in society with different social positions. All avoidable socioeconomic health inequalities are unfair, and as stated by WHO's Commission on the Social Determinants of Health, we have a moral obligation to try to reduce them. “Putting these inequities right is a matter of social justice. Reducing health inequities is, for the Commission on Social Determinants of Health, an ethical imperative.” This ethical imperative is especially apparent regarding the health of children and adolescents. Children’s right to the highest attainable standard of health is also enshrined in Article 24 of the Convention on the Rights of the Child. To reach the goal of a reduction of health inequalities, research is necessary to describe the social gradients of health. Research is also needed to better understand why these gradients occur. A better understanding and knowledge about health inequalities can lead to policies that reduce these inequalities and ensure children’s right to health.

This thesis investigates social inequality in child health using data from a Swedish population-based prospective birth cohort, the All Babies in Southeast Sweden (ABIS) cohort. Social inequality in obesity in the ABIS cohort is also compared with other birth cohorts participating in the Elucidating Pathways to Child Health Inequality (EPOCH) collaboration which includes cohorts from six high-income countries; Sweden, the Netherlands, Canada (one national and one cohort from Quebec), UK, Australia, and USA.

In Paper 1 we show that health inequalities in overweight and obesity are detectable already at two years of age and that these inequalities increase during childhood. In adolescents, low socioeconomic status increases the risk of becoming overweight and the risk of components of the metabolic syndrome, including high blood pressure and dyslipidemia (low high-density cholesterol).

The level of inequality in obesity in the Swedish ABIS cohort was lower than in the other participating countries in the EPOCH collaboration (Paper 2). Inequality was lower in absolute and relative terms when SES was measured by household income. Inequality was also lower in absolute, but not relative, terms when SES was measured by maternal education. This finding indicates that some of the policies implemented in Sweden may attenuate social inequalities in obesity in children. Examples of such policies with evidence for reducing social inequality in obesity implemented in Sweden include universal preschools and free school meals.

This thesis also investigates health inequalities in autoimmune disease (Paper 3). In this study, we found that low socioeconomic status increased

the risk of Type 1 Diabetes but not the other autoimmune diseases investigated. Path analysis indicated that part of the increased risk in children with low SES of Type 1 Diabetes might be mediated by a higher body mass index and an elevated risk of serious life events.

In the final paper, this thesis tests the hypothesis that differences in maternal and child self-control mediate social inequalities in obesity. Two measures of self-control were used; for mothers, the self-control variable was based on behaviors related to self-control (smoking during pregnancy, smoking during the child's first year of life, breastfeeding duration, and participating in the ABIS study with biological samples). For the children, the self-control variable was based on questionnaire data on the impulsivity subscale of the Strengths and Difficulties Questionnaire (SDQ). The results showed that the two measures of self-control mediated 87.5 % of the increased risk of obesity at age 19 years in children with low maternal education and 93 % of the risk if maternal BMI was also included in the self-control variable.

In the discussion part of this thesis, the conclusions that can be deduced from understanding the mechanisms of social inequality in child health are discussed. A theory with a central role of self-control for health inequality predicts that social inequality will increase without interventions. In an environment with rising numbers of stimuli of the human reward system, stimuli that also have negative long-term consequences (so-called Limbic traps), child and adolescent health, in general, will decrease. Because of the mechanisms related to SES and self-control, children with low SES will be disproportionally affected. The result of this development will be increasing levels of social inequalities in child health.

The discussion also includes implications for policies that may improve health and reduce inequalities. These policies should reduce the exposure of children and adolescents to harmful behaviors/limbic traps. Examples of policies that have this effect include universal preschools for all children, free healthy meals in preschools and schools, increased after-school activities for all children, and longer school days for adolescents with increased hours for physical activity, music, and art. Mobile phones and social media restrictions in schools and policies to reduce use at home should also be implemented. Finally, policies should be implemented to reduce residential and school segregation in the community.

SVENSK SAMMANFATTNING

Hälsoojämlikhet definierades av den Svenska kommissionen för jämlik hälsa som ”systematiska skillnader i hälsa mellan samhällsgrupper med olika social position.” Debatten om de bakomliggande orsakerna till hälsoojämlikhet tog fart efter att rapporten ”the Black Report” kom ut i Storbritannien på 1980-talet. I denna rapport konstaterades att ojämlikheten i hälsa hade ökat mellan socioekonomiska grupper trots införandet av fri sjukvård och andra samhällsförbättringar. Orsakerna till den ökande ojämlikheten har sedan dess debatterats och ett antal teorier har lagts fram för att förklara fenomenet. Fortfarande råder det dock oenighet kring hur de olika bakomliggande faktorerna leder fram till skillnaderna i hälsa. Internationella organisationer har samtidigt arbetat för att minska skillnaderna, bland annat WHO som 2008 bildades ”the Commission on Social Determinants of Health”. Denna kommission slog fast i sin rapport att vi alla har en moralisk plikt att minska skillnaderna i hälsa; ”Att ställa dessa skillnader till rätta handlar om social rättvisa. Att minska hälsoojämlikhet är för kommissionen ett etiskt imperativ”. Rätten till bästa möjliga hälsa slås också fast i Barnkonventionen, artikel 24. För att kunna minska hälsoojämlikheter behöver man studera inom vilka områden/sjukdomar skillnader uppstår och varför, med målet att utforma åtgärder för att minska skillnaderna.

Denna avhandling syftar till att studera socioekonomiska skillnader i barns hälsa. Avhandlingen baseras på data från den svenska prospektiva födelsekohortstudien Alla Barn i Sydöstra Sverige (ABIS). Social ojämlikhet i övervikt och obesitas jämförs även med den sociala ojämlikheten i motsvarande data från födelsekohorter i fem andra höginkomstländer; Nederländerna, Kanada, Storbritannien, Australien och USA.

Resultaten från Studie 1 visade att socioekonomiska skillnader i risken att utveckla obesitas kan upptäckas redan vid 2 års ålder och att denna skillnad i risk ökade under uppväxten. I tonåren framkom socioekonomiska skillnader gällande övervikt/obesitas samt för utvecklingen av högt blodtryck och lågt HDL-kolesterol (delar av det metabola syndromet).

Socioekonomisk ojämlikhet i förekomsten av obesitas i ABIS var mindre än i de övriga kohorterna i EPOCH-samarbetet (Studie 2). Detta gällde både i absoluta och relativa mått när socioekonomisk status mättes med hushållsinkomst. När socioekonomisk status baserades på moderns utbildningsnivå var skillnaderna mindre i ABIS i absoluta men inte i relativa mått. Fynden tyder på att samhällspolitiska åtgärder i Sverige tycks minska ojämlikhet i obesitas under barnaåren. Subventionerad förskola

och gratis skolmat i förskola och skola är exempel på åtgärder som visat sig ha en effekt på socioekonomiska skillnader i obesitas.

Vi har även studerat socioekonomiska skillnader i risk att utveckla autoimmuna sjukdomar (studie 3). Typ 1 Diabetes visade sig vara mer vanligt förekommande hos barn vars mödrar enbart hade förgymnasial utbildning. Denna skillnad kunde delvis förklaras av ett i genomsnitt högre BMI under barndomen och en ökad risk för allvarliga livshändelser i denna grupp. För övriga studerade autoimmuna sjukdomar fanns inga statistiskt signifikanta socioekonomiska skillnader.

I avhandlingens sista studie prövades hypotesen att den sociala ojämlikheten (mätt med moderns utbildningsnivå) och risken att utveckla obesitas medierades av skillnader i självkontroll hos mor och barn. Självkontroll hos modern estimerades genom följande beteendevariabler; rökning under graviditeten, rökning under barnets första levnadsår, amningsduration och grad av deltagande i ABIS-studiens datainsamling med biologisk provtagning. Barnets grad av självkontroll uppskattades genom analys av svar i frågeformuläret SDQs subskala om impulsivitet. Resultatet av studien visade att mor och barns självkontroll medierade 87,5 % av sambandet mellan moderns utbildningsnivå och barnets risk att ha utvecklat obesitas vid 19 års ålder. Sambandet stärktes ytterligare om även moderns BMI vid barnets 1 års ålder adderades till analysen. Den medierade effekten ökade då till 93 % av den totala.

En av avhandlingens slutsatser är att begreppet självkontroll bör ha en central roll i teorin om hälsoojämlikhetens orsaker. En sådan teori förutser att hälsoojämlikheten kommer att öka succesivt om inga interventioner görs. Hälsan hos barn och ungdomar kommer påverkas negativt av en miljö med ökande tillgång till allt fler stimuli av hjärnans belöningssystem, stimuli vilka också har negativa långtidseffekter för hälsan (s.k. Limbiska fällor ex. sociala medier). På grund av kopplingen mellan socioekonomisk status och självkontroll, kommer barn med låg socioekonomisk status drabbas i högre uträckning av denna ohälsa vilket kommer att leda till ökad hälsoojämlikhet.

Slutligen diskuteras vilka implikationer för hälso- och sjukvården, liksom för hälsopolitiken, som resultaten i avhandlingen kan få och hur man kan minska den sociala ojämlikheten i hälsa. Sådana hälsopolitiska åtgärder bör reducera barn och ungdomars risk för skadliga beteenden/limbiska fällor. Exempel på åtgärder inkluderar förskola för alla barn (oavsett om föräldrarna yrkesarbetar eller ej), fria hälsosamma måltider i förskola och skola, ökad möjlighet till aktiviteter efter skoltid, förlängda skoldagar för äldre barn med mer skolgymnastik, musik och estetiska ämnen, restriktioner för mobilanvändning för att motverka överanvändande av mobiltelefoner i hemmet och skolan, samt policys för att motverka boende och skolsegregation i samhället.

LIST OF PAPERS

I. White PA, Ludvigsson J, Jones MP, Faresjo T. Inequalities in cardiovascular risks among Swedish adolescents (ABIS): a prospective cohort study. BMJ Open. 2020 Feb 20;10(2):e030613. doi: 10.1136/bmjopen-2019-030613. PMID: 32086351; PMCID: PMC7044991. Published under CC-BY License.

II. White PA, Awad YA, Gauvin L, Spencer NJ, McGrath JJ, Clifford SA, Nikiema B, Yang-Huang J, Goldhaber-Fiebert JD, Markham W, Mensah FK, van Grieken A, Raat H, Jaddoe VWV, Ludvigsson J, Faresjö T; EPOCH Collaborative Group. Household income and maternal education in early childhood and risk of overweight and obesity in late childhood: Findings from seven birth cohort studies in six high-income countries. Int J Obes (Lond). 2022 Sep;46(9):1703-1711. doi: 10.1038/s41366-022-01171-7. Epub 2022 Jul 11. PMID: 35821522; PMCID: PMC9395266. Published under CC-BY License.

III. White PA, Faresjö T, Jones MP, Ludvigsson J. Low maternal education increases the risk of Type 1 Diabetes, but not other autoimmune diseases: a mediating role of childhood BMI and exposure to serious life events. Sci Rep. 2023 Apr 15;13(1):6166. doi: 10.1038/s41598-023-32869-x. PMID: 37061552; PMCID: PMC10105777. Published under CC-BY License.

IV. White PA, Ludvigsson J, Jones MP, Faresjö T. Maternal education and child obesity; the mediating role of maternal and child Self-control. Manuscript. Submitted (2023) to Social Science & Medicine.

ABBREVIATIONS

ABIS	All Babies In Southeast Sweden
ACEs	Adverse Childhood Experiences
AD	Autoimmune Disease
ADHD	Attention Deficit Hyperactivity Disorder
AMCC	Anterior Mid-Cingulate Cortex
AMG	Amygdala
BMI	Body Mass Index
CI	Confidence Interval
CVD	Cardiovascular Disease
COPD	Chronic Obstructive Pulmonary Disease
DAG	Directed Acyclic Graph
DBT	Dialectical Behavior Therapy
EPOCH	Elucidating Pathways Of Child Health
HDL	High-Density Lipoprotein
HPA	Hypothalamic Pituitary Adrenal
HS/HF	High-Sugar/High Fat Diet
JIA	Juvenil Idiopathic Arthritis
IBD	Inflammatory Bowel Disease
IR	Insulin Resistance
LDL	Low-Density Lipoprotein
LH	Learned Helplessness
NAFLD	Non-Alcoholic Fatty Liver Disease
NAc	Nucleus Accumbens
OR	Odds Ratio
PCOS	Polycystic Ovary Syndrome
RCT	Randomized Controlled Trial
RR	Risk Ratio
ROC	Receiver Operating Characteristic curve
SGA	Small for Gestational Age
SES	Socio-Economic Status
VTA	Ventral Tegmental Area
WHO	World Health Organisation

ACKNOWLEDGMENTS

Summarizing nine years of work in one comprehensive text is difficult. I was luckily ignorant of the obstacles ahead when I started this journey. My original idea for the thesis was simple enough. I aimed to determine the social inequality among children, primarily for Type 1 Diabetes and obesity, and then explain how much of these differences could be attributed to risk factors and behaviors (what I would now call mediating factors). The idea was based on the scenario of adults with cardiovascular disease, where several risk factors are known to be causally related to the disease. The result of my studies would then have had a clear policy implication: reducing risk factor x in low socio-economic groups would reduce social inequality in Type 1 Diabetes/obesity among children with x %, similar to saying that reducing smoking in low socioeconomic groups would reduce the social inequality of cardiovascular disease among adults with x percent. This would turn out to be less clear-cut than I first imagined.

I was lucky in two regards. First, I joined an excellent team for the development of my studies. My two supervisors were Tomas Faresjö, ever optimistic, encouraging, insightful, and with a deep-rooted concern about social inequality, and Johnny Ludvigsson, clear thought, interested in all aspects of science, iron-willed and founder of the great ABIS cohort study that has been the base for all of my studies. These two have been the perfect match for my project, both giving me the freedom to follow my thoughts and, at the same time, the support (both encouragement and deadlines) to get the papers done.

I was also lucky in the early days of my Ph.D. project that Johnny suggested that I draw how I thought variables were connected: how socioeconomic status was related to the different risk factors in Type 1 Diabetes and how they, thus, increased the risk of the disease. “Make some rings like this and draw arrows between them like that,” he said. Although I didn’t know it then, and Johnny certainly didn’t call it so, this was to become my first DAG (directed acyclic graph). The DAGs have become a tool that I believe is the key to how I came to understand social inequality in a new way.

I would not have come this far without another great scientist, Mike Jones, my light in the statistical jungle. Besides being a very likable person, Mike has a profound understanding of statistics but, at the same time, a practical understanding of how to use it, which has been an invaluable contribution to my work. One can go to Mike with an idea of a causal pathway or a question to answer, and he will come up with the best statistical approach to answer that pathway or question; he will also be able to back

those results with a theoretical understanding of the methods. With Mike's teaching and the statistical courses I have attended during my Ph.D. education, I've come to learn and appreciate statistics, including several statistical methods, as a natural part of my research.

Additional people that deserves recognition in the development of this thesis are Åshild Faresjö; friend and fellow researcher, Nicholas Spencer; role-model, dedicated to the cause of reducing social inequality in children, Jennifer McGrath; leader of the EPOCH collaboration with a keen eye for details and producing flawless results, also good at keeping me in line when my associations have wondered off too far "this is not what you have actually studied Par", Lise Gauvin; dedicated to the cause of social inequality and with great insight in the policy implications, Yara Abu Awad; my other light in the statistical jungle, a practical solution-focused statistician, Béatrice Nikiema; maybe unknowingly the one I learned from how to produce tables and results in epidemiological research (by copying her style), Fiona Mensah; ever polite and with great insight in the statistical methods and their limitations "mind your causal language Par", Jeremy Goldhaber-Fiebert; another inspiring, friendly researcher with racer-sharp intellect. Jody Heymann also deserves recognition for her insistence that public health researchers should always consider the policy implications of their research, something I picked up at my first INRICH conference and that has guided me since. Of course, also all the other participants in ABIS and the EPOCH collaboration: Maria Nygren; who helped me with statistics in the early days of my PhD, Wolfgang Markham; insightful in the theoretical ideas of social inequality, the Gen R group, including Hein Raat and Junwen Yang-Huang. In addition to my research collaborators I want to express my gratitude to my dear colleagues; the excellent doctors and nurses at Crown Princess Victoria Children´s Hospital in Linköping, the best Pediatric clinic in the world.

Finally, I thank my mother, father, sisters, and extended family for their for continuous love and support. My daughters, Edith and Siri, the pride and joy of my life, and my love Maria, wife and companion.

During my Ph.D. studies, I have sometimes told fellow Ph.D. students and colleagues that my Ph.D. was about obesity or Type 1 Diabetes; the subject of social inequality seemed too remote and even difficult to describe in Swedish ("hälsoojämlikhet," such a cumbersome word), at the end of the day though, most of my thoughts have not been mainly focused on these outcomes but the exposure in my studies: SES; Why do children from low socioeconomic groups experience worse health than their peers?

INTRODUCTION

Since the early days of my Ph.D. project, I have been involved in the Elucidating Pathways of Child Health Inequality (EPOCH) project, which aimed to find explanations for the association between Socioeconomic Status (SES) and health outcomes in children. I had been delegated the task of the paper on childhood obesity and had read up on the literature. When I approached my Ph.D. halftime seminar, things were going pretty well. I had published one paper on the inequality in cardiovascular risk factors and was almost done with the first paper on comparisons of the inequality gradient in obesity across the cohorts in the EPOCH collaboration. However, the next step, which was supposed to be an analysis of the mediating pathways, was still bothering me. Two mediators of childhood obesity that most consistently had been reported in epidemiological studies were maternal smoking during pregnancy and breastfeeding. Still, the explanatory mechanisms for how these mediators gave rise to childhood obesity seemed to be missing. As I was contemplating this fact, I read a very unusual study, it was a secondary analysis of the PROBIT cluster-randomized trial, a trial that had successfully increased breastfeeding in randomly selected regions and compared the BMI of these children at 8,5 years of age, the result was a small INCREASE in BMI in the group with a higher breastfeeding rate.[1] The same authors had also analyzed the BMI development of children born small for gestation (SGA), the outcome most clearly related to smoking during pregnancy, and found that the children had a lower, not higher, BMI than their peers at age 11,5 years.[2] These findings made me think about the two behaviors. As a Pediatrician, I knew that breastfeeding was hard work; the mother had to wake up several times per night, the feeding took longer than bottle feeding, and often the children woke up more during the night. Mothers with high education could go through severe complications like pain and mastitis/infections to breastfeed, which was supposed to increase the well-being of their child (reducing the risk of some diseases).

What was this called, the act of enduring hardship now to earn a reward later in time? And what were the mechanisms for that kind of behavior? Not being able to quit smoking during pregnancy was a sign of the opposite, the inability to control a rewarding behavior (nicotine) for a later benefit (child health). These thoughts took my thinking on mediators of SES- child obesity in a different direction. The road led to human behaviors and the battle between two systems.

Health Inequalities

The Swedish Commission on Health Inequality defined health inequality as systematic differences in health between groups in society with different social positions.[3] The most commonly used indicators of SES are educational attainment, income, and occupation.[4,5] The impact on childhood SES affects children's health in numerous ways.[6] Examples include the findings that children of mothers with low education have an increased risk of developing overweight, limiting long-standing illness as well as socio-emotional difficulties.[7] There is evidence that these health inequalities have increased during the last decades.[8,9] This happened during a time of increasing income inequalities across most OECD countries, with the fastest rise occurring in Sweden in recent years.[10] There is evidence, although disputed, for a connection between a country's level of income inequality and the level of health inequalities, with higher prevalence and absolute inequality for health problems with SES gradients in countries and states with higher income inequality.[11,12] Economic research has shown that income inequality is likely to keep rising, not least because of the increasing part of income that comes from return on capital.[13] Thus, the importance of studying SES inequalities is ever-increasing. What diseases and health problems are associated with low SES and why? All avoidable socioeconomic health inequalities are unfair, and as stated by the commission on the social determinants of health, we have a moral obligation to try to reduce them. “Putting these inequities right is a matter of social justice. Reducing health inequities is, for the Commission on Social Determinants of Health, an ethical imperative. The right to the highest attainable standard of health is enshrined in the Constitution of the World Health Organization (WHO) and numerous international treaties”.[14] This ethical imperative is especially apparent when it comes to the health of children and adolescents.

Theories of Social Inequality in Health

Since the publication of the Black Report from the UK in 1980, which showed increasing health differences between socioeconomic groups, there has been an ongoing debate about the importance of socioeconomic status (SES) for health and how it can be explained.[15-17] Theories for explaining these differences were described already in the Black Report itself and, at that time, included four major theories:

Natural and Social Selection

This theory states, "People with poor health tend to move down the occupational scale and concentrate in the lower social classes.” The Report concluded that although there was evidence for the fact that serious childhood illness and short stature (potentially a sign of ill health) could lead to lower

social status, this association explained only a fraction of the observed differences between social groups.[15]

Cultural/Behavioral Explanation

"The way people in different social groups choose to lead their lives: the behavior and voluntary lifestyle they adopt." Health inequalities arise because low social groups engage in more dangerous and health-damaging behaviors. The report concluded that lifestyle, including smoking, alcohol, and dietary differences, explained some, but not all, of the observed differences in health. The report also concluded that studies on cultural beliefs in different social groups had not identified significant differences in beliefs about what constitutes a healthy lifestyle. Thus, there was no evidence of a "culture of poverty".[15]

Structuralist/Materialist

This theory "emphasizes the role of the external environment: the conditions under which people live and work and the pressure on them to consume unhealthy products." Differences in housing affects health, income difference limits food choices, leading to a lack of fruit and vegetable intake, stress of low income leads to mothers going against medical advice and giving their children sweets to keep them happy and content on shopping trips and other stressful occasions, cigarette smoking in women could be a way of easing tension and helping them survive the stressful workload. The Report concluded that there was a complex relationship between individual behavior and structural and material factors; it is too simple to explain it all down to ignorance or laziness.[15]

The Artifact Explanation

"Methods of measuring occupational class – by the Register General's social class classification - artificially inflates the size and importance of health differences." The Report concluded that although there was general agreement that occupational class was an insufficient measure of SES, evidence supported that the measure used by the Register General underestimated the differences between social groups.[15]

Modern Theories

Over the following decades, the arguments between researchers on health inequality about the theories of inequality have been ongoing. The theories above have been improved, and additional theories have been constructed. One central problem for health inequality research has been the persistence of inequality in the welfare state. One of the leading modern researchers in health inequality, Johan Mackenbach, has summarized these theories and their relationship to the problem of persisting inequalities; in addition to the theories of the Black Report, they include:[18]

The Fundamental Cause Theory

This theory states that SES represents a fundamental cause that will affect the possibility of changing behavior when new information on how to prevent disease emerges. High SES gives "access to resources that can be used to avoid risks or to minimize the consequences of disease once it occurs. We define resources broadly to include money, knowledge, power, prestige, and the kinds of interpersonal resources embodied in the concepts of social support and social network".[19]

The Life Course Perspective

This theory focuses on the fact that some outcomes like cardiovascular disease can be the effect of exposures as early in life as in utero or during early childhood. One example is being born small for gestational age (SGA), which indicates intrauterine growth restriction. SGA is associated with an increased risk of adulthood diseases like COPD and Cardiovascular disease.[20] The Barker theory is part of this perspective; according to this theory, early programming in the uterus determines health outcomes later in life, including insulin resistance.[21] The life-course perspective also includes how disadvantages are transmitted through life; in the UK, low SES children are less likely to attend preschool, which reduces their chances of educational attainment, and low educational attainment leads to lower occupational status and income in adulthood, which is associated with worse health outcomes.[20] Consistent with the life-course perspective, studies have shown that health inequalities increase with age.[22]

The Personal Characteristics Theory

According to this theory, which Johan Mackenbach advocates for, the differences in health can be attributed to personal characteristics.[23] The primary characteristics investigated in this theory have been "the Big Five personality traits".[24] Another trait/characteristic investigated has been IQ.[25] Together, the investigated personal characteristics have been estimated to explain 20-50% of SES-related differences in health.[23]

The Neo-Materialistic Theory

According to this theory, inequalities in health arise due to differences in the distribution of material resources. It is recognized that these resources are clustered in low SES groups with "occupational hazards, poor housing, and unemployment."[26] This includes not only the income of the individual but also other resources, including the public expenditure on health-related policies. "In the US, higher income inequality is significantly associated with many aspects of infrastructure; unemployment, health insurance, social welfare, work disability, educational and medical expenditure, and even library books per capita".[27] These differences in resources lead to the negative health consequences that give rise to differences in health between

low and high SES groups. Its proponents have proposed this theory to better explain the observed differences in health between countries and states with different levels of income inequality than the psychosocial pathway.[28]

The Psychosocial Theory

The importance of psychosocial stress for health inequalities has been proposed in the work of Michael Marmot and Richard Wilkinson.[29,30] This theory states that social hierarchies induce status stress in humans, just like in other animals with social hierarchies. The theory further says that this status stress is increased with higher levels of income inequality and thus explains why health differences are more significant in unequal societies.[12]

The Diffusion of Innovation Theory

According to this theory, innovations are adopted at different rates throughout a society; early adopters are characterized by having leadership roles and higher incomes. Thus, high SES groups will benefit faster from innovations that improve health, and this will lead to an increase in health inequality.[31] Studies from Brazil have shown that improved access to care and public health policies aimed at reducing mortality in children initially increased inequalities.[32] In these studies, inequalities started to be diminished only when high SES groups reached the limit of the potential improvement, i.e., a very low neonatal and child mortality.

The Culture Capital Theory

Initially developed by Pierre Bourdieu, this theory focuses on the effect of cultural capital. Bourdieu described how cultural capital leads to the reproduction of hierarchies through the educational system by rewarding such things as "subtle modalities in the relationship to culture and language as affluence, elegance or distinction".[33] Cultural capital is a kind of capital that the individual acquires through social learning and comes in the form of health values, perceptions, health knowledge and behavioral norms which provides the non-material resources needed to develop a healthy lifestyle and deal effectively with health issues.[34] The fact that the acquisition of cultural capital depends on the social class-specific learning context explains why the health resources that emerge from it are also unequally distributed across the social classes.

In conclusion, there are many theories of why social inequality in health occurs. One of the central themes is that health-related behavior tends to be unequally distributed across socioeconomic groups, with more favorable behaviors in high SES groups and more unfavorable behaviors in the low SES groups, which gives rise to a social gradient in health. The theories above have tried to explain this in different ways but have failed to provide a complete explanation. One of the main reasons has been a reluctance to consider factors on the individual level that influence decision-

making.[23] To develop a general theory of health inequality, one must consider the mechanisms of human decision-making that regulate behavior.

The Dived Soul and the Role of Self-control

In ancient Greece, philosophers constructed theories about the mechanisms of human behavior. The human soul was recognized to consist of several parts, one rational and one or more irrational parts. In his book The Republic, Plato stated that the spirit had three parts: rational and two irrational: the spirited (emotional) and the appetite (pleasure-seeking) parts.[35] Aristotle also divided the soul into parts, the rational and the irrational; the irrational could be divided into the vegetative and the sensitive.[36] Aristotle acknowledged the presence of self-control in his book The Nicomachean Ethics, which he termed Enkrateia. An Enkratetic person would do the right action even though he desired to do the wrong one. The akratic person would instead give in to the desire to do the improper action, knowing that it was wrong.[37]

After the introduction of Christianity, behavior related to loss of self-control was categorized as sin. Thus, pride, greed, wrath, envy, lust, gluttony, and sloth were named the cardinal sins and were contrasted to the seven heavenly virtues: chastity, temperance, charity, diligence, patience, kindness, and humility.[38]

In the early 20th century, Sigmund Freud developed his theories of the working mechanism of the human psyche. Freud characterized the human psyche as consisting of three agents: The Id (emotions, pleasures), the Ego, and the Superego (norms, rational decision). The Ego was an intermediate who negotiated with the Id.[39] Also, in modern psychological treatments like Dialectical Behavioural Therapy (DBT), the methods include a division of the mind, referring to traditional Zen methods; DBT divides the mind into three parts: reasonable, wise, and emotional.[40]

On the other hand, B.F. Skinner, the founder of Behaviourism, thought the human mind was a “black box” and that its working mechanisms were unnecessary for researchers. Instead, Skinner focused on the effect of a given stimulus. He characterized stimuli as positive reinforcers (pleasure) or negative reinforcers (avoiding pain/anxiety), showing that both were sources of learned behaviors.[41] Much of his experiments were done in animal models like rats. Skinner's understanding of the human brain as beyond the reach of research and a focus on measurable variables have been part of the social science paradigm called positivism, which has emphasized data analysis without considering theories of human behavior.[42]

”Here take this, you are studying the wrong animal” Ancient Greek Philosopher to B.F. Skinner. This image was created with the assistance of AI, DALL·E 2.

Modern Research on Self-control

"*The frontal cortex makes you do the hard thing when it's the right thing to do*" - Robert Sapolsky.[43]

In his famous Marshmallow studies, Walter Michel found that the ability to resist the temptation of an immediate reward in favor of a larger later reward, the delay of gratification, varied significantly between children.[44] The experiments took place in the preschool at Stanford University, where the average parental educational level was high as the children's parents were either faculty or students at the university. In follow-up studies, Michel found that the children who could delay gratification had better educational attainment, lower BMI, were less likely to develop addictions and had a lower rate of divorce.[45] Walter Mischel developed a theory of two cognitive systems, the hot/cool system, to explain this finding.[46] One system aimed at long-term rewards while the other acted to get immediate rewards; the ability of the cool system to control the behavior was termed the ability to self-control/willpower.[46]

Roy Baumeister has studied the mechanisms of self-control. His studies have shown that the ability to self-control is not a static ability. Instead, self-control is a limited resource, and the brain's ability to perform this control is reduced by activity, much like a muscle becomes weaker with repetitive use. Baumeister has termed this ego depletion.[47] The abilities related to self-control can be affected by seemingly unrelated tasks. One example is an experiment where a participant first resists eating a piece of chocolate or a vegetable for some time; in the second step, the participant tries to solve an unsolvable puzzle. Participants who had resisted the chocolate gave up earlier than the other group. The ability for self-control also varies across the course of the day, and between different days, the ability is decreased every time an impulse is inhibited.[47] Baumeister's research has also shown that when asked to register moments of loss of self-control over several days, individuals report failing to impose self-control on several occasions each day.[48]

Modern Definition of Self-control

Modern theories of self-control have combined information from neuroscience and psychology into a neural circuit-based theory.[49] Similar to the hot and cool system in Mischel's studies (and the theories of the ancient Greek philosophers), decisions according to this theory will be a result of two processes: one higher-order goal process that takes place in the cortex where predictions about the effect of decision are made and how these effects relate to different higher-order goals (i.e., health).[50] The other process will be made in the mesolimbic system where the immediate reward potential of a behavior will trigger activation of the mesolimbic reward pathway, neurons in the Ventral Tegmental Area (VTA) that releases Dopamine in the

Nucleus Accumbens, and fear of consequences of a behavior that will trigger the Amygdala and Insula. These two processes will lead to a Desire/Impulse (I) and a Goal (G). An I-G conflict will arise, which will be resolved in the anterior cingulated cortex, leading to a behavior. Whether the Impulse or the Goal will decide the behavior will be a matter of the motivation and effort of the dorsolateral prefrontal cortex (dlPFC). The dlPFC will be affected by whether there are competing higher-order Goals that might be in line with the impulse. The dlPFC is also affected by other factors such as depletion of control capacity[51], stress level[52], and drugs such as alcohol. The subject sensitivity to certain stimuli will decide the strength of the impulse. Food, sugar, nicotine, drugs, sex, social connections, gambling, etc, will activate the reward pathways differently in different individuals. Competing Desires/Impulses may also influence the ability to self-control (e.g., avoiding the Amygdala activation of choosing something different from your peers).[53]

Modern neuroscience, including MRI and fMRI studies, has started to explain the underlying details of the mechanisms of self-control and its association with obesity and SES. It has been shown that the prefrontal cortex (PFC) plays a vital role in inhibiting signals from the limbic system; for example, in food choice tests, the thickness of the PFC is associated with better inhibitory control, which explains BMI differences.[54] Low SES is associated with thinner PFC.[55,56] Studies also show that whether the control effort is sufficient to overcome the temptation depends on the mental energy expended to inhibit the impulse and work toward the goal.[50] The anterior mid-cingulate cortex (aMCC) also plays a central role in self-control and related concepts such as persistence/tenacity/grit. Activity in the aMCC during effortful judgment predicts persistence, and it has also been reported that an increased grey matter level in the aMCC is associated with a higher level of persistence.[57] Greater aMCC activity leads to choosing healthy food over more calorically dense options, and obese individuals with successfully maintained weight loss show enhanced aMCC activation in response to food cues.[58,59]

The terminology regarding self-control can be somewhat confusing as there are several overlapping terms (self-regulation, delay of gratification, etc.); there is also overlap and a correlation with other constructs, such as persistence/tenacity/grit and executive functions. Self-control and related concepts are defined as having two central features. First, self-control should be self-initiated, i.e., putting away one's mobile phone while studying involves self-control, while a teacher putting away a student's mobile phone does not involve self-control. Second, self-control is only used when one option is more valuable in the long run, but the other is momentarily more attractive/pleasurable.[60] Self-control is initiated when a self-control conflict arises, which can thus be described as a tug-of-war between

impulses and higher-order goals.[61] Higher-order goals are more abstract (imagined futures) and more strongly associated with one's values and virtues. Higher-order goals vary in strength, like impulses. The strength of higher-order goals is determined by at least three factors: importance (the degree to which a goal represents a high-priority objective), commitment (one's determination to achieve the goal), and self-efficacy (one's perceived ability to accomplish the goal).[61]

The central role of self-control in human behavior has many consequences. One important consequence often overlooked is that behaviors related to self-control will be associated with each other in epidemiological studies. This kind of non-causal association used to be called spurious, but today, it is called confounding.

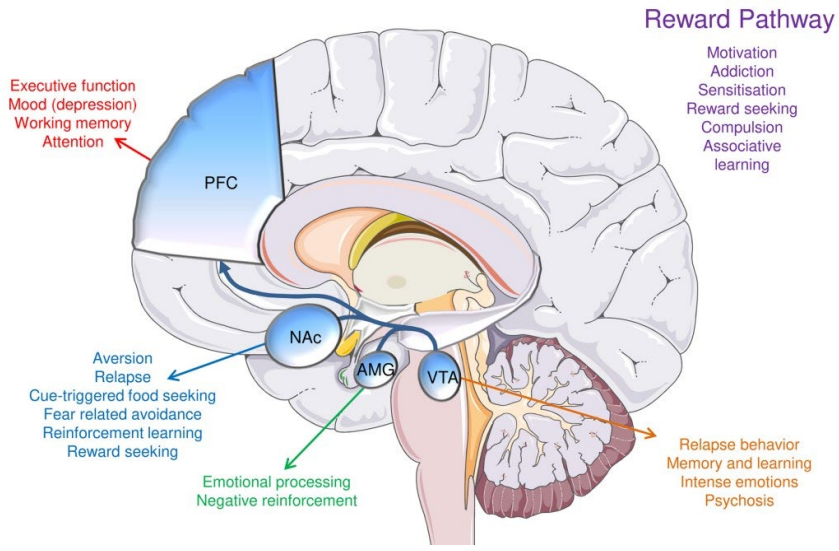


Figure 1. The reward pathway of the human brain. Neurons projecting from the VTA release Dopamine in the Nucleus Accumbens. Amygdala activation plays a central role in negative reinforcement. The Prefrontal cortex (dorsolateral part) has a central role in Self-control i.e., to suppress behaviors induced by the limbic system when an Impulse-Goal conflict arises. VTA =Ventral Tegmental Area, AMG Amygdala NAc Nucleus Accumbens, PFC Prefrontal Cortex. Picture from A. Jacques et al. *"The impact of sugar consumption on stress-driven, emotional and addictive behaviors"* Neuroscience & Biobehavioral Reviews, 2019. Published according to CC BY 4.0.

Confounding

When an observed association between two variables, i.e., ice-cream sales and sunburns, are not causally related but caused by a variable that affects both, i.e., high temperature, this is called confounding. Confounding bias is a core problem when researchers want to draw cause–effect conclusions in observational studies and the background to the critique of these studies.

In the early days of statistics, Karl Pearson found these "spurious" correlations and warned against drawing causal conclusions about correlation. There was no correlation when Pearson measured the length and width of human skulls in men and women separately. Still, when he combined the data from both groups, a correlation appeared (because a short skull was now associated with the confounding variable, woman, which was associated with a narrow skull). As Judea Pearl wrote in his book on the history of causal inference, this was a missed opportunity in history and would lead to the continuation of the dogma "association is not causation," which is still heard among scientists today.[62]

Mediation Analysis

Pearson's disciple, R.A. Fischer, continued the critique of observational studies but also, to his credit, came up with one potential solution, the randomized controlled trial (RCT). If an exposure or treatment was allocated randomly in a sufficiently large sample, then the effect of these confounders would be evenly distributed. Thus, any remaining effect would be related to the investigated exposure/treatment. There are two major problems with RCTs. The first problem is the dependency of sample size, which makes the risk of drawing wrong conclusions due to insufficient participants (power) high, so-called Type II error (not rejecting the null hypothesis when it is false).[63] The other problem with RCTs is that allocating exposure at random is not always ethically possible. This second problem put Fischer on the wrong side of history in the debate on smoking and lung cancer. In this debate, Fischer, even in the face of a large amount of data, upheld the thesis that smoking and lung cancer could potentially be caused by a confounding gene and not be causally related. Eventually, after the studies of Bradford Hill and the Surgent generals report in 1964 that stated that "Cigarette smoking is causally related to lung cancer in men," the relationship between exposure and outcome was finally generally accepted but with a delay of more than a decade since the first reports.[62]

Fischer's arguments and opinions also negatively influenced the development of causal statistical models. In 1912, Sewall Wright developed Path analysis in his studies on breeding traits in Guinea Pigs.[64] Unfortunately, for my thesis and the world, his approach, which included setting up a theoretical framework of the causal relationship between variables and a

method of calculating the mediating variables' relative importance, did not become part of the mainstream field of science.[62] Instead, a paradigm where science was supposed to be free of a priori assumptions and rely only on the observations in the data prevailed.

Interestingly, according to Judea Pearl, one of the first known causal diagrams made by Barbara Burks involves SES.[65] Evident from this DAG is the fact that Barbara Burk considered the relationship between SES and parental intelligence (child's heredity) to be bidirectional.[66]

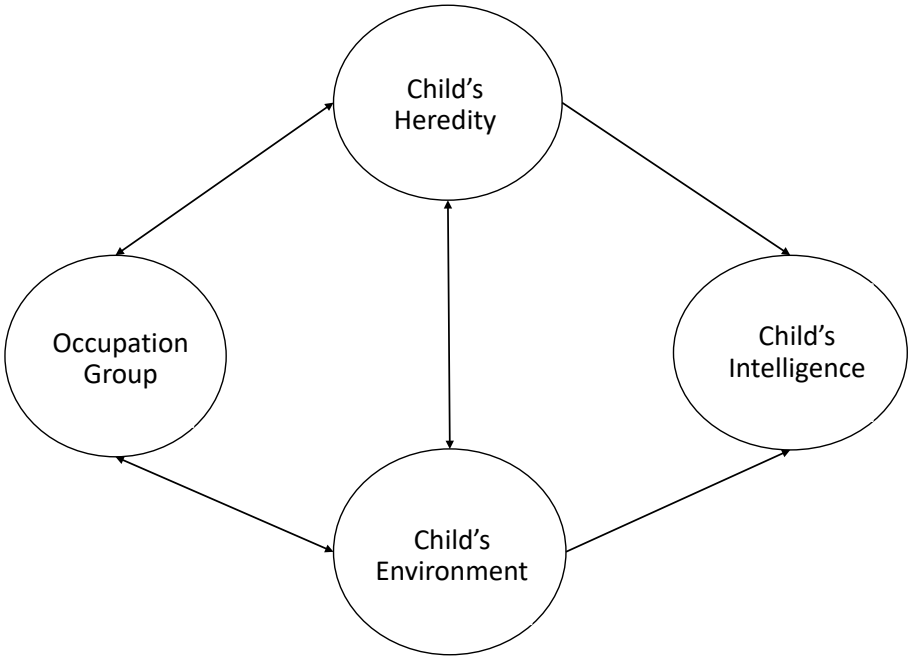


Figure 2. Barbara Burks figure of causal pathways in the relationship between Parental occupational group, Child's heredity (parental intelligence), child's environment and child's intelligence.

Sweden and Health Inequalities

The welfare state reduces the importance of many of the materialistic pathways to health inequality. In a pure market economy, there would have been a gradient in the quality of daycare/preschools and schools; however, public financing blocks this development. Child allowance and the fact that parental leave benefits only compensate for part of the salary and have an upper limit of compensation reduce income differences among families with young children.[67] Parents with higher education in Sweden also, through their behavior, reduce income differences by taking longer

parental leave, and this includes fathers.[68] The Swedish child health care system also reduces inequality by giving children equal distribution of curative and preventive health care. The system also provides repeated health information to parents regarding health and preventive measures to improve health literacy and reduce differences between SES groups.[69]

The Outcomes

Obesity

Obesity is an environmental disease; this is obvious from historical data. The prevalence of obesity in the USA has risen from 3% in 1890 to 35% in men aged 50-59 in 2000.[70] The prevalence of obesity in children and adolescents increased from 1970 to 2000. During the last decades, there is some evidence that the increases have plateaued in northern and western Europe and increased but at a slower rate in the US.[71-73] Although the total prevalence seems to have plateaued, the differences between socioeconomic groups have kept increasing.[9] Excess energy intake to energy expenditure causes adiposity and obesity, as the adipose cells store such energy in the form of triglycerides.[74] There is a strong association between the introduction of sugar in society and the increase in obesity prevalence, documented especially in indigenous people of the Pacific, which has the highest prevalence of obesity today.[75] There is also evidence for the "Thrifty gene hypotheses" that humans have accumulated mutations that make us especially good at deriving fat from fructose.[76]

Cardiovascular Risk Factors

Cardiovascular risk factors and disease in adults are some health outcomes most correlated to SES.[77] The fact that these differences start to arise already during childhood has been suspected, and low childhood SES has been shown to increase arterial stiffness in early adulthood.[78]

High-Density Lipoprotein (HDL)

The level of HDL is related to and decreases with elevated Triglycerides and insulin resistance (IR).[79] The association of low HDL with cardiovascular disease is strong.[80] However, medical treatments (CETP inhibitors) to increase HDL have failed to show an effect on cardiovascular outcomes.[81] HDL increases with physical activity due to reduced insulin resistance.[80]

Low-Density Lipoproteins (LDL)

LDL cholesterol is affected by dietary factors, including saturated fat and dietary cholesterol.[82] The metabolic syndrome is not correlated with an increased level of LDL, but with a qualitative change, the number of small-dense LDL particles that are the most atherogenic types of LDL cholesterol increase but not the total level of LDL.[83] LDL is recognized as the most important factor in the development of atherosclerotic plaque, and its causal

relationship with cardiovascular disease is proven by the risk reduction seen after initiation of LDL-lowering medications such as Statins.[84]

Hypertension

Blood pressure increases with BMI and vascular stiffness. Salt (sodium) intake is an important factor in developing hypertension.[85] Data from the Swedish Obesity Register show a prevalence of hypertension of 18.1% and, more specifically, 15.3% for systolic pressure and 5.5% for diastolic pressure hypertension in obese children (mean age 10,3 years).[86]

Metabolic Syndrome and Insulin Resistance

The components of the metabolic syndrome include insulin resistance (IR), glucose intolerance, hyperinsulinemia, dyslipidemia, and hypertension, defined as syndrome X by Reaven in 1988.[87] Later studies have shown that his syndrome also occurs in children and adolescents.[88] That the metabolic syndrome shared a common mechanism has been suspected since the original paper by Reaven, and also that IR had a central role, but the exact mechanisms are still being elucidated. Intracellular lipids play an important role in muscle cell IR and the development of general IR[89]. Muscle cell IR can be present even in lean individuals and reversible by weight reduction.[90] There is also strong evidence for a central role of fructose intake and metabolism in the development of IR.[76]

Type 1 Diabetes

Type 1 Diabetes is an autoimmune disease where the immune system is triggered to produce antibodies and destroy the insulin-producing Beta-cells of the pancreas.[91] Type 1 Diabetes has had an estimated annual increase of incidence of 2.4 % per year worldwide and 3-4 % in Europe.[92,93] Genes increase the risk of developing Type 1 Diabetes; HLA-types are the most important genetic risk factors.[94] However, the genetic composition of the populations has not changed across the timespan that the incidence of Type 1 Diabetes has increased. This increase must thus be attributed to one or more environmental factors.[95] An increased risk of Type 1 Diabetes has been found in individuals with obesity; this association has been stronger than for other autoimmune diseases.[96] This has given rise to the Accelerator hypothesis, which states that the increased incidence of Type 1 Diabetes could be caused by increased levels of obesity and a higher level of insulin resistance in the population.[97] Because men have higher levels of insulin resistance than women, the Accelerator theory could also explain the sex difference seen between Type 1 Diabetes, which is equally common in boys and girls and twice as common in boys after puberty, and other autoimmune diseases that are more common in girls/women.[98] Evidence from the ABIS study also suggests an important role of changes in the gut microbiome for the risk of developing Type 1 Diabetes.[99]

Autoimmune Diseases

The other autoimmune diseases studied in this thesis include Celiac Disease, Inflammatory Bowel Disease (which includes both Crohn's Disease and Ulcerative Colitis), Juvenil Idiopathic Arthritis (JIA), and Autoimmune Thyroid Disease (both Hashimoto's Disease/Hypothyroidism and Graves' Disease/Hyperthyroidism). These diseases share the increase in incidence with Type 1 Diabetes seen in recent decades, except for JIA, where the development is less clear due to changes in the classification of the disease.[100-103] The search for environmental and/or lifestyle factors that could explain this development is ongoing.[104] One of the most prominent hypotheses is the hygiene hypothesis, i.e., that an environment with less exposure to infections leads to inappropriate immunologic responses that characterize autoimmune disease.[105]

Conclusions About the Outcomes

For this thesis, it is sufficient to know that excess dietary intake of sugar/fructose, saturated fats, and salt are the primary reasons for the development of obesity, IR, and elevated apo-B/LDL. These effects, together with lack of physical activity and smoking, are the main causes of cardiovascular disease, the leading cause of mortality in the world.[106] Cardiovascular disease in adults is also one of the diseases most associated with SES.[12] Thus, it follows that the mechanisms of health behaviors, including dietary intake, smoking, and low physical activity, play a central role in the research on health inequalities.

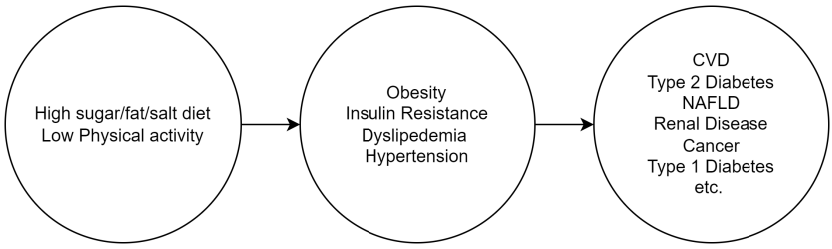


Figure 3. Mechanism in the metabolic syndrome. High sugar/fat/salt diet leads to obesity, insulin resistance, dyslipidemia and hypertension, which leads to increased risk of numerous outcomes including Cardiovascular disease (CVD), Type 1 and Type 2 Diabetes, Non-alcoholic fatty liver disease (NAFDL), Renal disease, Some Cancers, Neurodegenerative disease (Alzheimer's Disease, Dementia), Poly Cystic Ovary Syndrome (PCOS), Musculoskeletal problems, among other diseases.

AIM

The Overall Aim of the Thesis

The overall objective of this thesis is to investigate the impact of socioeconomic status on the health of children, adolescents, and young adults. Through investigations of the association between SES and specific disease groups, this thesis aims to add to the knowledge about which diseases are related to SES. The thesis also investigates the pathways that lead to the apparent SES-related differences in the outcomes, BMI/obesity and Type 1 Diabetes, including the mediating role of self-control.

Specific Aims

- **Paper 1** To determine whether SES predicts cardiovascular risk factors in Swedish adolescents and identify which socioeconomic factors were most important for developing each risk factor. Further, using longitudinal data, we aimed to investigate at what age overweight and obesity inequality developed and how the level of inequality changed during childhood.

- **Paper 2** To analyze the longitudinal relationships in relative and absolute terms between early childhood SES and the development of overweight and obesity at age 8–11 years and compare these across seven birth cohorts from six high-income countries.

- **Paper 3** To investigate whether SES was associated with the risk of developing autoimmune diseases. Second, to investigate whether SES influenced the age at autoimmune disease diagnosis. Third, to analyze pathways between SES and disease in diseases where an SES association could be established.

- **Paper 4.** This study aimed to estimate the mediating effect of maternal and child self-control in the relationship between childhood SES measured by maternal education and the development of higher BMI and obesity in early adulthood.

MATERIAL AND METHODS

This thesis is based on prospective birth cohort data in Sweden (the ABIS study) and six high-income countries (the EPOCH study). Data from the ABIS study has been cross-linked with the Swedish National Patient Registers to obtain medical diagnoses and information about healthcare utilization.

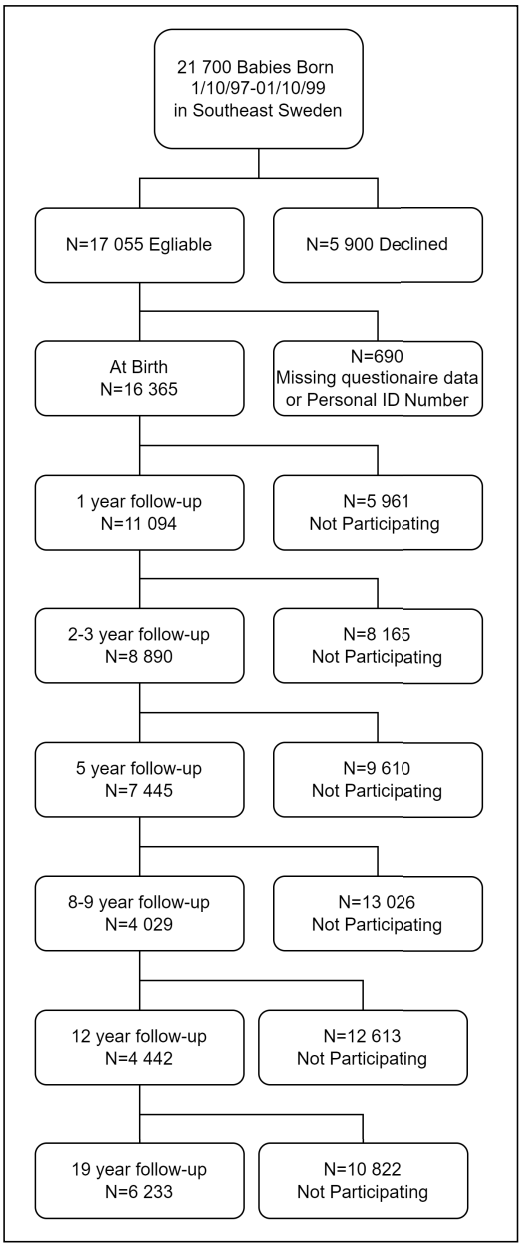
Table 1. Methods

	Paper 1	Paper 2	Paper 3	Paper 4
Study Design	Cohort	Multiple Cohorts	Cohort	Cohort
Cohort(s)	ABIS	ABIS EPOCH cohorts	ABIS	ABIS
Other data sources			National Patient Register	
Age groups	2-16 years	8-11 years	0-22 years	19 years
Exposure	Maternal Education Household Income Occupational Class White/Blue-Collar City	Maternal Education Household Income	Maternal Education Household Income	Maternal Education
Outcome	Overweight Low HDL High LDL High BP	Overweight Obesity	Type 1 Diabetes Celiac Disease JIA IBD Autoimmune Thyroid disease	BMI Obesity
Confounders		Sex Ethnicity Maternal Age	Sex Ethnicity Heredity of AD	
Mediators			BMI Serious Life Events	Maternal Self-control Child Self-control
Statistical Method	Logistic regression	Poisson regression Meta-analysis Slope Index of Inequality	Poisson regression Path Analysis	Poisson regression SEM

ABIS All Babies In Southeast Sweden, AD Autoimmune Disease, BMI Body Mass Index, BP Blood Pressure, EPOCH Elucidating Pathways Of Child Health, HDL High-Density Lipoprotein, JIA Juvenil Idiopathic Arthritis, IBD Inflammatory Bowel Disease, LDL Low-Density Lipoprotein, SEM Structural Equation Modelling

The ABIS Study

The All Babies In Southeast Sweden study, ABIS, is a population-based prospective birth cohort study that included 17,055 participants born between Oct 1997 and Oct 1999 in Southeast Sweden. All parents to children born during the study period were invited to participate, out of approx. Of 21,700 children born during the study inclusion time, 78,6% chose to participate.



The area of Southeast Sweden consists of five counties: Östergötland, Jönköping, Kronoberg, Kalmar, and Blekinge; it includes three out of Sweden's ten biggest cities, Linköping (5th) Norrköping (9th) and Jönköping (10th). The total population of the area is approx. 1.25 million people out of Sweden's total population of approx. 10 million.[107]

The maternal educational level of the original participants in the ABIS study is consistent with data on the average maternal education of women aged 25-35 in Sweden at the time the study was conducted.[108]

The level of income inequality in the population of southeast Sweden is close to the mean of the total population, between the most unequal areas (Stockholm) and the counties with the lowest income inequality (the Northern counties.[109]

The three cities included in Paper 1 represent different social histories and socioeconomic environments.[110] In that paper, Motala and Norrköping were labeled as blue-collar cities because of their mainly industrial history. The city of Linköping, with its history as a political and ecclesiastical administrative center of the county, was labeled as a white-collar city. Previous studies of these cities have exhibited marked public health

differences, including higher mortality in cardiovascular disease among adults in blue-collar cities and differences in life expectancy.[111,112]

The Swedish National Patient Register

The register collects data from medical records on medical diagnoses and in and out-patient visits. The diagnosis codes have been shown to have a high validity.[113] In the ABIS study, diagnoses of Type 1 Diabetes have also been cross-checked with the National Diabetes Register to ensure validity further.

The EPOCH Study

The Elucidating Pathways of Child Health Inequality Study, EPOCH, is a collaboration between researchers from six high-income countries: Sweden, the Netherlands, Australia, the United Kingdom, Canada, and the USA. The collaboration uses data from seven birth cohorts to compare social gradients in health outcomes across the participating countries. The birth cohorts involved are the All Babies in Southeast Sweden (ABIS) study, the Generation R (GenR) study (Rotterdam, Netherlands), the Longitudinal Study of Australian Children birth cohort (LSAC B), the Millenium cohort (MCS), Quebec Longitudinal Study of Child Development (QLSCD), National Longitudinal Study of Children and Youth, Canada (NLSCY) and National Longitudinal Study of Children and Youth, USA (USNLSY). A grant from the Canadian Institute of Health funded the EPOCH collaboration.

Statistical methods

Directed Acyclic Graph (DAG)

A DAG is a methodology to describe the relationship between variables. This description is based on previous research and clarifies the researcher's hypothesis. When the relationship between variables is uncertain, several DAGs can be produced to describe and compare the results of the hypotheses on which the DAGs are based. DAGs are also helpful in identifying which variables act as confounders of the exposure (e.g., SES) – outcome (e.g., obesity) relationship and should be adjusted for in the statistical analysis. The DAG can also identify possible mediators of the effect of the exposure (e.g., high sugar/high-fat diet, physical activity). The mediated effects can be analyzed in mediation analysis, but mediators should not be adjusted for in an analysis to determine the role of an exposure. In a DAG, it is also possible to identify Colliders. Colliders are variables with no causal effect on the outcome. If used in the analysis, colliders will confound the relationship between exposure and outcome because they are connected to a mediator. One limitation in analyses based on DAGs is that the relationship between variables cannot be bidirectional. The researcher needs to

choose which direction he/she deems most important and choose the direction of the arrow according to that choice.[114]

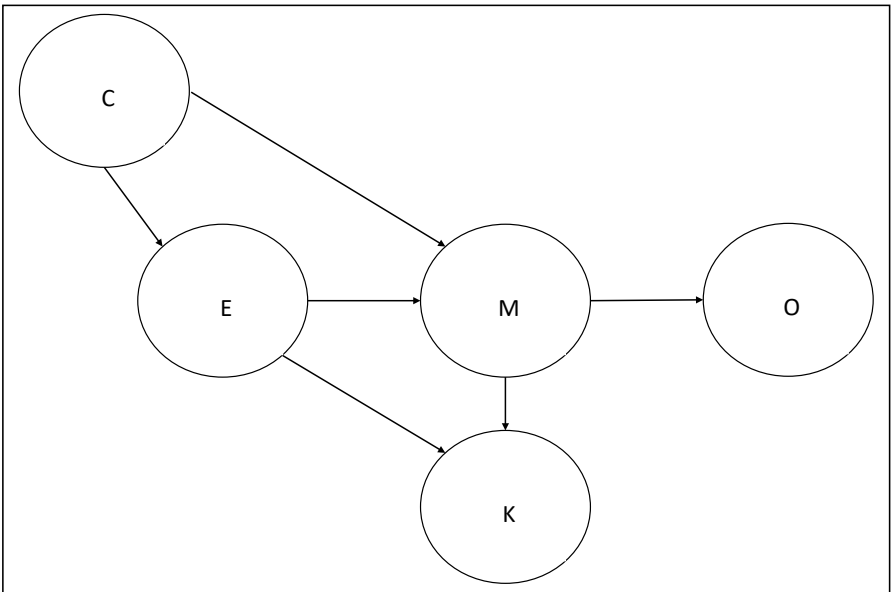


Figure 4. The basic components of a DAG. C= Confounder, E = Exposure, M = Mediator, K = Collider, O = Outcome.

Logistic Regression

Logistic regression is used when the outcome variable is binary, e.g., obese/not obese. The odds ratio (OR) is the exponential of the regression coefficient (b1), which is the estimated increase in the log odds of the outcome per unit increase in the exposure value. The OR shows how much a one-unit change in the predictor/exposure changes the odds of the outcome (similar to b in a linear regression). The odds ratio (OR) is the ratio of the odds of the event occurring (obesity) with the predictor/exposure (low SES) vs without the predictor (the reference value, e.g., high SES). If the OR is above one, the odds increase with the predictor increasing; if below one, the odds decrease with an increase of the predictor. The ORs are commonly reported with 95 % confidence intervals (CI); the true (population) value of the OR is somewhere between these two values with 95 % certainty. The width of the CI decreases with increased sample size due to the higher statistical reliability of larger samples. If the CI contains 1.00, e.g., 0.8-1.4, it is uncertain whether the predictor variable increases or decreases the odds of the outcome, and the p-value will not be statistically significant (p=>0.05).[115,116] In logistic regression, variables deemed as confounders can be adjusted for, producing an adjusted OR.[51] The adjusted OR

is the best available estimate of what the OR would be if the entire sample had recorded the same value of the potentially confounding variable(s).

ROC-curve

The Receiver-Operator-Characteristic (ROC) curve is used to estimate the predictive ability of a test for a disease. It can also be used to estimate the predictive power of an observed exposure variable (SES) on another observed outcome variable (obesity). The ROC curve plots the sensitivity (also called the True Positive Fraction) on the y-axis, that is, the fraction with the disease (obesity) that the model predicts correctly using the included predictor (e.g., maternal education). 1 – specificity (False Positive Fraction) is plotted on the X-axis. The area under the ROC curve (AUC) indicates the overall predictive value of the model in classifying the data into disease/no disease. The area under the ROC curve values ranges from 0.5 to 1. When the binary model can perfectly separate the classes, the area under the curve is 1. When the binary model cannot separate the classes better than chance, then the area under the curve is 0.5.[117]

Poisson Regression

In recent years, modified Poisson regression with robust variance estimation has become an increasingly popular method for analyses of longitudinal observational studies. This method produces Risk Ratios (RRs) rather than ORs. Similar to logistic regression, this method allows for adjusting for confounding variable(s). The benefit of RRs compared to ORs is that they are non-collapsible, meaning that adjustment can only increase precision and not change the estimate.[118] RRs do not change with prevalence in the same way as ORs do. When the outcome is rare, ORs and RRs will be of similar size, but if the outcome is common (>10 %), the ORs will be higher or lower than the RRs.[119]

Multiple Imputation

Multiple imputation is a method used to minimize the effect of missing data in statistical analyses of epidemiological studies. The method assumes that missing data is missing at random, i.e., that the missing data can be predicted using the observed data in the dataset. In this method, several plausible versions of the dataset are created, and the missing values are imputed using predictions based on the observed values in the dataset with an appropriate level of random variability. Standardized statistical methods estimate associations in the imputed datasets in the second step. Estimates will vary between the datasets as the imputed values will differ between the sets, and finally, the results are averaged together to give an overall estimate of associations.[120]

Inverse Probability Weights

Inverse probability weighting is another method to reduce potential response bias. In this method, the probability of participation is calculated using variables with information about the population or the original cohort. This method is used and could be preferable to MI in studies with multiple follow-ups where some individuals will either have close to all variables in a specific follow-up if they participated in that follow-up but lack all variables if they didn't participate, in this case, the validity of MI could be questioned and Inverse probability weighting could be a better option.[121]

Slope Index of Inequality (SII)

The SII indicates the difference in the prevalence of an outcome in the most advantaged group compared to the least advantaged. SII is a regression-based index that accounts for the socioeconomic distribution of the population, excluding the size of socioeconomic groups as a source of variability in estimating the magnitude of inequalities in health.[122] The SII represents the difference in an estimated value of an outcome between the most advantaged and the most disadvantaged while considering all other subgroups. SII takes the value zero if there is no inequality. For adverse indicators, negative values indicate a concentration among the disadvantaged, and positive values among the advantaged. SII is an absolute measure of inequality. The larger the absolute value, the higher the level of inequality. SII considers all population subgroups, i.e., high, middle, and low educational level or occupational classes I-V; the subgroups are weighted according to their population share.[123]

Meta-analysis and Forest-plots

Meta-analysis is a method for quantitative pooling of estimates from multiple studies in such a way that statistically more reliable studies, e.g., large sample size studies, are given greater weight than less reliable studies. It can increase precision in the pooled estimate but also incorporate a risk of misleading interpretations if variations across studies are not carefully considered.[124] The Forest Plot is a graphical result presentation used to present data in a meta-analysis. In the Forest Plot, the point estimate, the RR in cases with dichotomous outcomes, with 95% Confidence Intervals of the individual studies, is shown, as well as the pooled estimate with its 95% CI. The meta-analysis also provides an estimation of heterogeneity between the studies concerning the quantity being pooled; it is measured by the I2 statistic, which ranges from 0 to 100%, indicating the magnitude of heterogeneity.[124] A high level of heterogeneity suggests that there might be an underlying reason for the observed differences between studies; such reasons for heterogeneity include population, study method, and healthcare systems differences between the individual studies.[125]

Latent Variables in Structural Equation Models (SEM)

SEM is a regression-based method to analyze the relationship between observed and unobserved (latent) variables. Unlike conventional regression,

however, all regressions are estimated simultaneously. SEM includes observed variables, which are, as the name implies, constructs that can be measured directly, such as years of education or body mass index. SEM also includes latent variables that cannot be measured directly but are measured indirectly through several observed variables that are then statistically combined into a single latent variable. Path analysis is one type of SEM that only includes observed variables and can include analysis of direct and indirect effects of variables based on a priori assumptions about the relationship between variables. In SEM, a latent variable is commonly used in social and psychological studies for such constructs as personality, abilities, and emotions. The observed variables used to construct the latent variables could be survey items, total scores of different instruments, behavioral observations, or physical characteristics. Structural equation modeling is especially useful for modeling latent variables and their relation to other observed variables. The latent variable is interpreted using Factor loadings, which is the correlation between the observed variable and the latent variable constructed. It ranges from -1 to 1; if the correlation is high, it is close to 1; if a high value in the indicator is correlated with a low value of the latent variable, the factor will be close to -1. In the regression part of the analysis, composite scores are produced by summing the indicators using standardizing scores and taking a mean. Variance in the indicators is assumed to be attributable to all latent variables that influence it, a unique factor that is reliable and specific to that indicator, and random error.[126]

Ethical Considerations

One potential ethical problem in a longitudinal study that spans from birth to adulthood is the participant's right to make decisions about their participation and to give informed consent. This problem has been addressed in the ABIS study by giving increasing levels of responsibility for the informed consent process to the child as the children become older. The parents of the ABIS study provided informed consent to participate at the child's birth after receiving written and oral information about the study. From the follow-up at age eight and onward, the children were also considered to have given consent if they answered the child questionnaire in the follow-up. In the first follow-up in adulthood at age 19 and the ongoing follow-up at age 24, only the participants were given written information regarding the study. The participants gave their informed consent in the follow-ups in adulthood while filling in the online questionnaire of each follow-up. The ABIS study, including follow-ups and linkage to Register data, has been approved by the Research Ethics Board at the Faculty of Health Sciences at Linköping University (Dnr 96-287, Dnr 99-321, Dnr 03-092, Dnr 2013/253-32, Dnr 2016-427-32) and the Faculty of Medicine at Lund University (LU 83-97), Sweden.

RESULTS

Paper I

This paper finds a gradient for three out of four health outcomes: overweight/obesity, low HDL, and high blood pressure. Educational level and parental occupation were better predictors of outcomes than household income. Blue-collar city was the best predictor of low HDL, however, most of the association between the blue-collar city and the outcomes was reduced after adjustment for individual-level SES measures.

We also analyzed the development of inequality during childhood. This analysis showed that an increased risk of obesity in children with low maternal education was detectable already at two years of age. The level of inequality increased in later follow-ups; the OR of obesity in the low maternal education group at 12 years of age was 2.16 (1.29-3.61).

Table 2. *Association between maternal education level at birth and child overweight or obese at four ages*

Timepoint:	2 years	5 years	8 years	12 years
Available sample approach				
Age: mean (SD)	2.73 (0.30)	5.34 (0.31)	7.86 (0.38)	12.40 (0.91)
Sample size available	7925	6602	2998	3337
Low Maternal education	1.18	1.30	1.16	1.70
Overweight*	(1.03, 1.34)	(1.13, 1.50)	(0.94, 1.42)	(1.39, 2.06)
Low Maternal education	1.56	1.52	2.28	2.16
Obesity*	(1.12, 2.17)	(1.15, 1.99)	(1.31, 3.95)	(1.29, 3.61)

*Odds ratio (95% confidence interval)

Note: The available sample approach uses any participant with all necessary data recorded at least one age. This is a simplified table from Table 4 in paper 1 of the thesis.

Paper II

This paper investigates two measures of early childhood SES, household income and maternal education, and their association with overweight and obesity in late childhood in seven birth cohorts from six high-income countries (the EPOCH study). The paper's major finding was that a social gradient was present in all cohorts but that the slope of the gradient varied across the cohorts, absolute inequality being lowest in the Swedish ABIS cohort. The social inequality in obesity in ABIS for income was lowest in relative and absolute terms, and the social inequality when measured by maternal education was lowest in absolute but not relative terms. This did not follow the generally observed relationship between prevalence and absolute and

relative inequality suggested by Houweling, who states that low prevalence should be associated with low absolute inequality but high relative inequality.[127] An explanatory theory should consider social and family policies affecting the relationship between SES and overweight/obesity. We suggest four potential policies that might have influenced the results of our study: universal preschools, generous parental leave regulation, a ban on advertisements for children, and free preschool and school meals.

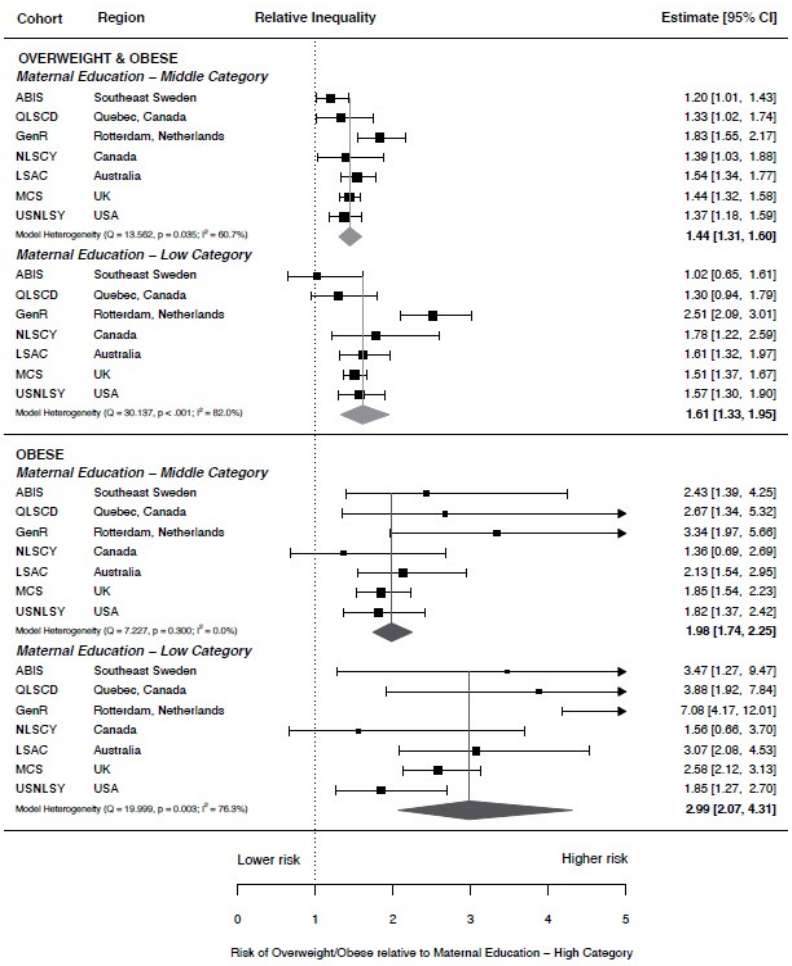


Figure 5. Forest plots of overweight and obesity by maternal education. RRs for each cohort and Pooled RR for middle and low maternal education.

Paper III

This paper found a social gradient for Type 1 Diabetes but not for the other investigated autoimmune diseases (Celiac Disease, IBD, JIA, and Autoimmune Thyroid Disease). There were no significant differences in the age of diagnosis related to the two measures of SES: Maternal education and household income. In a Path Model, we investigated the mediating effect of two variables associated with Type 1 Diabetes: Serious Life Events (SLE) and BMI. We found that the two indirect pathways mediated 17 % of the association.

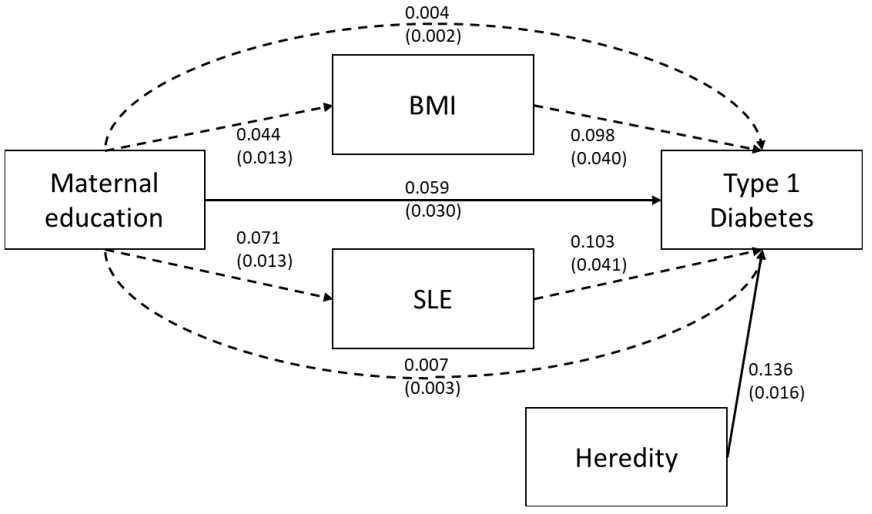


Figure 6. Path model of pathways between Maternal Education and Type 1 Diabetes. Solid lines indicate direct path, while dashed lines indicate indirect paths.

Paper IV

In this study, we investigated our hypothesis of the relationship between SES, measured by maternal education, and the development of high BMI and obesity at 19 years of age. We found an increased risk of obesity in children to parents with low maternal education; the relative risk for overweight in low education was RR 1.51 (1.26, 1.82), and for obesity, RR 1.66 (1.07, 2.57). To investigate the mediating pathways between maternal education and BMI/obesity we used two variables; maternal self-control and child self-control. The maternal self-control variable was constructed using the variance in other self-control-related behaviors: smoking during

pregnancy, smoking during the child's first year of life, the number of times the child participated in the ABIS study with biological samples (blood and feces), and the duration of breastfeeding. We also included maternal BMI from the ABIS one-year follow-up in a second model. The result showed that maternal self-control and child self-control (model 1) mediated 85% of the effect on BMI and 87.5 % of the effect of obesity risk. Adding maternal BMI (model 2) to the latent variable increased the mediated indirect effect to 95% of the total effect on BMI and 93% of the obesity risk.

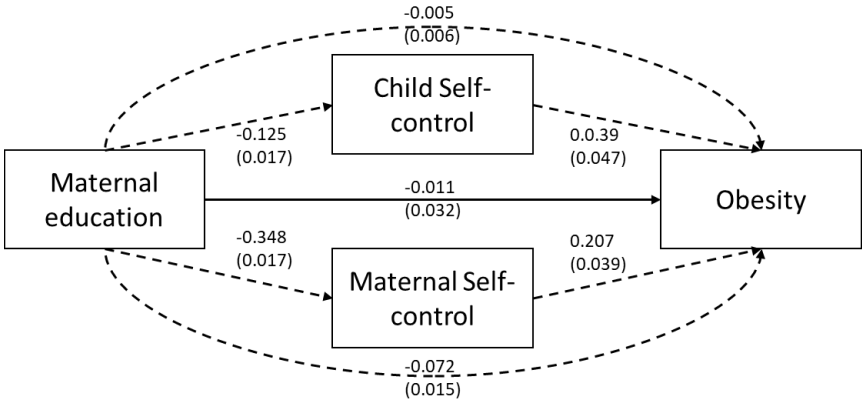


Figure 7. Path model of pathways between maternal education and obesity. Solid lines indicate direct paths while dashed lines indicate indirect paths through child self-control and maternal self-control. Model 1 = the latent variable maternal self-control is constructed using smoking during pregnancy, smoking during the child's 1st year of life, participation with biological samples, and duration of breastfeeding.

DISCUSSION

Child Health Inequalities in Sweden

This thesis aimed to investigate health inequalities in childhood, adolescence, and early adulthood. The thesis results show that inequalities are present already in early childhood and increase with age. Differences in overweight and obesity are one of the first detectable inequalities, and this inequality is then transmitted into differences in the health outcomes associated with obesity, including cardiovascular risk factors and increased risk of Type 1 Diabetes. To reduce inequalities, a central question is the reasons for differences in health behaviors, including dietary differences (the most important behavior for the results of this thesis). Based on previous research and our understanding of the mechanisms of the development of an unhealthy diet, eating habits, and the development of obesity, a hypothesis was formed: self-control has a central role in the pathway between SES and obesity. We tested this hypothesis in the fourth paper, and the findings aligned with our hypothesis.

Missing Mediators in the SES – T1D Pathway

In our study on mediating factors between maternal education and Type 1 Diabetes, we could only explain a small part of the risk difference with the two indirect paths, BMI and SLE (17 % of the relationship).[128] In the paper, we discuss the limitations, including the fact that BMI was only measured at one time-point, and we believe that additional BMI values in later follow-ups could have increased the percentage mediated by BMI/obesity. Still, the percentage mediated is unlikely to reach the high level seen, for example, in the fourth paper on self-control and obesity. What could be the additional mediators not measured in our paper?

The close relationship between maternal education and self-control could be helpful in this search, i.e., behaviors related to low self-control should be suspected. Of these factors, insulin resistance (IR) is one likely mediator. In the ABIS studies in this thesis, we do not include any measure of IR. However, our research on cardiovascular risk factors found a social gradient in low levels of HDL, which is closely related to insulin resistance.[129] Low HDL is associated with insulin resistance even in non-obese subjects; thus, only measuring BMI is insufficient to assess this pathway.[130] Insulin resistance is related to sedentary time/lack of physical activity and dietary factors like the amount of fructose in the diet.[131,132] A mediating role of insulin resistance would be in line with the accelerator theory proposed as an explanation for the increased risk of Type 1 Diabetes with higher BMI.[97,133]

Another potential mediator could be peak sugar intake. In Sweden, children are traditionally given candy only on Saturdays. Therefore, the frequency of candy/sweet intake is relatively homogenous in the ABIS cohort, which measures only frequency (i.e., how many days a week the child eats candy, drinks sugar-sweetened drinks, etc.). However, ABIS has no measure of the amount of candy consumed at each intake. Auto-antigen release from Beta-cells increases when the pancreatic islets are flooded with a high glucose concentration, increasing the risk of an autoimmune reaction.[134] Thus, one potential pathway from low maternal education to Type 1 Diabetes could be the higher intake of glucose, especially in the form of sugar-sweetened drinks and candy. There is indirect evidence of a higher sugar intake in the ABIS cohort. Children with low maternal education have an increased risk of dental caries RR 2.31 (95% CI = 1.81;2.96) at age 5 (results from the EPOCH study on oral health).[135]

SES and Autoimmune Diseases

In paper 3, we, in addition to Type 1 Diabetes, also investigated the association between SES and other autoimmune diseases. The results showed no association between these diseases and SES. Understanding the relationship between SES and self-control-related variables could be helpful when searching for environmental factors that explain the rise in prevalence of these diseases. The lack of association with SES indicates that the environmental factors responsible are unlikely to be those associated with obesity (high sugar/high-fat diet and lack of physical activity). Instead, the search for environmental causes should focus on environmental changes that affect the entire population equally. Examples of such changes are increased hygiene[136], antibiotics[137], and Gut-microbiome changes.[138] Findings from the ABIS study support the role of antibiotics and the gut-microbiome for the development of JIA.[139,140]

A recent study using IBD diagnoses in ABIS and a Norwegian cohort found a slight increase in the hazard ratio of low maternal education.[141] It is not impossible that SES could influence the risk of autoimmune diseases other than Type 1 Diabetes, but the effect seems to be limited.

A Municipality Effect on Cardiovascular Risk Factors

In our study on cardiovascular risk factors, we included three variables of SES on the individual level and one variable on a higher municipality level called white/blue collar city. In the paper, we concluded that most of the effect of the city of residence was due to individual-level variables. However, for three out of four outcomes, the risk of children from a blue-collar city remained positive also after adjustment for the three individual-level variables: overweight OR 1.39 (0.70, 2.73), low HDL OR 1.41 (0.55, 3.60), and elevated blood pressure OR 1.12 (0.58, 2.14). These differences aren't negligible, although the relatively small power of the study makes the exact effect uncertain. A small but significant effect aligns with previous research

on neighborhood effects on health behavior in Sweden; 6% of smoking during pregnancy differences have been attributed to neighborhood effects.[142]

SES in Sweden vs. Other High-Income Countries

In our international collaboration, a repeated finding has been the relatively low effect of low household income in Sweden vs other participating high-income countries. This finding was consistent with health inequality from other Nordic countries where income and educational level have been used to investigate BMI differences in Danish children or obesity in Norwegian adolescents.[143,144] Increases in income have been found to have almost no effect on health inequality in Sweden.[145]

A theory that includes a central role of self-control for health inequality provides a hypothesis for explaining these observations. The rationale for focusing on immediate income among parents in high-income countries with low levels of welfare, like the USA, will be a mix of both immediate needs and long-term goals, e.g., to earn savings for the child's education or paying for a health insurance plan (or being provided one by an employer). In Sweden, the long-term effects of accumulating income for the health and safety of one's family and children are reduced due to welfare policies like free higher education and free healthcare. Thus, deciding between taking time off to care for the child (which is supposed to benefit the child's development) or working to make money becomes increasingly a self-control conflict. Parents with higher education will be more likely to follow the long-term goal due to positive peer pressure and the gradient in self-control. That this is the case in Sweden is evident in the social gradient in parental leave, including paternity leave. Fathers with higher education take longer parental leave than those with low education.[68] Because parental leave only compensates for part of the parent's income, income differences between high and low-educational groups are reduced.[67] Thus, parental income in early childhood becomes less correlated with education and other measures of SES and self-control.

Income is both a measure of the actual income available for the family and a measure of social stratification and self-control. This can be seen when measuring the association between self-control-related behaviors and income at three time points during childhood. The association between these variables and income increases when the child ages and the income better reflects other SES variables like education.

Table 3. Low household income at three-time points during childhood and association with low maternal education at birth, smoking during pregnancy, and child obesity. The association increases in late childhood compared to early childhood.

	Low Maternal Education[a]		Smoking During Pregnancy		Child Obesity 8 yrs.	
Low Income[b]	OR	CI	OR	CI	OR	CI
The year 2000	3.83	3.19;4.61	3.47	2.93;4.09	1,13	0.56;2.25
The year 2006	5.20	4.24;6.37	4.69	3.92;5.60	1.97	0.98;3.94
The year 2012	5.55	4.49;6.86	5.35	4.45;6.43	2.62	1.22;5.64

[a] Maternal Education measured at birth.
[b] Low income is defined as 1st income quintile. The reference category is High income (5th quintile)
OR= Odds Ratio CI = 95 % Confidence Intervals

A General Theory of Social Inequality in Health

In their book "A General Theory of Crime," the authors Gottfredson and Hirschi stated that self-control played a central role in criminality and related outcomes such as accidents and addiction.[42] Criminality provides immediate gratification of desires, e.g., money without work, revenge without court delay, and crime is exciting, risky, and thrilling. On the other hand, criminality tends to produce few or meager long-term benefits. The major benefit of crime is often the relief from momentary irritation. Irritation from a crying child can be the stimulus for physical abuse, taunting by a stranger in a bar stimulus for aggravated assault, etc.[42] Thus, the authors concluded that low self-control, the inability to inhibit impulses and preserve focus on long-term goals, is the central reason for criminality.

Although an important step in understanding criminality and human behavior, the authors in their book had an overly polemic approach, stating that social factors, including SES, had little or no effect on the behaviors of criminality. This kind of polemic discussion is not constructive. Instead, it threatens to lock the different opinions, where researchers, instead of looking at the evidence objectively, try to defend the paradigm of their field. Neither is it helpful to avoid a subject that can be informative for our understanding due to fears of the political consequences, e.g., that politicians will be less responsive to arguments about the importance of reducing social inequality. Such fears can be noted already in the Black Report, where differences in personal character were discussed but given little importance.[15] Similarly, Johan Mackenbach discusses the fear of a "blame the victim" debate as an obstacle in the research on the persistence of inequality in the welfare state.[18]

A general theory of health inequality should be an integration that includes differences in self-control as a central path. There is no need, however, to exclude either genetic or environmental causes of self-control in such a model.

Genetics

Twin studies have found that self-control has a genetic component, with an estimated heritability of 60% in one meta-analysis.[146] Attention deficit hyperactivity disorder (ADHD), the current diagnosis for the individuals with the lowest control of impulsivity, is partly genetic.[147]

Training/Neuroplasticity

"By abstaining from pleasures, we become temperate, and it is when we have become so that we are most able to abstain from them; similarly too in the case of courage; for by being habituated to despise terrible things and to stand our ground against them we become brave, and it is when we have become so that we shall be most able to stand our ground against them." Aristotle, Nicomachian Ethics book II

The prefrontal cortex is not fully developed until the mid-twentieth, and it can be improved even after that age by neuroplasticity and training in self-control and executive functions.[148,149] The studies on the improvement of self-control are generally short-term experiments of a couple of weeks and have shown small but significant effects.[150] Their importance has been to show that self-control can be trained across the lifespan. However, for children and adolescents in the real world, the most important task to improve self-control is likely to be schoolwork, as adolescents report that schoolwork is the activity in their lives that requires the most self-control.[60] There is evidence in ABIS for a divergence in self-control during childhood between children with low and high maternal education. While self-control improves in children with high and middle levels of maternal education from the age of 8 to 12 years, children with low maternal education show no such improvement.

The main effect of education on self-control is unlikely to be the training effect as extension through reforms in the duration of education has shown only a small effect on reductions in health inequality; adding one year of compulsory education led to only a 2.1% reduction in mortality before the age of 40, while one extra year of education after compulsory education reduces the risk with 40%. The interpretation of this finding must be that it is not the duration of education but the other mechanisms of SES/educational level - Self-control - outcome pathway that explain most of the relationship [151]

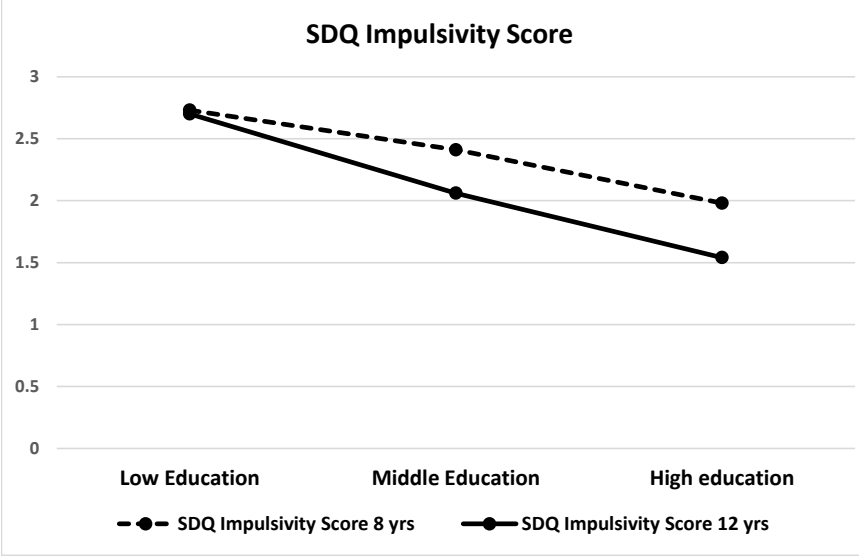


Figure 8. Diagram of mean score in SDQ impulsivity subscale. The mean score is unchanged between the age of 8 and 12 in the children with low maternal education but improves in those with middle and high maternal education leading to increased differences between the groups.

Stress

Wilkinson and Marmot have promoted the role of psychosocial stress in health inequalities in the psychosocial theory of health inequality, which states that low SES induces status stress in humans.[29,30] This theory could be consistent with a central role of self-control in health inequality as self-control is reduced by stress with activation of the HPA axis and the release of glucocorticoids that reduce prefrontal lobe inhibition of the limbic system.[52] Psychosocial stress and its complications, such as reduced sleep also decrease PFC control.[152]

Peer Pressure

Studies have shown that peer interaction can improve self-control or reduce it depending on the quality of the interaction. Thus, the presence of peer interaction and acceptance by peers improve self-control, while rejection by peers reduces self-control ability.[153] Social network studies in adults have shown that the risk of obesity increases by 57% if a friend becomes obese, while the influence of a spouse becoming obese was a 37 % increased risk of obesity development.[154] High SES individuals are encouraged to improve their self-control because of the increased probability that their peers engage in self-control-related behaviors like physical activity and a healthy diet. In contrast, low SES individuals will have an increased risk of exposure to peers that engage in immediate rewards with adverse long-term

effects, e.g., delinquency, smoking, alcohol, and a high sugar/high-fat diet.[15] Studies have shown that the peer-pressure impact can be reduced by reducing segregation; moving from a low SES neighborhood to a higher SES area reduced the risk of obesity and Diabetes.[155]

Self-efficacy

Low SES is associated with lower self-efficacy in schoolwork.[156] Negative experiences of inability to change a behavior or succeed in a challenging task will influence future self-efficacy in similar situations (one's perceived ability to achieve a goal successfully).[157] Self-efficacy is important for the strength of the higher-order goal in a self-control situation.[50] Thus, repeated inability to change behavior and outcomes (e.g., weight reduction in obesity) may lead to low self-efficacy. Related to low self-efficacy is the state of learned hopelessness (the expectation that even if I try, I will not succeed and the result will be negative) or helplessness (what I do doesn't affect the outcome), LH.[158] In LH, persons perceive their ability to change the current situation as low and become passive. Thus, LH reduces self-control by reducing commitment to the higher-order goal.[50,159]

Vicious Cycles and Limbic Traps

"*Now, in everything, the pleasant or pleasure is most to be guarded against (-) for if we dismiss pleasure, we are less likely to go astray. It is by doing this, then, that we shall best hit the mean.*"
- Aristoteles, Nicomachian Ethics book II.

Throughout life, we are constantly exposed to positive and negative reinforcers that can trigger impulses, loss of self-control, and lead to behaviors. Many of these behaviors may put us in a worse position for self-control in the future, leading to a vicious cycle. Some authors have called these behaviors (teenage) "snares"[160]. I would like to term these behaviors "Limbic Traps" because of their connection with the limbic system and their ability to reduce future attempts to reverse or disengage from the behavior.

The Limbic Trap of a High Sugar – High-Fat Diet

That high sugar/high-fat diet is a limbic trap is becoming increasingly evident.[161] Recent research has found that the HS/HF diet increases signaling in the limbic reward pathway and decreases the preference for low-fat foods. This brain rewiring/plasticity was found after only eight weeks on the HS/HF diet, and it happened before any changes in BMI or hormone levels could be detected (insulin resistance or leptin levels).[162] Also, high fructose intake has been found to increase leptin resistance in animals.[163,164] The adipose tissue expresses Leptin, the hormone that regulates body-fat composition. Increased levels of adipose tissue increase Leptin expression, which increases satiety. Thus, Leptin functions as a homeostatic feedback that controls body fat composition at a certain level.[165] In obesity, Leptin levels are chronically increased and even higher than expected from the amount of adipose tissue. However, the Leptin signaling in the Hypothalamus is decreased, mirroring the effect of chronically increased insulin in developing insulin resistance.[165] Once an HS/HF diet has led to obesity,

reversing this outcome becomes increasingly difficult as attempts to reduce weight are counteracted by leptin resistance and decreases in basal metabolic rate.[166] The high sugar/high-fat diet constitutes a limbic trap that reduces the ability to control eating behavior by at least three mechanisms: increased reward signaling, decreased satiety, and reduced metabolism during weight reduction once a person has become obese.

The Limbic Traps of Addictive Substances

"O God, that men should put an enemy in their mouths to steal away their brains!" - Cassio (Act II, Scene iii) Othello by William Shakespeare.

Addictive substances have varying acute effects on self-control, ranging from alcohol, which reduces self-control, to nicotine, which increases self-control temporarily. Alcohol addiction has been shown to impair executive function and the ability to self-control.[167] Addictive substances have in common the effects of an acute increase in dopamine that will always be followed by a decrease. This decrease then leads to craving for the drug and the vicious cycle that leads to addiction. After chronic use of the drug, dopamine response toward other non-drug stimuli is reduced, reducing the motivation for different types of healthier rewarding behaviors (social interaction, etc.).[168] Addiction could thus be seen as a limbic trap because of multiple effects on self-control, including acute impacts of the drug, reduced reward of other behaviors, and, with substances like alcohol; damage to the frontal lobes that decreases the ability to self-control.

The Limbic Trap of Social Media and Mobile Phone Use

Increasing evidence points to the adverse health effects of social media. Social media use has been shown to increase depression and anxiety symptoms in youths.[169] A reduction of social media use to 30 min a day decreased symptoms of depression in adolescents.[170] Habitual checking behaviors on social media have been associated with differential development in brain areas related to self-control; with constant reinforcement, dopaminergic neurons within the limbic reward pathway and the amygdala become increasingly responsive to social feedback. This, in turn, leads to increased activation of PFC to control emotional reactions to social feedback.[171] This mechanism becomes a positive feedback loop like in other addictive behaviors. Thus, social media use constitutes a limbic trap by increasing reward sensitivity from social media, increasing anxiety, i.e., glucocorticoids, increasing the need to activate the PFC to control negative emotions induced by social feedback, thus decreasing self-control for other self-control-related behaviors.

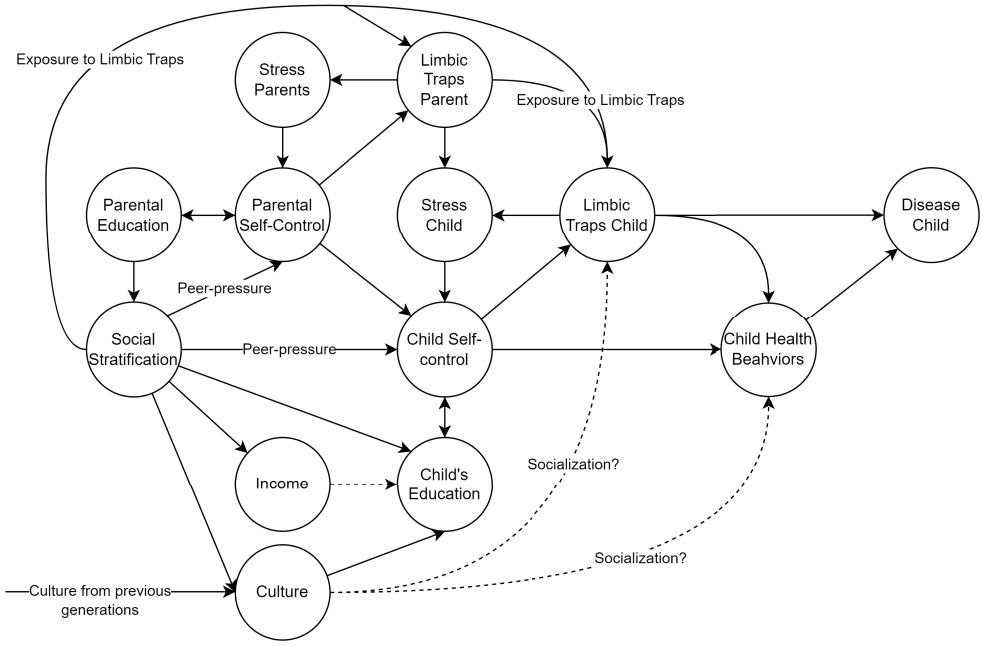


Figure 9. A General Theory of Social Inequality in Child Health,

1) Parental self-control affects parental educational level that leads to social stratification of the parents and child.
2) Peer-pressure and status stress due to social stratification (positive or negative) affect the parents and child's self-control. Social stratification also affects the parents and child's exposure to limbic traps.
3) Parental self-control affects the risk of parental limbic traps which reduces self-control in a feedback loop by increasing psychosocial stress and other mechanisms (intoxication, neural and metabolic effects).
4) Parental self-control affects child self-control by several mechanisms (genetics, ability to control child behavior).
5) Child self-control affects the child's educational attainment which feedback to child self-control. The feedback consists of self-control training during schoolwork and depending on the level of success in school, an increase or decrease of self-efficacy.
6) Child self-control also leads to child's risk of limbic traps that feed-back via stress and other mechanism to decrease self-control.
7) Child self-control also affect health behaviors unrelated to limbic traps such as physical activity.
8) Together limbic traps including high-sugar/high-fat diet, smoking and health behaviors like physical activity leads to the child risk of disease (incl metabolic and cardiovascular disease).
9) Because of the social gradient in self-control and the mechanisms described in this thesis, the result is social inequality in health. Parental income and material resources may play a role in countries without universal funding of educational systems and health care. Culture may bypass parental and child self-control by socialization of behaviors.

Self-control and Health Inequality Theories

In this thesis's introduction, numerous health inequality theories were described. These theories could be integrated with the findings of this thesis that self-control plays a central role in health inequalities.

Life-course Perspective

The environmental exposure that could increase or decrease self-control and the Limbic traps described are consistent with the theory that adversities across the lifespan add up to the high level of inequality we find in adulthood.

The Behavioral and Personal Characteristics Theory

The self-control theory differs from the behavioral and personal characteristics theory only by focusing on a different trait, self-control than most previous studies have focused on. As such, the self-control theory is consistent with the behavioral and personal characteristics theory hypothesis that individual-level factors are important for health inequality.

Natural Selection

The self-control theory is also consistent with this theory, i.e., that some difference between social groups is due to the social mobility of high and low self-control individuals.

The Neo-Materialistic and Fundamental Cause Theory

The materialistic theories, including the fundamental cause theory and the neo-materialistic theory, which both state that differences in material resources, including public investments in policies related to health, explain health inequalities, are the theories least consistent with the self-control theory. However, it is clear that in a country with limited or decentralized education and health funding, such as the USA, materialistic pathways could be significant and increase health inequalities. In the USA, states with a high proportion of low-income families invest less (!) in public goods than those with lower poverty levels.[27]

Important policies for child and adolescent health are investments in preschool policies, as levels of investment in preschool have been associated with decreased levels of obesity in children.[172] Another important policy is investment in universal preschool and school meals that have been shown to reduce obesity when introduced in the UK.[173] A materialistic pathway from SES to disease must be included in a General Theory of Health Inequality. However, the impact of this pathway is reduced in welfare countries with universal funding for health and education.

The Importance of Income Inequality

There is robust evidence for the correlation between country and state levels of income inequality and the prevalence of some diseases, including cardiovascular disease.[12] The Psychosocial Theory has attributed this to

increased levels of status stress.[174] The neo-materialistic theory emphasizes the distribution of access to health-related resources.[28] Another important and related finding is a correlation between income inequality and ambivalence in stereotype content; this finding shows that people in countries with high-income inequality justify their inequality by increased differences in the two components of stereotypes: competence and warmth. Low SES individuals are deemed increasingly incompetent but with a compensating high level of warmth.[175] Increasing levels of attributing stereotypes dependent on social class could increase the importance of socioeconomic status for the human tendency to divide people into Us and Them.[43] Sapolsky has described the importance of Us and Them, including the fact that empathy for groups of people we consider as part of our own (Us) is automatic, while empathy for those outside of our group (Them) demands cognitive work. Studies also show that encounters with people outside our group activate the amygdala, which is then suppressed by the prefrontal cortex.[43] Thus, the development in high-income countries described by Piketty, where the increase in return on capital is always higher than the increase of income from work, leading to ever-increasing levels of income inequality, could have implications for health inequality.[13]

The Cultural Capital Theory

As stated in the Black report, there is little evidence for a culture of poverty, i.e., that socialization in low SES individuals would lead to beliefs that behaviors with adverse health effects aren't dangerous (like smoking). One example is the number of individuals who reported that they wanted to quit smoking during the last year in the USA. 70 % report that they want to stop independent of the SES category.[176] It could be argued, however, that the kind of peer pressure described as important for self-control is a form of cultural capital. Even if low SES individuals are aware of the negative consequences of a behavior, they still suffer from the increased exposure to opportunities to engage in that behavior and the need for self-control. In contrast, high SES individuals will benefit from the positive peer pressure described.

SES and Self-control in Dopamine Nations

The Limbic traps described are only a sample of the potential Limbic traps and behaviors that occur. Other behaviors related to the reward system include different types of screen time, including computer gaming, excessive shopping, gambling, and criminality. Limbic traps due to activation of the amygdala/insula include aggressive behavior that can lead to crime and abuse, social isolation due to social anxiety, school refusal, etc. Child trauma is, in a way, a transmission of parental low self-control from the parent to the child, as adverse childhood experiences (ACEs) increase the risk of other self-control-related behaviors later in life.[177] The teenage years are a vulnerable time, and the Dunedin Multidisciplinary Health and Development Study found that "teenage snares" explained a significant part

of the relationship between low self-control and health.[178] In her book, Anna Lembke describes the current situation in the US as a "Dopamine Nation".[179] Never before have we had access to such a variety of stimuli to trigger our reward system. Given the mechanisms of self-control, being a depletable resource, and how stimuli of the limbic system can produce Limbic traps that impair our self-control, this new environment will likely increase health inequalities unless we improve it. Children and adolescents are the groups most vulnerable to this environment due to their lower self-control ability and, in the case of adolescents, increased level of activation in the reward pathway and the amygdala by stimuli.[49] Without interventions, harmful behaviors like high sugar/high-fat diet and social media use are likely to follow in the path of cigarette smoking. Because self-control on average is higher in high SES individuals, high SES individuals will, on average, be more successful in behavioral change, e.g., to quit smoking. Peer pressure from fellow high SES friends and family will increase to promote quitting. In low SES, the rationalizations seen in individuals who fail to quit smoking will reduce successful quitting.[180] This rationalization for not quitting will be spread among low SES individuals who are unsuccessful in quitting through peer contagion, decreasing motivation for behavioral change even further in low SES individuals.[181] A similar development can be expected in the new social media environment, i.e., as evidence for the harmful effect of the behavior increases, high SES individuals will be more successful than low SES to disengage from the behavior. High SES parents will benefit from positive peer pressure to help them reduce their children and adolescents' social media use. At the same time, low SES families will be affected by negative peer pressure that diminishes their ability to restrict social media and screen time.

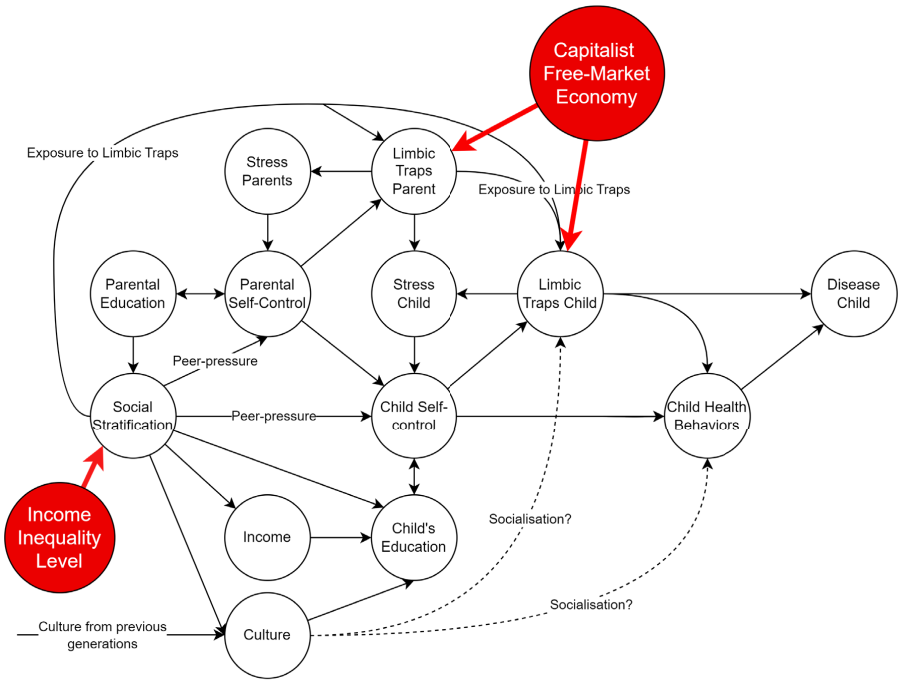


Figure 10. Effect of Capitalism. Capitalism increases income inequality, leading to increased importance of social stratification (segregation between socioeconomic groups, status stress and Us-Them categorization). The free-market economy also produces increasing levels of stimuli of the reward system/Limbic traps including social media, sugar/caffeine-containing beverage, fast-food, computer games, online casinos, quick loans, alcohol, cigarettes and e-cigarettes etc.

How to Reduce Health Inequality

Implications for Political and Public Health Policy

A clear understanding of the role of self-control in social inequalities in health clarifies how these inequalities can be reduced (and gives a rationale for some of the public health policies already in place). Policies that are likely to reduce health inequalities related to differences in self-control, including child obesity risk differences, should:

1) Bypass parental self-control: for example, by providing free universal preschool, school, and after-school activities. Provide healthy, universal, free preschool/school meals.
2) Stimuli control: restrict mobile phone use for children and adolescents (regulations in schools, personal logins on social media that restrict usage during schooldays and nights on weekdays), limit access to candy and unhealthy snacks in schools, age limit on energy

drinks, alcohol, tobacco, vaping, etc. A ban on advertisements for children.

3) Avoid reducing self-control. Evidence is growing that screen time/social media use reduces self-control.[182,183] Limitations on screen time/social media use could reduce the negative impact of these behaviors on self-control.
4) Train self-control: Give every child attention in preschool/school by teachers in classes with a high teacher-to-student ratio. The Carolina Abecedarian Project found that intervening in early childhood to improve the education of low SES children could improve downstream outcomes related to self-control in adult life, both the educational attainment of the children and their adulthood health outcomes, including obesity, blood pressure, and other metabolic variabels.[184]
5) Reduce segregation: equalize positive peer pressure and reduce negative peer pressure. The moving-to-opportunity study showed that moving from a neighborhood with low SES to a higher SES neighborhood decreased anxiety symptoms in both parents and children.[185] Later follow-ups have also shown a reduced risk of obesity and Diabetes in adulthood.[155] These studies indicate the important role of reducing segregation to improve self-control.

Studies like the Carolina Abecedarian Project have found that intervening in early childhood to improve the education of low SES children can improve downstream outcomes in adult life.[184] Given the central importance of self-control for social inequalities in health, these early educational interventions likely affect self-control. One potential pathway is that better school readiness amplifies self-control development throughout the school system by improving participants' results in school, leading to more positive feedback and higher self-efficacy. High self-efficacy improves concentration and self-control across the years in school. Greater success in school also leads to higher adult SES with positive effects of higher SES such as increased positive self-control peer pressure. Evidence for a continuous divergence in self-control ability is evident in the ABIS study. High maternal education in the ABIS study is associated with better self-control at eight years of age and the differences between SES groups keep increasing during the subsequent year, becoming even greater at age 12 (see Figure 6).

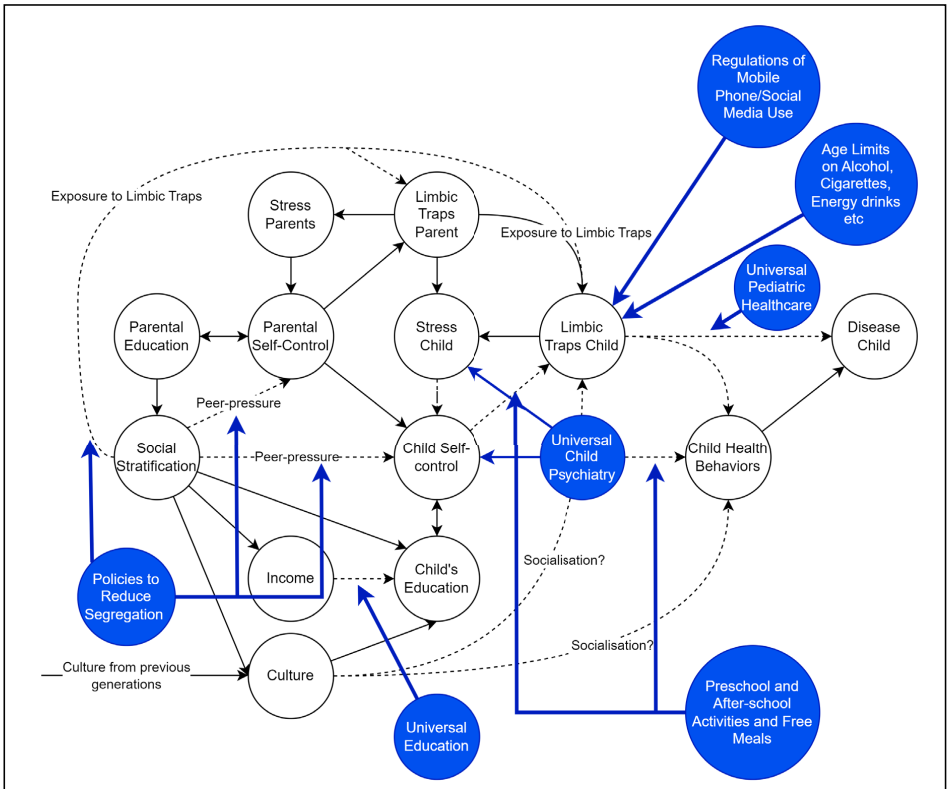


Figure 11. Examples of policies and interventions to reduce the effect of Limbic traps on child health and reduce health inequality due to the gradient in self-control.

Implications for Physicians

Physicians can reduce health inequality through medical interventions. This form of secondary prevention does not affect the root cause of the health problem (i.e., the obesogenic/anxiogenic and self-control-reducing environment). Still, it reduces the effects of that environment on disease development. Currently, the number of drugs used for this purpose is increasing, ranging from ADHD medication, anti-depressants, and anti-psychotics to new anti-obesity medicines, but also including traditional medications directed against cardiovascular risk factors such as anti-hypertension, lipid-lowering, and antithrombotic drugs. It may sometimes seem tragic that doctors should prescribe medicines for conditions that could be addressed by improving the environment with political and public health policy. However, these medications are justified by the Limbic traps that might be avoided through their use. Especially in adolescents, the group most vulnerable to positive and negative reinforcers and with their

relatively low self-control ability, medications can reduce the risk of Limbic traps like poor school performance and drop out of school (psychopharmaceutic including ADHD medications)[186], engaging in criminality[187], illicit-drug use[188], or developing obesity (the GLP-1 analogs)[189].

Understanding the central role of self-control in health inequalities should influence the clinician's decision-making and treatment strategy. Therapies that involve reduced levels of need for self-control are likely favorable in patients with low SES and should be considered when compliance problems are identified. Examples of such therapies include treatments with longer duration (semaglutide instead of liraglutide, which is taken once a week instead of every day, PCSK9-inhibitor that are taken once every second week in favor of tablet treatment of dyslipidemia. Automatization of treatment with advanced hybrid closed loop (aHCL) pumps for the treatment of Type 1 Diabetes is likely to be especially beneficial in patients with low SES.

Implication for Epidemiologists/Scientists

One of the main findings of this thesis is the interrelationship between SES and other variables that involve self-control. Epidemiologists interested in drawing causal inferences about associations between variables should be aware of the potential common pathway through self-control that might confound their findings.

According to the theories of mediation analysis, association can be interpreted as causation if the temporal order of events is correct, i.e., that exposure happened before the outcome and confounding has been excluded.[190] Mediation analyses are an important field of research that can bring light to and answer important questions unsuitable to the gold standard method, RCTs.

However, any observational study must consider the central role of self-control in human behavior. Thus, the association between self-control-related behaviors such as criminality and obesity[191], traffic accidents and obesity,[192] breastfeeding, and educational attainment[193], must always consider that self-control could be the confounding variable that explains the observation.

Suppose the purpose of a study is to draw causal inference about a particular exposure, which happens to be related to self-control. In that case, scientists should adjust for SES, other variables related to social stratification that may vary between countries but could include, e.g., sex, ethnicity, religion, etc., preferably some measure of individual self-control (the brief-Self-control scale or similar) and additional variables related to self-control, but which are not on the causal pathway to the outcome, e.g., breastfeeding, smoking, obesity, criminality, accidents, drug addiction, etc. If the observed relationship is present after these adjustments, one could potentially say that a causal pathway is probable. This observation/pathway should preferably be investigated with an RCT to confirm the relationship.

In some circumstances where it is challenging to do RCTs or animal studies, e.g., social media exposure, but the observational data indicate a

high possibility for adverse effects, the reasonable action is to be cautious and reverse the burden of proof. Instead of trying to prove something is harmful, assume it is dangerous until proven safe. As the Surgent General writes, "At this time, we do not yet have enough evidence to determine if social media is sufficiently safe for children and adolescents. We must acknowledge the growing body of research about potential harms, increase our collective understanding of the risks associated with social media use, and urgently take action to create safe and healthy digital environments that minimize harm and safeguard children's and adolescents' mental health and well-being during critical stages of development."[194] We should not fall into the same trap that stalled progress in the smoking-lung cancer debate: to try to prove something obvious but that is difficult and time-consuming to prove by the methods available to us. In the case of smoking, that trap cost thousands of lives.

Strengths and Limitations

The ABIS study is a large prospective birth cohort study. One strength of the study is the richness of the data, which includes multiple variables, including questionnaire data on psychosocial factors and life events, in combination with biological samples and clinical data from registers based on medical records.

One strength of the ABIS study is that a prospective design reduces so-called Recall bias compared to cross-sectional studies. Recall bias is when measures of exposure variables are reported incorrectly and differently between individuals with and without the outcome of interest, which affects the association between exposure and outcome measurements.[195]

Another strength of the ABIS study is that important variables in this thesis, including maternal educational level, are representative when compared with national data.[108] This increases the external validity of our results to the general Swedish population. The prevalence of one of the outcomes, overweight and obesity, has also been shown to be similar to previous studies in Sweden.[196]

ABIS cross-linking with Swedish register data improves the quality of disease diagnoses and reduces loss to follow-up. The register data also include information about the number of health-care visits in in- and outpatient clinics and pharmaceutical information about prescriptive drugs used to confirm the diagnosis of Type 1 Diabetes.

Finally, a strength of this thesis is the EPOCH collaboration, which has allowed us to compare the ABIS data with leading birth cohorts in high-income countries, including the Millennium cohort in the UK.

A limitation of the ABIS study is the drop-out rate. A higher drop-out rate in later follow-ups is a common problem in longitudinal studies. In the ABIS study, the participation rate has fluctuated over the years; in later follow-ups at age 19, the participation rate increased compared to the follow-ups at 8 and 12 years. For some variables collected by cross-linking with

the National Patient Register, like the data of diagnoses, there is almost no loss to follow-up.

The loss to follow-up has been higher in children with low parental educational levels. Our analyses addressed this by inverse probability weighting when we calculated the prevalence of overweight and obesity in paper 2. However, the higher loss to follow-up of low SES individuals might also affect the social gradients measured in this thesis. Individuals who drop out might be expected to have worse health than those who continue to participate. A study investigating this issue found that in their longitudinal study, drop-out reduced prevalence but not the association between exposures like SES and an outcome (disruptive behavior in school children).[197]

Data on height and weight in the ABIS study is based on self-report except for the measures in Paper 1 on cardiovascular risk factors, where a trained nurse measured height and weight. Self-reported height and weight could introduce reporting bias, e.g., social desirability bias, meaning that parents with obese children report a lower weight than the actual weight. However, the weighted prevalence of overweight and obesity in Paper 2 is similar to a nationally representative study with measures of height and weight by school nurses.[198] Studies on the effect of reporting bias in parental-reported height and weight versus results when a trained nurse measures height and weight have shown that the influence of SES on this bias is limited.[199]

Our indicators and the variables used to measure maternal self-control in Paper 4 are, at this stage, not yet validated measurements but tentative variables based on relevant factors available in our data collection. Although we believe this construct shows good face validity, we acknowledge that it relies on assumptions about the relationship between variables that we cannot confirm within the context of the data of our observational study. Future research is needed to strengthen the evidence for this behavioral construct as a validated measure of self-control.

Future Research

More research is needed to confirm the role of self-control in health inequality. This should include longitudinal studies with multiple measures of self-control and tests of executive functions. The measurement of self-control with a latent variable based on behaviors could be validated in such a study. It would also be interesting to investigate and compare levels of parent and child self-control across countries with different cultures and social and economic policies to see how these differences affect self-control development.

CONCLUSIONS

All humans struggle with self-control, in a tug-of-war between the frontal lobe and our limbic system. The capitalist market economy has clearly understood that producing stimuli of the limbic system is a great way to make money, and many of the leading companies in the world produce products that have the potential to become Limbic traps. The incentive for the companies to restrict the use of their products is low; the effects, including increased anxiety, only lead to higher usage levels and thus improve the companies' profits.

Thus, it falls on the legal government and legal institutions to improve our shared environment through policies and legislation. Children and adolescents are an especially vulnerable group because of their reduced ability to self-control and increased level of reward from the limbic system. Policies must be directed at this fact and implemented to free children and adolescents from the constant need for self-control due to exposure to Limbic traps. Policies should focus on creating a suitable environment for child and adolescent development free from screens, using universal preschools, schools, and after-school activities. To improve children and adolescents' mental and physical health, it may be necessary to prolong schooldays with lessons that reduce anxiety and improve physical health. Art[200], music[201], and physical activity[202] have been shown to reduce anxiety. Increased levels of physical activity could have additional benefits, e.g., daily physical education has been shown to improve school performance in boys.[203] Policies should also increase pressure to refrain from limbic behavior by raising taxes on harmful behaviors such as cigarettes, alcohol, and sugar and by introducing age limits on energy drinks and e-cigarettes. Regulations on commercial advertising for Limbic traps, e.g., fast food, soft drinks, online gambling, social media, and instant loans, would also be beneficial.

A recognition of the mechanisms of self-control in inequality also predicts the upcoming battles that threaten to increase health inequalities. With the mounting evidence of the harmful effect of screen time on child development and obesity and its rewarding properties for parents (pacifying the children), this is the next battlefield for public health. Screen time, social media use, and gaming should be of special concern as there is evidence that they reduce self-control, potentially widening self-control-related inequality in the coming generations. Given the differences in self-control described in this thesis, radical measures might be necessary, such as prohibiting children's use of digital media using child-specific personal logins on online gaming and social media platforms with age limitations, like the age restriction implemented for other harmful behaviors like cigarette and alcohol consumption.

REFERENCES

1. Martin RM, Kramer MS, Patel R, et al. Effects of Promoting Long-term, Exclusive Breastfeeding on Adolescent Adiposity, Blood Pressure, and Growth Trajectories: A Secondary Analysis of a Randomized Clinical Trial. *JAMA Pediatrics* 2017; 171(7): e170698.
2. Kramer MS, Martin RM, Bogdanovich N, Vilchuk K, Dahhou M, Oken E. Is restricted fetal growth associated with later adiposity? Observational analysis of a randomized trial. *Am J Clin Nutr* 2014; 100(1): 176-81.
3. Kommisionen För Jämlik Hälsa. Det handlar om jämlik hälsa. Statens offentliga utredningar 2016:55. Stockholm, 2016.
4. Calixto OJ, Anaya JM. Socioeconomic status. The relationship with health and autoimmune diseases. *Autoimmun Rev* 2014; 13(6): 641-54.
5. Shavers VL. Measurement of socioeconomic status in health disparities research. *J Natl Med Assoc* 2007; 99(9): 1013-23.
6. Pearce A, Dundas R, Whitehead M, Taylor-Robinson D. Pathways to inequalities in child health. *Arch Dis Child* 2019; 104(10): 998-1003.
7. Rougeaux E, Hope S, Law C, Pearce A. Have health inequalities changed during childhood in the New Labour generation? Findings from the UK Millennium Cohort Study. *BMJ Open* 2017; 7(1): e012868.
8. Shackleton N, Hale D, Viner RM. Trends and socioeconomic disparities in preadolescent's health in the UK: evidence from two birth cohorts 32 years apart. *J Epidemiol Community Health* 2016; 70(2): 140-6.
9. 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.
10. OECD. Key indicators on the distribution of household disposable income and poverty, 2007, 2015, and 2016 or most recent year. http://www.oecd.org/social/soc/IDD-Key-Indicators.xlsx; 2018.
11. Pickett KE, Wilkinson RG. Child wellbeing and income inequality in rich societies: ecological cross sectional study. *Bmj* 2007; 335(7629): 1080.
12. Wilkinson RG, Pickett KE. Income inequality and socioeconomic gradients in mortality. *Am J Public Health* 2008; 98(4): 699-704.
13. Piketty T. About "Capital in the Twenty-First Century". *American Economic Review* 2015; 105(5): 48-53.
14. CSDH. Closing the gap in a generation: health equity through action on the social determinants of health. Final Report of the Commission

on Social Determinants of Health. Geneva: World Health Organization; 2008.
15. Townsend P, Davidson N, Whitehead M. The Black Report and the Health Divide. Harmondsworth: Penguin; 1986.
16. Smith GD, Bartley M, Blane D. The Black report on socioeconomic inequalities in health 10 years on. *Bmj* 1990; 301(6748): 373-7.
17. Macintyre S. The black report and beyond what are the issues? *Social Science & Medicine* 1997; 44(6): 723-45.
18. Mackenbach JP. The persistence of health inequalities in modern welfare states: The explanation of a paradox. *Social Science & Medicine* 2012; 75(4): 761-9.
19. Link BG, Phelan J. Social conditions as fundamental causes of disease. *J Health Soc Behav* 1995; Spec No: 80-94.
20. Wadsworth ME. Health inequalities in the life course perspective. *Soc Sci Med* 1997; 44(6): 859-69.
21. Barker DJ. The developmental origins of insulin resistance. *Horm Res* 2005; 64 Suppl 3: 2-7.
22. Bambra C, Netuveli G, Eikemo TA. Welfare state regime life courses: the development of western European welfare state regimes and age-related patterns of educational inequalities in self-reported health. *Int J Health Serv* 2010; 40(3): 399-420.
23. Mackenbach JP. New trends in health inequalities research: now it's personal. *The Lancet* 2010; 376(9744): 854-5.
24. Chapman BP, Fiscella K, Kawachi I, Duberstein PR. Personality, socioeconomic status, and all-cause mortality in the United States. *Am J Epidemiol* 2010; 171(1): 83-92.
25. Batty GD, Gale CR, Tynelius P, Deary IJ, Rasmussen F. IQ in early adulthood, socioeconomic position, and unintentional injury mortality by middle age: a cohort study of more than 1 million Swedish men. *Am J Epidemiol* 2009; 169(5): 606-15.
26. Smith GD, Blane D, Bartley M. Explanations for socio-economic differentials in mortality: Evidence from Britain and elsewhere. *European Journal of Public Health* 1994; 4(2): 131-44.
27. Kaplan GA, Pamuk ER, Lynch JW, Cohen RD, Balfour JL. Inequality in income and mortality in the United States: analysis of mortality and potential pathways. *Bmj* 1996; 312(7037): 999-1003.
28. Lynch JW, Smith GD, Kaplan GA, House JS. Income inequality and mortality: importance to health of individual income, psychosocial environment, or material conditions. *BMJ* 2000; 320(7243):1200-4.
29. Marmot M. Status Syndrome. London: Bloomsbury; 2004
30. Wilkinson RG, Pickett K. The Spirit Level: Why More Equal Societies Almost Always Do Better. Harlow: Penguin Books; 2010.
31. Rogers EM. Diffusion of Innovations. New York: Free Press; 1962.
32. Victora CG, Vaughan JP, Barros FC, Silva AC, Tomasi E. Explaining trends in inequities: evidence from Brazilian child health studies. *The Lancet* 2000; 356(9235): 1093-8.

33. Lareau A, Weininger EB. Cultural capital in educational research: A critical assessment. *Theory and Society* 2003; 32(5): 567-606.
34. Abel T. Cultural capital and social inequality in health. *J Epidemiol Community Health* 2008; 62(7): e13.
35. Plato. The Republic (c. 375 B.C.E.). Cambridge: Cambridge University Press; 2000.
36. Aristotle. De Anima (c 350 B.C.E). https://classics.mit.edu/Aristotle/soul.html
37. Aristotle. Nicomachean Ethics. 2 ed. Cambridge: Cambridge University Press; 2014.
38. The Editors of Encyclopaedia. Seven deadly sins. Encyclopedia Britannica, 2023.
39. Freud S. The Ego and the Id. London: The Hogarth Press Ltd; 1949.
40. Salsman N, Linehan MM. Dialectical-behavioral therapy for borderline personality disorder. *Primary Psychiatry* 2006; 13(5): 51.
41. Crain W. Theories of Development: concepts and applications. New Jersey: Prentice-Hall; 2000.
42. Gottfredson MR, Hirschi T. A general theory of crime: Redwood City: Stanford University Press; 1990.
43. Sapolsky RM. Behave: The Biology of Humans at Our Best and Worst. Harlow: Penguin Press; 2017.
44. Mischel W, Shoda Y, Rodriguez MI. Delay of gratification in children. *Science* 1989; 244(4907): 933-8.
45. Schlam TR, Wilson NL, Shoda Y, Mischel W, Ayduk O. Preschoolers' Delay of Gratification Predicts their Body Mass 30 Years Later. *The Journal of pediatrics* 2013; 162(1): 90-3.
46. Metcalfe J, Mischel W. A hot/cool-system analysis of delay of gratification: dynamics of willpower. *Psychol Rev* 1999; 106(1): 3-19.
47. Baumeister RF, Bratslavsky E, Muraven M, Tice DM. Ego depletion: is the active self a limited resource? *J Pers Soc Psychol* 1998; 74(5): 1252-65.
48. Hofmann W, Vohs KD, Baumeister RF. What People Desire, Feel Conflicted About, and Try to Resist in Everyday Life. *Psychological Science* 2012; 23(6): 582-8.
49. Casey BJ. Beyond simple models of self-control to circuit-based accounts of adolescent behavior. *Annu Rev Psychol* 2015; 66: 295-319.
50. Kotabe HP, Hofmann W. On Integrating the Components of Self-Control. *Perspect Psychol Sci* 2015; 10(5): 618-38.
51. Baumeister RF. Self-regulation, ego depletion, and inhibition. *Neuropsychologia* 2014; 65: 313-9.
52. Arnsten AFT. Stress signalling pathways that impair prefrontal cortex structure and function. *Nature Reviews Neuroscience* 2009; 10(6): 410-22.
53. Edelson M, Sharot T, Dolan RJ, Dudai Y. Following the crowd: brain substrates of long-term memory conformity. *Science* 2011; 333(6038): 108-11.

54. Lavagnino L, Mwangi B, Bauer IE, et al. Reduced Inhibitory Control Mediates the Relationship Between Cortical Thickness in the Right Superior Frontal Gyrus and Body Mass Index. *Neuropsychopharmacology* 2016; 41(9): 2275-82.
55. Farah MJ. The Neuroscience of Socioeconomic Status: Correlates, Causes, and Consequences. *Neuron* 2017; 96(1): 56-71.
56. Lawson GM, Duda JT, Avants BB, Wu J, Farah MJ. Associations between children's socioeconomic status and prefrontal cortical thickness. *Dev Sci* 2013; 16(5): 641-52.
57. Touroutoglou A, Andreano J, Dickerson BC, Barrett LF. The tenacious brain: How the anterior mid-cingulate contributes to achieving goals. *Cortex* 2020; 123: 12-29.
58. Harding IH, Andrews ZB, Mata F, et al. Brain substrates of unhealthy versus healthy food choices: influence of homeostatic status and body mass index. *Int J Obes (Lond)* 2018; 42(3): 448-54.
59. McCaffery JM, Haley AP, Sweet LH, et al. Differential functional magnetic resonance imaging response to food pictures in successful weight-loss maintainers relative to normal-weight and obese controls. *Am J Clin Nutr* 2009; 90(4): 928-34.
60. Duckworth AL, Taxer JL, Eskreis-Winkler L, Galla BM, Gross JJ. Self-Control and Academic Achievement. *Annu Rev Psychol* 2019; 70: 373-99.
61. Burt CH. Self-Control and Crime: Beyond Gottfredson and Hirschi's Theory. *Annu Rev Criminol* 2020; 3(1): 43-73.
62. Pearl J, Mackenzie D. The Book of Why. Harlow: Penguine Books; 2019.
63. Abdulatif M, Mukhtar A, Obayah G. Pitfalls in reporting sample size calculation in randomized controlled trials published in leading anaesthesia journals: a systematic review. *British Journal of Anaesthesia* 2015; 115(5): 699-707.
64. Denis D, Legerski J. Causal modeling and the origins of path analysis. *Theory & Science* 2006; 7(1): 2-10.
65. King DB, Montañez-Ramírez LM, Wertheimer M. Barbara Stoddard Burks: Pioneer behavioral geneticist and humanitarian. In: Kimble GA, Boneau CA, Wertheimer M, eds. Portraits of pioneers in psychology, Vol 2. Washington, DC: American Psychological Association; 1996: 213-25.
66. Burks BS. On the Relative Contributions of Nature and Nurture to Average Group Differences in Intelligence. *Proceedings of the National Academy of Sciences* 1938; 24(7): 276-82.
67. Duvander A-Z. Family policy in Sweden: An overview. *Social insurance report* 2008; 15: 1-18.
68. Eriksson H. Taking Turns or Halving It All: Care Trajectories of Dual-Caring Couples. *Eur J Popul* 2019; 35(1): 191-219.
69. Wettergren B, Blennow M, Hjern A, Soder O, Ludvigsson JF. Child Health Systems in Sweden. *The Journal of pediatrics* 2016; 177S: S187-S202.

70. Helmchen LA, Henderson RM. Changes in the distribution of body mass index of white US men, 1890-2000. *Ann Hum Biol* 2004; 31(2): 174-81.
71. Buoncristiano M, Spinelli A, Williams J, et al. Childhood overweight and obesity in Europe: Changes from 2007 to 2017. *Obes Rev* 2021; 22 Suppl 6: e13226.
72. Collaboration NCDRF. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet* 2017; 390(10113): 2627-42.
73. Stierman B, Ogden CL, Yanovski JA, Martin CB, Sarafrazi N, Hales CM. Changes in adiposity among children and adolescents in the United States, 1999-2006 to 2011-2018. *Am J Clin Nutr* 2021; 114(4): 1495-504.
74. Hill JO, Wyatt HR, Peters JC. Energy balance and obesity. *Circulation* 2012; 126(1): 126-32.
75. Johnson RJ, Lanaspa MA, Sanchez-Lozada LG, et al. Fat storage syndrome in Pacific peoples: a combination of environment and genetics? *Pac Health Dialog* 2014; 20(1): 11-6.
76. Johnson RJ, Sánchez-Lozada LG, Andrews P, Lanaspa MA. Perspective: A Historical and Scientific Perspective of Sugar and Its Relation with obesity and Diabetes. *Adv Nutr* 2017; 8(3): 412-22.
77. Toch-Marquardt M, Menvielle G, Eikemo TA, et al. Occupational class inequalities in all-cause and cause-specific mortality among middle-aged men in 14 European populations during the early 2000s. *PLoS One* 2014; 9(9): e108072.
78. Puolakka E, Pahkala K, Laitinen TT, et al. Childhood Socioeconomic Status and Arterial Stiffness in Adulthood: The Cardiovascular Risk in Young Finns Study. *Hypertension* 2017; 70(4): 729-35.
79. Rashid S, Watanabe T, Sakaue T, Lewis GF. Mechanisms of HDL lowering in insulin resistant, hypertriglyceridemic states: the combined effect of HDL triglyceride enrichment and elevated hepatic lipase activity. *Clin Biochem* 2003; 36(6): 421-9.
80. Farrer S. Beyond Statins: Emerging Evidence for HDL-Increasing Therapies and Diet in Treating Cardiovascular Disease. *Adv Prev Med* 2018; 2018: 6024747.
81. Lincoff AM, Nicholls SJ, Riesmeyer JS, et al. Evacetrapib and Cardiovascular Outcomes in High-Risk Vascular Disease. *N Engl J Med* 2017; 376(20): 1933-42.
82. Schoeneck M, Iggman D. The effects of foods on LDL cholesterol levels: A systematic review of the accumulated evidence from systematic reviews and meta-analyses of randomized controlled trials. *Nutr Metab Cardiovasc Dis* 2021; 31(5): 1325-38.
83. Blaton V. How is the Metabolic Syndrome Related to the Dyslipidemia? *Ejifcc* 2007; 18(1): 15-22.

84. Borén J, Chapman MJ, Krauss RM, et al. Low-density lipoproteins cause atherosclerotic cardiovascular disease: pathophysiological, genetic, and therapeutic insights: a consensus statement from the European Atherosclerosis Society Consensus Panel. *Eur Heart J* 2020; 41(24): 2313-30.
85. Grillo A, Salvi L, Coruzzi P, Salvi P, Parati G. Sodium Intake and Hypertension. *Nutrients* 2019; 11(9): 1970.
86. Hagman E, Danielsson P, Elimam A, Marcus C. The effect of weight loss and weight gain on blood pressure in children and adolescents with obesity. *International Journal of Obesity* 2019; 43(10): 1988-94.
87. Reaven GM. Banting lecture 1988. Role of insulin resistance in human disease. *Diabetes* 1988; 37(12): 1595-607.
88. Ahrens W, Moreno LA, Mårild S, et al. Metabolic syndrome in young children: definitions and results of the IDEFICS study. *Int J Obes (Lond)* 2014; 38 Suppl 2: S4-14.
89. Krssak M, Falk Petersen K, Dresner A, et al. Intramyocellular lipid concentrations are correlated with insulin sensitivity in humans: a 1H NMR spectroscopy study. *Diabetologia* 1999; 42(1): 113-6.
90. Petersen KF, Dufour S, Morino K, Yoo PS, Cline GW, Shulman GI. Reversal of muscle insulin resistance by weight reduction in young, lean, insulin-resistant offspring of parents with type 2 diabetes. *Proc Natl Acad Sci U S A* 2012; 109(21): 8236-40.
91. Giwa AM, Ahmed R, Omidian Z, et al. Current understandings of the pathogenesis of type 1 diabetes: Genetics to environment. *World J Diabetes* 2020; 11(1): 13-25.
92. Patterson CC, Gyurus E, Rosenbauer J, et al. Trends in childhood type 1 diabetes incidence in Europe during 1989-2008: evidence of non-uniformity over time in rates of increase. *Diabetologia* 2012; 55(8): 2142-7.
93. Group DP. Incidence and trends of childhood Type 1 diabetes worldwide 1990-1999. *Diabet Med* 2006; 23(8): 857-66.
94. Noble JA, Erlich HA. Genetics of type 1 diabetes. *Cold Spring Harb Perspect Med* 2012; 2(1): a007732.
95. Rewers M, Ludvigsson J. Environmental risk factors for type 1 diabetes. *Lancet* 2016; 387(10035): 2340-8.
96. Räisänen L, Lommi S, Engberg E, Kolho KL, Viljakainen H. Central obesity in school-aged children increases the likelihood of developing paediatric autoimmune diseases. *Pediatr Obes* 2022; 17(3): e12857.
97. Fourlanos S, Harrison LC, Colman PG. The accelerator hypothesis and increasing incidence of type 1 diabetes. *Curr Opin Endocrinol Diabetes Obes* 2008; 15(4): 321-5.
98. Lockshin MD. Sex differences in autoimmune disease. *Lupus* 2006; 15(11): 753-6.
99. Bélteky M, Milletich PL, Ahrens AP, Triplett EW, Ludvigsson J. Infant gut microbiome composition correlated with type 1 diabetes

acquisition in the general population: the ABIS study. *Diabetologia* 2023; 66(6): 1116-28.
100. West J, Fleming KM, Tata LJ, Card TR, Crooks CJ. Incidence and prevalence of celiac disease and dermatitis herpetiformis in the UK over two decades: population-based study. *Am J Gastroenterol* 2014; 109(5): 757-68.
101. Cosnes J, Gower-Rousseau C, Seksik P, Cortot A. Epidemiology and natural history of inflammatory bowel diseases. *Gastroenterology* 2011; 140(6): 1785-94.
102. McLeod DS, Cooper DS. The incidence and prevalence of thyroid autoimmunity. *Endocrine* 2012; 42(2): 252-65.
103. Manners PJ, Bower C. Worldwide prevalence of juvenile arthritis why does it vary so much? J Rheumatol 2002; 29(7):1520-30.
104. Lionetti E, Catassi C. The Role of Environmental Factors in the Development of Celiac Disease: What Is New? *Diseases* 2015; 3(4): 282-93.
105. Molodecky NA, Kaplan GG. Environmental risk factors for inflammatory bowel disease. *Gastroenterol Hepatol (N Y)* 2010; 6(5): 339-46.
106. World Health Organization. Global Health Estimates 2020: Deaths by Cause, Age, Sex, by Country and by Region, 2000-2019. 2020. https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death.
107. Statistics Sweden. Population in the country, counties and municipalities and population change. www.scb.se
108. Sepa A, Frodi A, Ludvigsson J. Psychosocial correlates of parenting stress, lack of support and lack of confidence/security. *Scandinavian Journal of Psychology* 2004; 45(2): 169-79.
109. Statistics Sweden. Income and tax statistics. www.scb.se
110. Faresjö T, Rahmqvist M. Educational level is a crucial factor for good perceived health in the local community. *Scandinavian Journal of Public Health* 2010; 38(6): 605-10.
111. Wennerholm C, Grip B, Johansson A, Nilsson H, Honkasalo ML, Faresjö T. Cardiovascular disease occurrence in two close but different social environments. *Int J Health Geogr* 2011; 10: 5.
112. Faresjö T, Ludvigsson J, Wennerholm C, Faresjö Å, Nilsson H. [Public health differences between »the twin cities« persist]. *Lakartidningen* 2019; 116.
113. Ludvigsson JF, Andersson E, Ekbom A, et al. External review and validation of the Swedish national inpatient register. *BMC Public Health* 2011; 11: 450.
114. Digitale JC, Martin JN, Glymour MM. Tutorial on directed acyclic graphs. *J Clin Epidemiol* 2022; 142: 264-7.
115. Field A. Discovering statistics using IBM SPSS Statistics. 4th ed. London: SAGE Publications Ltd. 2013.
116. Szumilas M. Explaining odds ratios. *J Can Acad Child Adolesc Psychiatry* 2010; 19(3): 227-9.

117. Hajian-Tilaki K. Receiver Operating Characteristic (ROC) Curve Analysis for Medical Diagnostic Test Evaluation. *Caspian J Intern Med* 2013; 4(2): 627-35.
118. Zou GY, Donner A. Extension of the modified Poisson regression model to prospective studies with correlated binary data. *Stat Methods Med Res* 2013; 22(6): 661-70.
119. Cummings P. The relative merits of risk ratios and odds ratios. *Arch Pediatr Adolesc Med* 2009; 163(5): 438-45.
120. Sterne JA, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *Bmj* 2009; 338: b2393.
121. Seaman SR, White IR. Review of inverse probability weighting for dealing with missing data. *Stat Methods Med Res* 2013; 22(3): 278-95.
122. Moreno-Betancur M, Latouche A, Menvielle G, Kunst AE, Rey G. Relative Index of Inequality and Slope Index of Inequality: A Structured Regression Framework for Estimation. *Epidemiology* 2015; 26(4): 518-27.
123. Health Equity Assessment Toolkit (HEAT) 2.0 ed. Geneva: World Health Organization; 2017. p. Software for exploring and comparing health inequalities in countries. Built-in database edition.
124. Higgins JPT TJ, Chandler J, Cumpston M, Li T, Page MJ, Welch VA. Cochrane Handbook for Systematic Reviews of Interventions Version 6.4 ed: Cochrane; 2023.
125. Chang Y, Phillips MR, Guymer RH, et al. The 5 min meta-analysis: understanding how to read and interpret a forest plot. *Eye* 2022; 36(4): 673-5.
126. Bollen KA, Hoyle RH. Handbook of structual Equation modeling Latent Variables in Structual Equation Modeling 2nd ed. New York: The Guilford Press; 2023.
127. Houweling TA, Kunst AE, Huisman M, Mackenbach JP. Using relative and absolute measures for monitoring health inequalities: experiences from cross-national analyses on maternal and child health. *Int J Equity Health* 2007; 6: 15.
128. White PA, Faresjö T, Jones MP, Ludvigsson J. Low maternal education increases the risk of Type 1 Diabetes, but not other autoimmune diseases: a mediating role of childhood BMI and exposure to serious life events. *Sci Rep* 2023; 13(1): 6166.
129. Andersson White P, Ludvigsson J, Jones MP, Faresjo T. Inequalities in cardiovascular risks among Swedish adolescents (ABIS): a prospective cohort study. *BMJ Open* 2020; 10(2): e030613.
130. Pantoja-Torres B, Toro-Huamanchumo CJ, Urrunaga-Pastor D, et al. High triglycerides to HDL-cholesterol ratio is associated with insulin resistance in normal-weight healthy adults. *Diabetes Metab Syndr* 2019; 13(1): 382-8.
131. Yaribeygi H, Maleki M, Sathyapalan T, Jamialahmadi T, Sahebkar A. Pathophysiology of Physical Inactivity-Dependent Insulin

Resistance: A Theoretical Mechanistic Review Emphasizing Clinical Evidence. *J Diabetes Res* 2021; 2021: 7796727.
132. Softic S, Stanhope KL, Boucher J, et al. Fructose and hepatic insulin resistance. *Crit Rev Clin Lab Sci* 2020; 57(5): 308-22.
133. Betts P, Mulligan J, Ward P, Smith B, Wilkin T. Increasing body weight predicts the earlier onset of insulin-dependant diabetes in childhood: testing the 'accelerator hypothesis' (2). *Diabet Med* 2005; 22(2): 144-51.
134. Kämpe O, Andersson A, Björk E, Hallberg A, Karlsson FA. High-glucose stimulation of 64,000-Mr islet cell autoantigen expression. *Diabetes* 1989; 38(10): 1326-8.
135. Goldfeld S, Francis KL, O'Connor E, et al. Comparative inequalities in child dental caries across four countries: Examination of international birth cohorts and implications for oral health policy. *PLoS One* 2022; 17(8): e0268899.
136. Bach JF. The hygiene hypothesis in autoimmunity: the role of pathogens and commensals. *Nat Rev Immunol* 2018; 18(2): 105-20.
137. Vangoitsenhoven R, Cresci GAM. Role of Microbiome and Antibiotics in Autoimmune Diseases. *Nutrition in Clinical Practice* 2020; 35(3): 406-16.
138. Hold GL. Western lifestyle: a 'master' manipulator of the intestinal microbiota? *Gut* 2014; 63(1): 5-6.
139. Kindgren E, Ludvigsson J. Infections and antibiotics during fetal life and childhood and their relationship to juvenile idiopathic arthritis: a prospective cohort study. *Pediatric Rheumatology* 2021; 19(1): 145.
140. Kindgren E. Early Life Environmental Risk Factors and Gut Microbiota in Juvenile Idiopathic Arthritis : - More than a gut feeling [Doctoral thesis, comprehensive summary]. Linköping: Linköping University Electronic Press; 2022.
141. Sigvardsson I, Størdal K, Östensson M, Guo A, Ludvigsson J, Mårild K. Childhood Socioeconomic Characteristics and Risk of Inflammatory Bowel Disease: A Scandinavian Birth Cohort Study. *Inflammatory Bowel Diseases* 2023.
142. Sellström E, Arnoldsson G, Bremberg S, Hjern A. The neighbourhood they live in: does it matter to women's smoking habits during pregnancy? *Health Place* 2008; 14(2): 155-66.
143. Morgen CS, Andersen PK, Mortensen LH, 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; 7(1): e011781.
144. Lien N, Kumar BN, Holmboe-Ottesen G, Klepp KI, Wandel M. Assessing social differences in Overweight among 15- to 16-year-old ethnic Norwegians from Oslo by register data and adolescent self-reported measures of socio-economic status. *Int J Obes (Lond)* 2007; 31(1): 30-8.

145. Bremberg S. Does an increase of low income families affect child health inequalities? A Swedish case study. *J Epidemiol Community Health* 2003; 57(8): 584-8.
146. Willems YE, Boesen N, Li J, Finkenauer C, Bartels M. The heritability of self-control: A meta-analysis. *Neurosci Biobehav Rev* 2019; 100: 324-34.
147. Faraone SV, Larsson H. Genetics of attention deficit hyperactivity disorder. *Mol Psychiatry* 2019; 24(4): 562-75.
148. Friese M, Frankenbach J, Job V, Loschelder DD. Does Self-Control Training Improve Self-Control? A Meta-Analysis. *Perspectives on Psychological Science* 2017; 12(6): 1077-99.
149. Takacs ZK, Kassai R. The efficacy of different interventions to foster children's executive function skills: A series of meta-analyses. *Psychol Bull* 2019; 145(7): 653-97.
150. Cranwell J, Benford S, Houghton RJ, Golembewski M, Fischer JE, Hagger MS. Increasing self-regulatory energy using an Internet-based training application delivered by smartphone technology. *Cyberpsychol Behav Soc Netw* 2014; 17(3): 181-6.
151. Ljungdahl S, Bremberg SG. Might extended education decrease inequalities in health?-a meta-analysis. *Eur J Public Health* 2015; 25(4): 587-92.
152. Maski KP, Kothare SV. Sleep deprivation and neurobehavioral functioning in children. *International Journal of Psychophysiology* 2013; 89(2): 259-64.
153. King KM, McLaughlin KA, Silk J, Monahan KC. Peer effects on self-regulation in adolescence depend on the nature and quality of the peer interaction. *Dev Psychopathol* 2018; 30(4): 1389-401.
154. Christakis NA, Fowler JH. The spread of obesity in a large social network over 32 years. *N Engl J Med* 2007; 357(4): 370-9.
155. Ludwig J, Sanbonmatsu L, Gennetian L, et al. Neighborhoods, obesity, and diabetes--a randomized social experiment. *N Engl J Med* 2011; 365(16): 1509-19.
156. Tan CY, Gao L, Hong X, Song Q. Socioeconomic status and students' science self-efficacy. *British Educational Research Journal* 2023; 49(4): 782-832.
157. Bandura A. Self-efficacy mechanism in human agency. *American psychologist* 1982; 37(2): 122.
158. Kristenson M, Eriksen HR, Sluiter JK, Starke D, Ursin H. Psychobiological mechanisms of socioeconomic differences in health. *Social Science & Medicine* 2004; 58(8): 1511-22.
159. Sorrenti L, Filippello P, Orecchio S, Buzzai C. Learned helplessness and learning goals: role played in school refusal. a study on italian students. *Mediterranean Journal of Clinical Psychology* 2016; 4(2).
160. Moffitt TE, Arseneault L, Belsky DW, et al. A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences* 2011; 108: 2693-8.

161. Jacques A, Chaaya N, Beecher K, Ali SA, Belmer A, Bartlett S. The impact of sugar consumption on stress driven, emotional and addictive behaviors. *Neurosci Biobehav Rev* 2019; 103: 178-99.
162. Edwin Thanarajah S, DiFeliceantonio AG, Albus K, et al. Habitual daily intake of a sweet and fatty snack modulates reward processing in humans. *Cell Metab* 2023; 35(4): 571-84.e6.
163. Shapiro A, Mu W, Roncal C, Cheng KY, Johnson RJ, Scarpace PJ. Fructose-induced leptin resistance exacerbates weight gain in response to subsequent high-fat feeding. *Am J Physiol Regul Integr Comp Physiol* 2008; 295(5): R1370-5.
164. Shapiro A, Tümer N, Gao Y, Cheng KY, Scarpace PJ. Prevention and reversal of diet-induced leptin resistance with a sugar-free diet despite high fat content. *Br J Nutr* 2011; 106(3): 390-7.
165. Mendoza-Herrera K, Florio AA, Moore M, et al. The Leptin System and Diet: A Mini Review of the Current Evidence. *Front Endocrinol (Lausanne)* 2021; 12: 749050.
166. Garvey WT. Is obesity or Adiposity-Based Chronic Disease Curable: The Set Point Theory, the Environment, and Second-Generation Medications. *Endocr Pract* 2022; 28(2): 214-22.
167. Maharjan S, Amjad Z, Abaza A, et al. Executive Dysfunction in Patients With Alcohol Use Disorder: A Systematic Review. *Cureus* 2022; 14(9): e29207.
168. Volkow ND, Fowler JS, Wang GJ, Swanson JM. Dopamine in drug abuse and addiction: results from imaging studies and treatment implications. *Molecular Psychiatry* 2004; 9(6): 557-69.
169. Braghieri L, Levy Re, Makarin A. Social Media and Mental Health. *American Economic Review* 2022; 112(11): 3660-93.
170. Hunt MG, Marx R, Lipson C, Young J. No More FOMO: Limiting Social Media Decreases Loneliness and Depression. *Journal of Social and Clinical Psychology* 2018; 37(10): 751-68.
171. Maza MT, Fox KA, Kwon S-J, et al. Association of Habitual Checking Behaviors on Social Media With Longitudinal Functional Brain Development. *JAMA Pediatrics* 2023; 177(2): 160-7.
172. Miyawaki A, Evans CEL, Lucas PJ, Kobayashi Y. Relationships between social spending and childhood obesity in OECD countries: an ecological study. *BMJ open* 2021; 11(2): e044205-e.
173. Parnham JC, Chang K, Millett C, et al. The Impact of the Universal Infant Free School Meal Policy on Dietary Quality in English and Scottish Primary School Children: Evaluation of a Natural Experiment. *Nutrients* 2022; 14(8).
174. Wilkinson RG. Socioeconomic determinants of health. Health inequalities: relative or absolute material standards? *Bmj* 1997; 314(7080): 591-5.
175. Durante F, Fiske ST, Kervyn N, et al. Nations' income inequality predicts ambivalence in stereotype content: how societies mind the gap. *Br J Soc Psychol* 2013; 52(4): 726-46.

176. Jamal S. Quitting Smoking Among Adults — United States, 2000–2015: U.S. Department of Health and Human Services / Centers for Disease Control and Prevention, 2017.
177. 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; 73(12): 1087-93.
178. Moffitt TE, Arseneault L, Belsky D, et al. A gradient of childhood self-control predicts health, wealth, and public safety. *Proc Natl Acad Sci U S A* 2011; 108(7): 2693-8.
179. Lembke A. Dopamine nation: finding balance in the age of indulgence. New York: Penguin Publishing Group; 2021.
180. Kleinjan M, van den Eijnden RJ, Engels RC. Adolescents' rationalizations to continue smoking: the role of disengagement beliefs and nicotine dependence in smoking cessation. *Addict Behav* 2009; 34(5): 440-5.
181. Dishion TJ, Tipsord JM. Peer contagion in child and adolescent social and emotional development. *Annu Rev Psychol* 2011; 62: 189-214.
182. Zhang K, Li P, Zhao Y, Griffiths MD, Wang J, Zhang MX. Effect of Social Media Addiction on Executive Functioning Among Young Adults: The Mediating Roles of Emotional Disturbance and Sleep Quality. *Psychol Res Behav Manag* 2023; 16: 1911-20.
183. Law EC, Han MX, Lai Z, et al. Associations Between Infant Screen Use, Electroencephalography Markers, and Cognitive Outcomes. *JAMA Pediatrics* 2023; 177(3): 311-8.
184. Campbell F, Conti G, Heckman JJ, et al. Early childhood investments substantially boost adult health. *Science* 2014; 343(6178): 1478-85.
185. Leventhal T, Brooks-Gunn J. Moving to opportunity: an experimental study of neighborhood effects on mental health. *Am J Public Health* 2003; 93(9): 1576-82.
186. Jangmo A, Stålhandske A, Chang Z, et al. Attention-Deficit/Hyperactivity Disorder, School Performance, and Effect of Medication. *J Am Acad Child Adolesc Psychiatry* 2019; 58(4): 423-32.
187. Lichtenstein P, Halldner L, Zetterqvist J, et al. Medication for attention deficit-hyperactivity disorder and criminality. *N Engl J Med* 2012; 367(21): 2006-14.
188. Chang Z, Lichtenstein P, Halldner L, et al. Stimulant ADHD medication and risk for substance abuse. *J Child Psychol Psychiatry* 2014; 55(8): 878-85.
189. Weghuber D, Barrett T, Barrientos-Pérez M, et al. Once-Weekly Semaglutide in Adolescents with obesity. *New England Journal of Medicine* 2022; 387(24): 2245-57.
190. VanderWeele TJ. Mediation Analysis: A Practitioner's Guide. *Annu Rev Public Health* 2016; 37: 17-32.

191. Powell AW, Siegel Z, Kist C, Mays WA, Kharofa R, Siegel R. Pediatric youth who have obesity have high rates of adult criminal behavior and low rates of homeownership. *SAGE Open Med* 2022; 10: 20503121221127884.
192. Homaie Rad E, Khodadady-Hasankiadeh N, Kouchakinejad-Eramsadati L, et al. The relationship between weight indices and injuries and mortalities caused by the motor vehicle accidents: a systematic review and meta-analysis. *J Inj Violence Res* 2020; 12(1): 85-101.
193. Reneé P-E, Claire C, Maria AQ. Association between breastfeeding duration and educational achievement in England: results from the Millennium Cohort Study. *Archives of Disease in Childhood* 2023; 108(8): 665.
194. Social Media and Youth Mental Health: The U.S. Surgeon General's Advisory, 2023.
195. Althubaiti A. Information bias in health research: definition, pitfalls, and adjustment methods. *J Multidiscip Healthc* 2016; 9: 211-7.
196. Sjöberg A, Moraeus L, Yngve A, Poortvliet E, Al-Ansari U, Lissner L. Overweight and obesity in a representative sample of schoolchildren – exploring the urban–rural gradient in Sweden. *Obes Rev* 2011; 12(5): 305-14.
197. Wolke D, Waylen A, Samara M, et al. Selective drop-out in longitudinal studies and non-biased prediction of behaviour disorders. *Br J Psychiatry* 2009; 195(3): 249-56.
198. Sjöberg A, Moraeus L, Yngve A, Poortvliet E, Al-Ansari U, Lissner L. Overweight and obesity in a representative sample of schoolchildren - exploring the urban-rural gradient in Sweden. *Obes Rev* 2011; 12(5): 305-14.
199. Brettschneider AK, Ellert U, Schaffrath Rosario A. Comparison of BMI derived from parent-reported height and weight with measured values: results from the German KiGGS study. *Int J Environ Res Public Health* 2012; 9(2): 632-47.
200. Sandmire DA, Rankin NE, Gorham SR, et al. Psychological and autonomic effects of art making in college-aged students. *Anxiety, Stress, & Coping* 2016; 29(5): 561-9.
201. de Witte M, Pinho AdS, Stams G-J, Moonen X, Bos AER, van Hooren S. Music therapy for stress reduction: a systematic review and meta-analysis. *Health Psychology Review* 2022; 16(1): 134-59.
202. Carter T, Pascoe M, Bastounis A, Morres ID, Callaghan P, Parker AG. The effect of physical activity on anxiety in children and young people: a systematic review and meta-analysis. *Journal of Affective Disorders* 2021; 285: 10-21.
203. Karlsson M, Fritz J, Cöster M, Karlsson C, Rosengren B. Daglig fysisk aktivitet på schemat: bättre skolresultat hos pojkarna-Men för flickorna var det ingen skillnad–Bunkefloprojektet följde grundskoleelever under nio år. *Läkartidningen* 2019; 116.

Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

https://doi.org/10.3384/9789180754170

FACULTY OF MEDICINE AND HEALTH SCIENCES

Linköping University Medical Dissertation No. 1885, 2024
Department of Health, Medicine and Caring Sciences

Linköping University
SE-581 83 Linköping, Sweden

www.liu.se

LINKÖPING UNIVERSITY