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The influence of socioeconomic status on prevalence of overweight and obesity in adolescents and the importance of resilience

The YoungHUNT4 Study (2017-2019).

Master's thesis in Clinical Health Science: Obesity and Health

Supervisor: Steinar Krokstad

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Abstract

Title: The influence of socioeconomic status on prevalence of overweight and obesity in adolescents and the importance of resilience: The YoungHUNT4 Study (2017-2019).

Background: The increasing prevalence of overweight and obesity have become one of the greatest public health challenges over the last decades, resulting in several severe physical and psychological health consequences at both individual and societal levels. Children and adolescents from lower socioeconomic status suffer the highest risks of overweight and obesity from social determinants in health. Social network is also of great importance during the years of adolescence and may be beneficial to investigate as a possible protective factor, to increase the chances of a better outcome in health despite the presence of socioeconomic risk factors. The aim of this study is to examine the associations between BMI and perceived financial situation in the family, and to investigate if this association could be moderated by the level of resilience in adolescents.

Method: The study is a cross sectional study based on epidemiological data from YoungHUNT4 (2017-2019), including 8066 students, apprentices, and school dropouts between 13-19 years old. BMI was calculated from anthropometric measures or self-reported height and weight, and perceived financial situation in the family and resilience in adolescents were obtained through questionnaires. Multivariable linear regression analysis was first used to investigate the relationship between BMI in adolescents and perceived financial situation, and resilience. Secondly, the moderation hypotheses of interacted effects of financial situation and different levels of resilience was examined with marginal effects and predicted mean BMI, to examine the categorical differences in the population at specific resilience scores. All analyses were adjusted for age and sex.

Results: Adolescents from low-income families had statistically significantly higher mean BMI compared to peers from better- or the same income levels as others. A significant positive association was found between BMI and lower levels of resilience in adolescents, in an increasing exposure-response relationship, with an increasing mean BMI as the resilience score in adolescents lowers. The results also confirmed the moderation hypothesis between resilience and economic situation, suggesting that adolescents from low-income families with lower levels of resilience had the highest associated risk for overweight and obesity. Only small variations in BMI were found at high levels of resilience across all financial categories, suggesting that higher levels of resilience may serve as a protective factor against the present risk of being from a low-income household.

Conclusion: The study adds to the existing literature on the relationship between family economy and BMI, and highlights the importance of resilience and social network in adolescence for promoting and maintaining a healthy body weight at early stages in life. Further research should aim to explore the casualty of this association and examine possible effects of separate resilience factors, to gain a better understanding of the mechanisms of resilience.

Sammendrag

Tittel: Assosiasjonen mellom sosioøkonomisk status og forekomst av overvekt og fedme blant ungdom og betydningen av resiliens: En studie basert på Ung-HUNT4 (2017-2019).

Bakgrunn: Den økende forekomsten av overvekt og fedme har blitt en av verdens største folkehelseutfordringer de siste tiårene, som medfører flere alvorlige fysiske og psykiske helsekonsekvenser både hos enkeltindividet og på samfunnsnivå. Barn og ungdom med lavere sosioøkonomisk status er under den største risikoen fra sosiale determinanter i helse. Sosiale nettverk er også viktige komponenter i ungdomsårene, som også kan ha indirekte effekter på og helse og livskvalitet. Målet med denne studien er å undersøke sammenhengene mellom BMI og opplevd familieøkonomi, og å undersøke om denne sammenhengen kan modereres av graden av resiliens hos ungdom.

Metode: Denne tverrsnittsstudien er basert på epidemiologiske data fra Ung-HUNT4 (2017-2019), og inkluderer 8066 elever, lærlinger og ungdom med avbrutt skolegang mellom 13-19 år. BMI ble beregnet fra antropometriske målinger eller selvrapportert høyde og vekt, og variabler for opplevd familieøkonomi og resiliens ble innhentet via Ung-HUNT4 spørreskjema. Multivariabel lineær regresjon ble først brukt for analyse av assosiasjon mellom BMI hos ungdom og opplevd familieøkonomi, og resiliens. Deretter ble moderasjonshypotesen om kombinert effekt av familieøkonomi og ulike nivåer av resiliens undersøkt med marginale effekter og predikert BMI, for å undersøke de kategoriske forskjellene i populasjonen ved spesifikke verdier av resiliens. Alle analyser ble justert for alder og kjønn.

Resultater: Ungdom fra lavinntektsfamilier hadde statistisk signifikant høyere gjennomsnittlig BMI sammenlignet med jevnaldrende med bedre- eller samme inntektsnivå som andre. En signifikant positiv assosiasjon ble funnet mellom BMI og lavere nivåer av resiliens hos ungdom, i en økende eksponering-respons-relasjon, med en økende BMI ved lavere nivåer av resiliens. Resultatene bekreftet også moderasjonshypotesen mellom resiliens og familieøkonomi, og antydte at ungdom fra lavinntektsfamilier med lavere nivåer av resiliens hadde den høyeste assosierte risikoen for overvekt og fedme. Kun små variasjoner i BMI ble funnet ved høye nivåer av resiliens i alle økonomiske kategorier, noe som tyder på at høyere nivåer av resiliens kan fungere som en beskyttende faktor, til tross for økt risiko ved lavere inntektsnivå i familien.

Konklusjon: Studien supplerer den eksisterende litteraturen om forholdet mellom familieøkonomi og BMI, og fremhever viktigheten av resiliens og sosiale nettverk i ungdomsårene for å fremme og opprettholde en helsemessig kroppsvekt fra barndommen. Ytterligere forskning bør ta sikte på å utforske årsakssammenhengen til denne foreningen og undersøke mulige effekter av separate resiliensfaktorer, for å få en bedre forståelse av mekanismene for resiliens.

Acknowledgments

This master thesis was carried out at the Norwegian University of Science and Technology (NTNU), and I am proud to submit my final thesis in Clinical Health Science: Obesity and Health. The last two years of preparing and working on this project have been challenging, but most of all very instructive, and I would like to thank my supervisors, Steinar Krokstad, Trine Tetlie Eik-Nes and Erik R. Sund. Their guidance, feedback and encouragement during this project has been of great value and much appreciation throughout the whole process.

I have been fortunate enough to collaborate with HUNT Research Centre on this project, with valuable data materials from The Trøndelag Health Study (HUNT), which is a collaboration between HUNT Research Centre, the Faculty of Medicine and Health Sciences (NTNU), Trøndelag County Council, Central Norway Regional Health Authority, and the Norwegian Institute of Public Health. I am very grateful to have gotten the opportunity to carry out this study in such an important field and current matter.

Lastly, I would also like to thank my family, friends and colleagues for their support, patience and motivation during the last year. I am forever grateful for all your help.

Helle Tung Dyrendahl
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List of Abbreviations

BMI	Body Mass Index
CI	Confidence Interval
IOTF	International Obesity Task Force
NCD	Non-communicable Chronic Diseases
READ	Resilience Scale for Adolescents
SD	Standard Deviation
PCT	Percentile
WHO	World Health Organization

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1 Introduction

1.1 Background and relevance

Overweight and obesity have become one of the greatest challenges in public health worldwide over the last decades, reaching the level of a global pandemic in both developed and developing countries (1). The World Health Organization (WHO) reveals that a staggering 60% of adults and almost one in three children (29% of boys and 27% of girls) are living with overweight or obesity in Europe in 2022, in the latest European Regional Obesity Report (2). These proportion rates also reflect the current prevalence in Norway, where the proportion of the population living with overweight or obesity has increased considerably over the last decades, and almost doubled since the beginning of the 2000s (3). Numbers from the National Public Health Survey 2020 showed that 59% of men, and 47% of women in the population are living with overweight or obesity in Norway, in similarity to the rest of the European region (4). The prevalence in the younger generations in Norway are of similar trends, but somewhat lower than the European proportions. In the latest observations from 2017-2019 the Nord-Trøndelag health survey for adolescents (YoungHUNT4) shows that approximately 24% of boys and 25% of girls are overweight or obese (5).

The mechanisms behind this development are complex and most likely caused by the combination of several factors of both individual, structural and environmental components. During the last decades with considerable increase of overweight and obesity, the societal changes have also been substantial. The increased urbanization, new technology and changes in the food system are causing changes in our dietary patterns and also seen to decrease the level of physical activity in the total population (2). Still, there are notable systematic differences in health and tendencies of body weight at different socioeconomic levels, both for Norway as a country, and also within counties and the same cities. The proportion of the Norwegian population living with persistent poverty has increased from 8% to 10% the last two decades, and the proportion of children, adolescents and young adults in this group are also increasing (6). The following theoretical background aims to address the consequences of overweight and obesity and how socioeconomic characteristics could be potential risk factors, as well as the possible preventative factors of social network.

1.2 Theoretical background

1.2.1 Definitions

Body mass index (BMI) is the most common tool used in categorizations of overweight and obesity in the population and gives a representation of the relationship between height and weight. For adults over 18 years this is calculated by weight (kg) divided by height (m)². BMI categories are defined by The World Health Organization in the following: underweight (BMI ≤ 18.5), normal weight (BMI ≥ 18.5 to <25), overweight (BMI ≥ 25 to <30) and obesity (BMI ≥ 30) (1, 2).

The relationship between weight and height in children and adolescents under the age of 18 are somewhat more complex due to puberty, differences in sex and variations in growth patterns. Thus, age- and sex- specific cut off points for BMI in child centiles based on age, gender and BMI, were established and based on large datasets from six countries (7) by the Childhood Obesity Working Group of the International Obesity Task Force (IOTF) The ITOF cut offs for overweight and obesity are IOTF 25 and IOFT 30, which refers to BMI 25 and 30 for adults over 18. As an example, the cut off points corresponding to obesity for boys and girls at 13 years of age, are at BMI 26.84 for boys and 27.76 for girls (7, 8).

1.2.2 Consequences of overweight and obesity

Obesity is recognized as a complex disease, defined as "*abnormal or excessive accumulation of fat that presents a risk to health*" (2). The individual consequences of excess fat can result in chronic inflammation, osteoarthritis or other musculoskeletal disorders, disability and/or hormone imbalance in both adipose tissues, the liver and digestive system (9). In the European region overweight and obesity is the responsible cause of over 1.2 million deaths every year (2).

In addition to being a burdensome disease on its own, overweight and obesity is also a leading risk factor to disability and to the evolvement of numerous non-communicable diseases (NCDs) such as cancers, cardiovascular diseases, type 2 diabetes, and chronic respiratory diseases. In the European region NCDs accounted for 90% of all deaths in 2021 and were also the cause of 80% of premature deaths at ages between 30-69 years, according to WHO (1, 2). The development of overweight and obesity often happens over time, and even though the prevalence increases with age there are considerable health issues across all ages. For children and adolescents, it enhances the risks of obesity, disability and multimorbidity in adult life, and early onset is shown to be a challenging process to reverse (1, 10, 11).

As well as physical consequences, an additional outcome from development of overweight and obesity in childhood and adolescents is increased risk of obtaining adverse psychological challenges. The development and growth taking place in the years of adolescence makes youth particularly susceptible to psychosocial consequences, concerning self-image, body dissatisfaction, social stigmatization, peer victimization and depression (12, 13). These factors can also result in negative effects on social determinants in health, like social life, academic performances, lower overall quality of life, and also result in higher rates of unemployment in adult life (12). Adolescents struggling with obesity are also found to be associated with higher ratios and prevalence of depression, in comparison to non-obese peers (14).

Societal consequences and the economic burden of overweight and obesity were estimated to approximately 68 billion (Norwegian Krone) annually, in a report by Menon Economics in 2019 (3). The estimate includes both direct cost from health care services, disability and the loss of labor, production and paid taxes.

1.2.3 Causes and socioeconomic risk factors

The causal drivers behind overweight and obesity must be understood as combinations of several factors. Individual factors like genes, diet and nutrition and physical activity are related determinants, but there are also several societal and environmental circumstances influencing the development of overweight and obesity in childhood and adolescents. In regard to treatment and prevention it is necessary to understand the multifactorial causes behind the disease, which are far more complex than only the individual factors of unhealthy dietary habits and physical inactivity (2). Socioeconomic status also plays an important role in the prerequisites for good health, and is often measured by education level, occupation and level of income. Several systematic reviews suggest that there is an increased risk of overweight and obesity amongst individuals from a lower socioeconomic background, especially in high income and developing countries (12, 15-18). Both income, education and occupation are highly interconnected, and are also often reflected in an individual's level of health literacy. Health literacy refers to the ability to make healthy life choices and also seek out, process and understand relevant information to promote good health and maintain a healthy body weight throughout life (19, 20).

The effect on public health through these socioeconomic factors contributes to social inequalities and considerable differences in preconditions for good health. The latest public health White Paper in Norway (*Folkehelsemeldingen 2022-2023*) emphasizes the importance of reducing the increasing differences in social inequalities, by making it the primary goal in the national strategy to improve the overall public health in Norway (21).

Socioeconomic status can also be persistent over generations, as children and adolescents are highly influenced by their parents, and the social environment often generates typical habits, patterns, life choices and opportunities (22). The U.S. population based *National Health and Nutrition Examination Survey* from 2005-2008 concluded that children and adolescents from low-income families are more likely to be obese than higher income counterparts, indicating that income can be an important determinant in health (23).

1.2.4 Social network and resilience

Family functioning and the social and emotional support from parents are important factors during childhood, but social networks can also be essential in regard to supportive relationships, especially during adolescence (24). In a US study including 74 obese children it was demonstrated that the presence of close friends plays a unique role in health-related quality of life and was also associated with higher social self-efficacy (25). One way to measure the level of social network is through resilience components, which may include social competence, self-esteem and self-efficacy, social support and family cohesion (26). Hjemdal et al (2006) developed the Resilience Scale for Adolescents (READ), to create a common ground for further research on these factors (27).

Several previous studies have investigated resilience in relation to emotional symptoms, anxiety and depression, where higher resilience seemed to be a protective factor and associated with a better outcome despite the presence of related risk factors (26-28). In regard to overweight and obesity, the effect of resilience has not been studied on the same scale, but a few studies have examined the association between body weight and emotional symptoms (24), and obesity risk in relation to family functioning (29). Both studies found associations of higher perceived body weight or risk of overweight and obesity at higher levels of emotional symptoms or poor family functioning, which indicates that these resilience factors also could affect overweight and obesity as well (24, 29).

1.3 Project aim

The consequences and leading causes to the increasing prevalence of overweight and obesity is thoroughly studied and explained in previous research. All the latest reports from WHO, NCD Child, the World Obesity Federation and the latest White Paper in Norway are in consensus regarding managing and reduction through improvement of the prevention strategies (2, 21, 30, 31). In a preventative perspective, children and adolescents are the future adult population and the foundation for future generations, and it should be our main focus to enhance the prospect for good health from early on in life (2).

The link between lower socioeconomic status and increased risk of overweight and obesity is well supported in previous research, but it might be beneficial to gain more insight in possible protective mechanisms, as a different angle to the preventative strategy. The aim of this study is to examine the associations between overweight and obesity and perceived financial situation, and to investigate if this association may be moderated by the level of resilience to possibly increase the chances of a better outcome in health despite the risk of being from a lower socioeconomic background, specifically lower income.

1.3.1 Research questions

Is there an association between perceived financial status and body mass index in adolescents and does resilience moderate this association?

2 Material and method

2.1 Study population in YoungHUNT4

This thesis is based on epidemiological data from The Nord-Trøndelag Health Study (HUNT), which is a population-based health survey conducted in Nord-Trøndelag County in four phases since 1984. The YoungHUNT surveys cover the adolescents in HUNT, including high school students, apprentices and school dropouts between 13-19 years old. Between 2017 and 2019 a total of 10609 individuals were invited to the fourth phase of the survey (YoungHUNT4), and 8066 students and apprentices participated by completing questionnaires and health examinations (76% response rate) (5). Students in high school completed the questionnaires during school hours, and the anthropometric measurements of height and weight were examined and obtained by health personnel using an InBody 770 body composition analyzer. Apprentices (and adolescents who had left school before they had finished their education) completed the questionnaires during apprentice gatherings, with self-reported measurements of height and weight (32).

2.2 Study design

This study is a cross sectional study based on data material from YoungHUNT4, examining possible associations between BMI in adolescents and different levels of perceived financial situation in their families. In addition, the study investigates the possible moderating effect on the association at different levels of resilience, a proxy for social network representing family cohesion, social- and personal competence. Figure 1 presents the analytic model of the main variables, moderator and covariates.

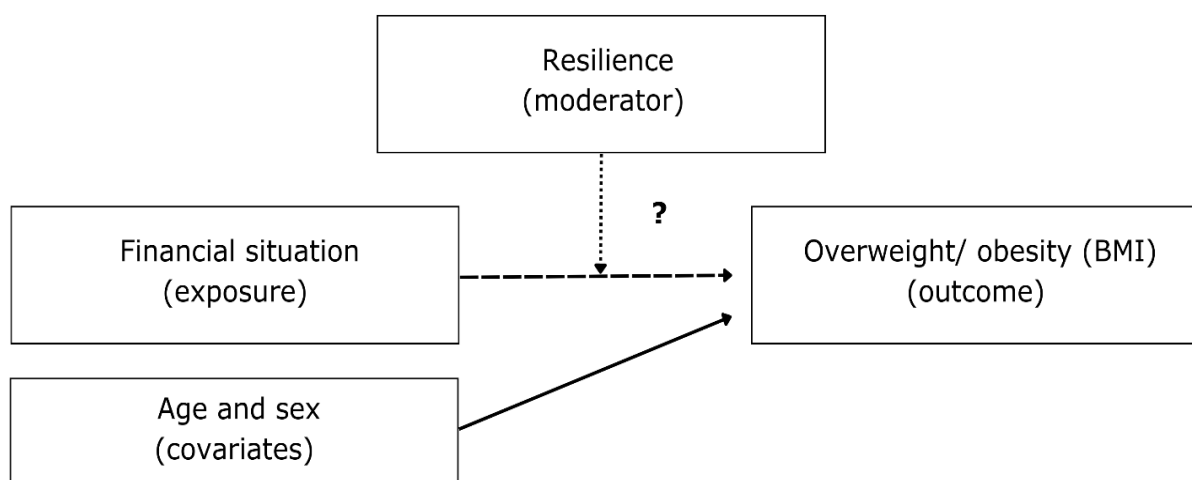


Figure 1: Analytic model

2.2.1 Inclusion and exclusion criterias

All respondents with complete data on main variables (height and weight for BMI and perceived financial situation in the family) as well as sex and age were included in the first part of the analysis. One exclusion criteria was made regarding motor ability impairment. Hence, individuals reporting "a little", "somewhat" and "severely" levels of motor ability impairment were excluded from this study. Limitations on motor abilities may affect an individual's BMI for other reasons than family economy, which could have led to bias in the results. These adolescents were therefore excluded, to increase the validity and reliability of the results obtained from the association analysis. In the analysis which included the items in the resilience score, it was necessary with complete data on the cluster variable for resilience to be able to calculate the mean resilience score. In depth descriptions of all included variables are included in the following chapter. An overview of total participants and excluded variables and missing data is presented in figure 2.

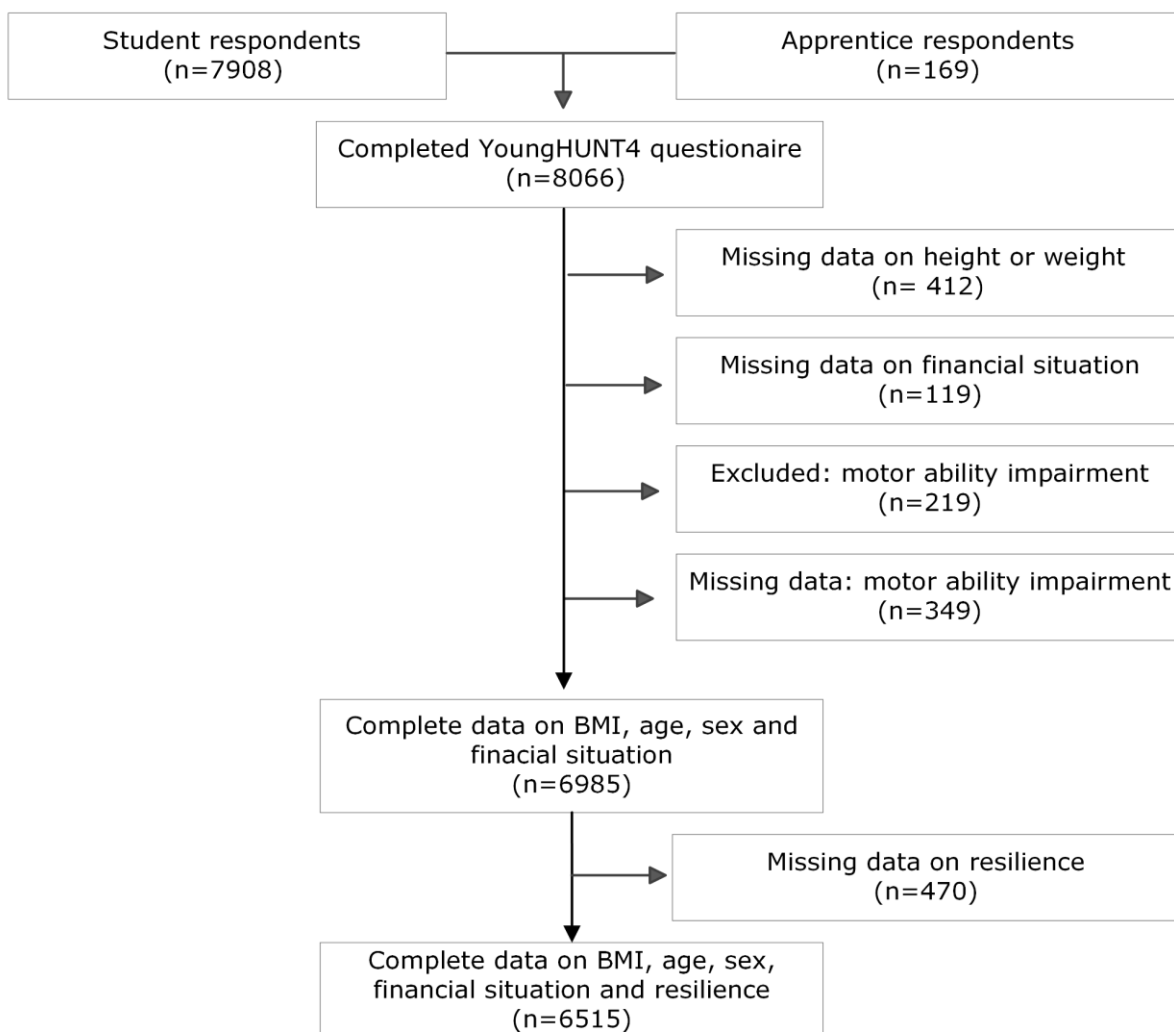


Figure 2: Flow chart of respondents, excluded-, missing- and complete data. The YoungHUNT4 Survey (2017-2019).

2.3 Study variables

Body Mass Index (BMI)

Height and weight were used to calculate participants BMI (formula kg/m²), obtained from anthropometric measurements of students, and self-reported height and weight from apprentices. BMI z-scores were calculated for every participant to create variable *BMIz*, measuring how many standard deviations an individual's BMI is above or below the mean BMI for their age and sex. Categories for underweight, normal weight, overweight and obesity were defined by *BMIz* and applied using the UK references based on the international age-and sex-specific BMI cut-offs established by Cole et al. in 2000 and updated in 2007 (7, 33). The Norwegian ISO-BMI cut-offs were not accessible for the dataset in this study, and the UK-WHO Growth References from 2007 were therefore used (8, 34).

Perceived financial situation in the family

The participants' perceptions of the household economy were based on the questionnaire question: "How well off do you think your family is compared to most others?". Answers were categorized in three possible responses: "About the same as others", "better financial situation than others" and "worse financial situation than others" (32). The first category, representing the *same financial situation as others*, was used as the reference category in the regression analysis.

Resilience

A resilience score was created from a cluster variable which included nine items covering "social network and neighborhood" in YoungHUNT4, which include 9 of the 28 items in the original Resilience Scale for Adolescents (READ), developed by Hjemdal et al (2006) (27). The cluster text in YoungHUNT4 was "how have you thought or felt about yourself, and about your family during the last month?", with the nine variables representing family cohesion, social competence and self-image. The first three statements; "I easily find new friends", "I always find something fun to talk about" and "I am good at talking to new people" represent social competence. The following three statements represent family cohesion: "in my family, we share views of what is important in life", "I feel comfortable with my family" and "my family view the future as positive even when sad things happen". The last three variables; "I feel skilled", "I know how to reach my goals" and "in adversity, I tend to find something good to help me grow" were statements representing personal competence (32). All nine statements had the same response alternatives in a 5-point Likert-scale: "totally agree", "agree", "average", "disagree" or "totally disagree", coded as one to five, respectively.

The Cronbach's alpha reliability coefficient for all nine resilience variables was 0.87, demonstrating that all the variables in the cluster were closely related with adequate internal consistency. A mean score of resiliency combining all 9 items was generated into a continuous variable ranging from 1.0 - 5.0, including all resilience items of family cohesion, social- and personal competence, with higher scores indicating lower degree of resilience (24, 27). To categorize the mean scores of resilience, individuals with means between 1 and 1.99 were labeled as "high resilience", means between 2-2.99 as "medium high resilience", mean 3-3.99 as "medium low resilience" and means between 4-5 as "low resilience". The first group, representing adolescents with the highest resilience score, was used as the reference category in the regression analysis.

2.4 Statistical analysis

Stata/MP version 17.0 was used for all analyses in this study. Descriptive statistics were used to summarize and present the characteristics of the population, presented as frequencies (n), percentages (%), means and standard deviations (SD). Multivariable linear regression was first performed to examine the differences in mean BMI between different categories of perceived financial situation in the family, and at the different levels of resilience. The analyses were adjusted for the covariates sex and age, to account for the influence of these factors on the association between BMI and perceived financial situation or resilience. In this regression analysis, BMI and age were treated as continuous variables, and financial situation, resilience and sex as categorical variables. The financial category "same financial situation" was used as the reference category in comparison with better- and worse financial situations, and "high resilience" was used as the reference category for resilience categories. The analysis was performed using the *regress* command in Stata. The results are presented with beta coefficients (Coef.), representing change in mean BMI (units) for a unit increase in the predictors. The precision of all estimates is reported with 95% confidence intervals (CIs) and p-values (P). P <0.05 were considered statistically significant.

The second part of the analysis tested the moderation hypotheses of interacted effects between family economy categories at different values of resilience, first assessed with marginal effects and predicted mean BMI using the *margins* command and *marginsplot*, for BMI values at resilience categories. To further examine the statistical significance and precision of the predicted estimates, a second analysis of marginal effects was performed at different resilience percentiles, for expected mean change in BMI. The results of the marginal effects of resilience are presented in table 3, figure 7 and figure 8, as predicted BMI or expected change in BMI, with 95% CIs.

2.5 Ethical considerations

This study is based on data materials from the YoungHUNT4 Survey, with a license from Norwegian Data Inspectorate (HUNT4 17/00426-7/GRA), and after approval from the Regional Committee for Medical and Health Research Ethics (REK). Participation in YoungHUNT4 was voluntary and informed consent was collected from all parents of participants under the age of 16 (35, 36). All personal health data obtained from the participants has been kept anonymously and ordinary guidelines for privacy policies and research ethics were followed for the data material in use. This study has also been approved by REK and HUNT databank (appendix 1 and 2).

An ethical consideration to take into account, is to avoid that the project contributes to any further stigmatization of the research groups, especially individuals with overweight or obesity, or lower income families. This project aims to examine the possible connection between risk factors for overweight and obesity to gain a better understanding of the current situation, and to contribute to improved strategies for prevention and reduce stigmatization of the individuals in the research groups. We will be aware of how the findings are presented and communicated avoiding inappropriate communication.

3 Results

3.1 Descriptive characteristics of the study population

The study population included 6515 adolescents with complete data on all included variables. Total frequencies (n) for all variables as well as the distribution between BMI categories are presented in table 1. Categorical variables are presented as frequency and percentages (%) and continuous variables as means and standard deviations (SD).

The mean age of all participants was 16.1 years, and both boys and girls were equally represented with 49.1% girls and 50.9% boys. The mean BMI in the population was 22.2, and the distribution of BMI categories shows that 6.1% was categorized as underweight, 70% as normal weight, 17.1% as overweight and 6.8% as obese.

Table 1: Descriptive characteristics of total frequencies and distribution at BMI categories. The YoungHUNT4 Survey (2017-19).

Independent variables	Total n (%)	BMI categories n=7037 (22.2 ± 4.2)			
		Under wt. 432 (6.1)	Normal wt. 4922 (70)	Overweight 1205 (17.1)	Obesity 478 (6.8)
Age, years (mean ± SD)	7402 (16.1 ± 1.8)				
Sex	7402				
Male	3748 (50.9)	146 (4.1)	2477 (69)	713 (19.8)	256 (7.1)
Female	3654 (49.1)	286 (8.3)	2445 (71)	492 (14.3)	222 (6.4)
Financial situation	7947				
Same as others	5682 (71.5)	312 (6.2)	3520 (70.1)	849 (16.9)	338 (6.7)
Better situation	1636 (20.6)	92 (6.4)	1026 (71.6)	234 (16.3)	80 (5.6)
Worse situation	629 (7.9)	22 (4.1)	344 (64.4)	110 (20.6)	58 (10.9)
Resilience score¹ (mean ± SD)	7399 (2.2 ± 0.8)	(2.1)	(2.1)	(2.2)	(2.3)
High resilience	3186 (43)	183 (6.4)	2041 (71.6)	470 (16.5)	156 (5.5)
Medium-high resil.	2979 (40)	156 (5.9)	1856 (70.7)	435 (16.6)	180 (6.9)
Medium-low resil.	1087 (15)	51 (5.4)	623 (65.6)	195 (20.5)	81 (8.5)
Low resilience	147 (2)	4 (3.3)	75 (61.5)	22 (18)	21 (17.2)

BMI body mass index, n number of participants, SD standard deviation.

¹ Categorical resilience scores: high 1-1.99, medium-high 2-2.99, medium-low 3-3.99, low 4-5.

Financial status in the population

In total, 7.9% perceived their family's financial situation as "worse" compared to others (table 1), and some differences in the distribution of BMI were found within the financial categories. Values from table 1 and graphic illustration in figure 3 showed a higher percentage of overweight (**20.6%**) and obesity (**10.9%**) in adolescents with a worse financial situation, compared to adolescents with the same financial situation as others (16.9% overweight and 6.7% with obesity) and better financial situation (16.3% overweight and 5.6% with obesity).

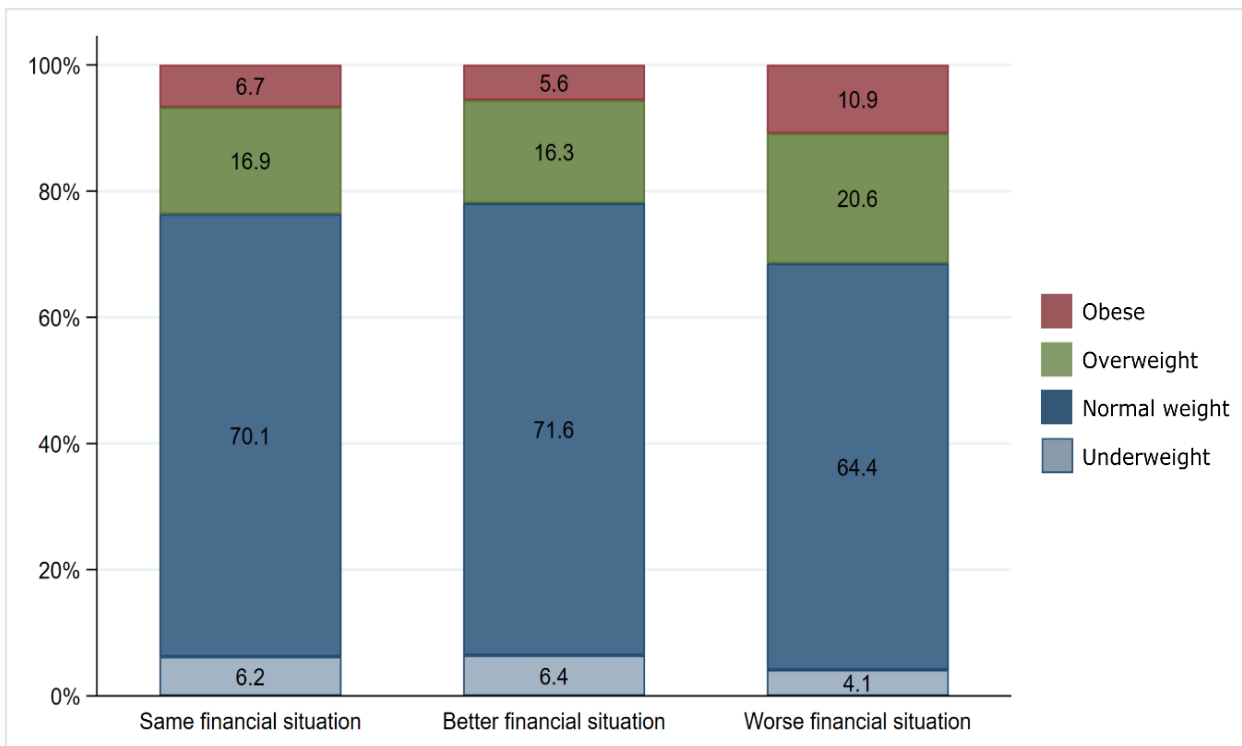


Figure 3: Percentage distribution of BMI within economic categories

Resilience in the population

The mean resilience score for all adolescents in this study was 2.2. There was a slight difference in mean scores between BMI categories in degree of resilience, indicating a tendency of lower levels of resilience as BMI increases (table 1). The total frequency of the resilience categories showed that 43% of the population were categorized with high resilience, with a mean score between 1-1.99 (above the overall mean at 2.2). A total of 40% reported scores of medium-high resilience, with a mean score between 2-2.99, whereas 15% reported medium-low resilience with a mean between 3-3.99. Of all 2% were categorized with low resilience with a mean between 4-5 (table 1).

The graphic illustration in figure 4 (and values from table 1) showed the categorical distribution of BMI within each of the resilience categories. The relative frequency of obesity increased at lower levels of resilience, with the highest percentage of obesity in adolescents with low resilience (**17.2%**), compared to 5.4%, 6.9% and 8.5% at high-, medium high- and medium-low resilience, respectively.

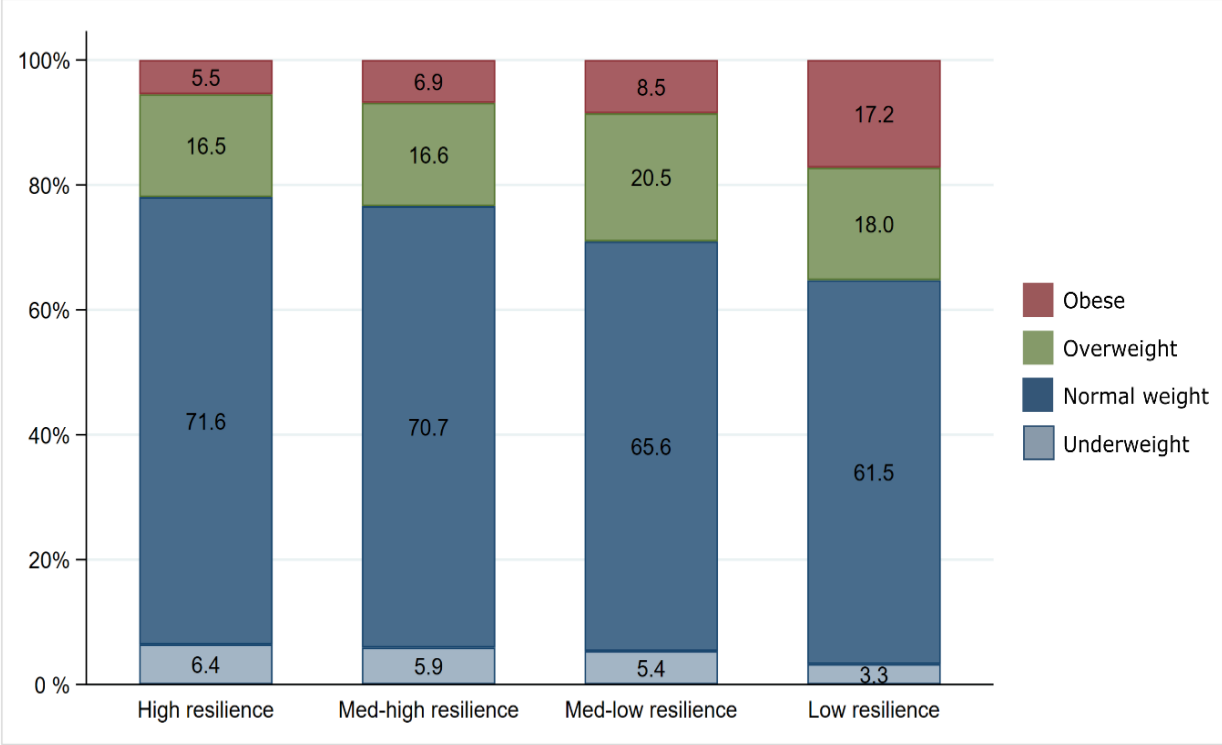


Figure 4: Percentage distribution of BMI within resilience categories

3.2 Associations between BMI and financial situation and resilience

The results of the multivariable linear regression analysis are presented in table 2, in two models. The R-squared remained 0.10 across both models, indicating that the included variables accounted for 10% of the variation in this analysis. The p-value <0.001 indicated that the model was a good fit for the data and that it is very unlikely for these results to be due to chance.

Table 2: Multivariable regression models for mean differences in BMI

BMI	Model 1 (n=6985) ²		Model 2 (n=6515) ³	
	Coef. (95% CI)	P-value	Coef. (95% CI)	P-value
Age, years	0.71 (0.65 to 0.76)	0.000	0.70 (0.64 to 0.75)	0.000
Sex (ref. male)				
Female	-0.40 (-0.59 to -0.21)	0.000	-0.32 (-0.51 to -0.12)	0.002
Financial situation (ref. same financial situation)				
Better financial situation	-0.08 (-0.32 to 0.15)	0.486	-0.06 (-0.31 to 0.18)	0.607
Worse financial situation	0.78 (0.43 to 1.13)	0.000	0.67 (0.30 to 1.04)	0.000
Resilience (ref. high resilience)				
Medium-high resilience			-0.01 (-0.23 to 0.20)	0.893
Medium-low resilience			0.41 (0.11 to 0.71)	0.007
Low resilience			1.59 (0.86 to 2.32)	0.000
R-squared	0.1001 (10%)	<0.001	0.1016 (10.2%)	<0.001

BMI body mass index, *n* number of participants, *Coef.* coefficient, *CI* confidence interval.

² Model 1 includes all participants with complete data on BMI, financial situation and covariates.

³ Model 2 includes all participants from model 1, and participants with complete data on resilience.

Associations between BMI and financial situation in the family

A significant positive association between worse financial status and BMI was found in model 2, indicating that adolescents from this economic category had 0.67 units higher mean BMI than the reference group (0.67; 95% CI 0.30 to 1.04) $p=0.000$ (table 2). No differences were found when comparing those with worse financial status with those with a better financial situation ($p = 0.386$). The associated differences in BMI for adolescents in different economic situations are illustrated in figure 5.

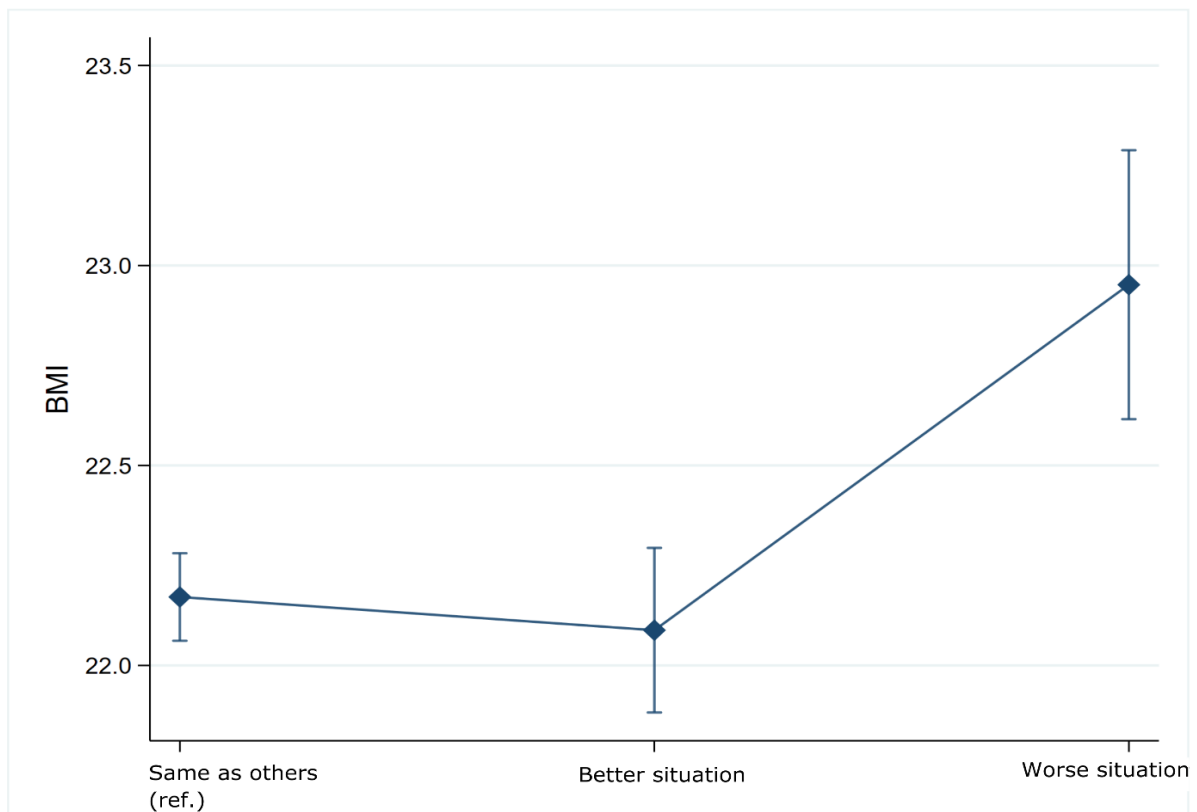


Figure 5: Associations between BMI and financial situations.

Associations between BMI and resilience in adolescents

The associations between BMI and resilience presented in table 2 (model 2) showed a significant positive association between BMI and both medium-low and low resilience. Figure 6 illustrates the associated differences in BMI for adolescents with different levels of resilience. The mean BMI of adolescents with medium-low resilience was estimated to be **0.41** units higher than the reference category (Coef.=0.41; 95% CI 0.11 to 0.71, $p=0.007$), and adolescents with low resilience was estimated to have **1.59** units higher mean BMI than the reference category (Coef.=1.59; 95% CI 0.86 to 2.32, $p=0.000$), indicating that a mean resilience score below average (score 3.0-5.0) is associated with higher BMI in adolescents. No significant associations were found between medium-high resilience and the reference category ($p=0.893$), indicating no differences in BMI between higher categories of resilience.

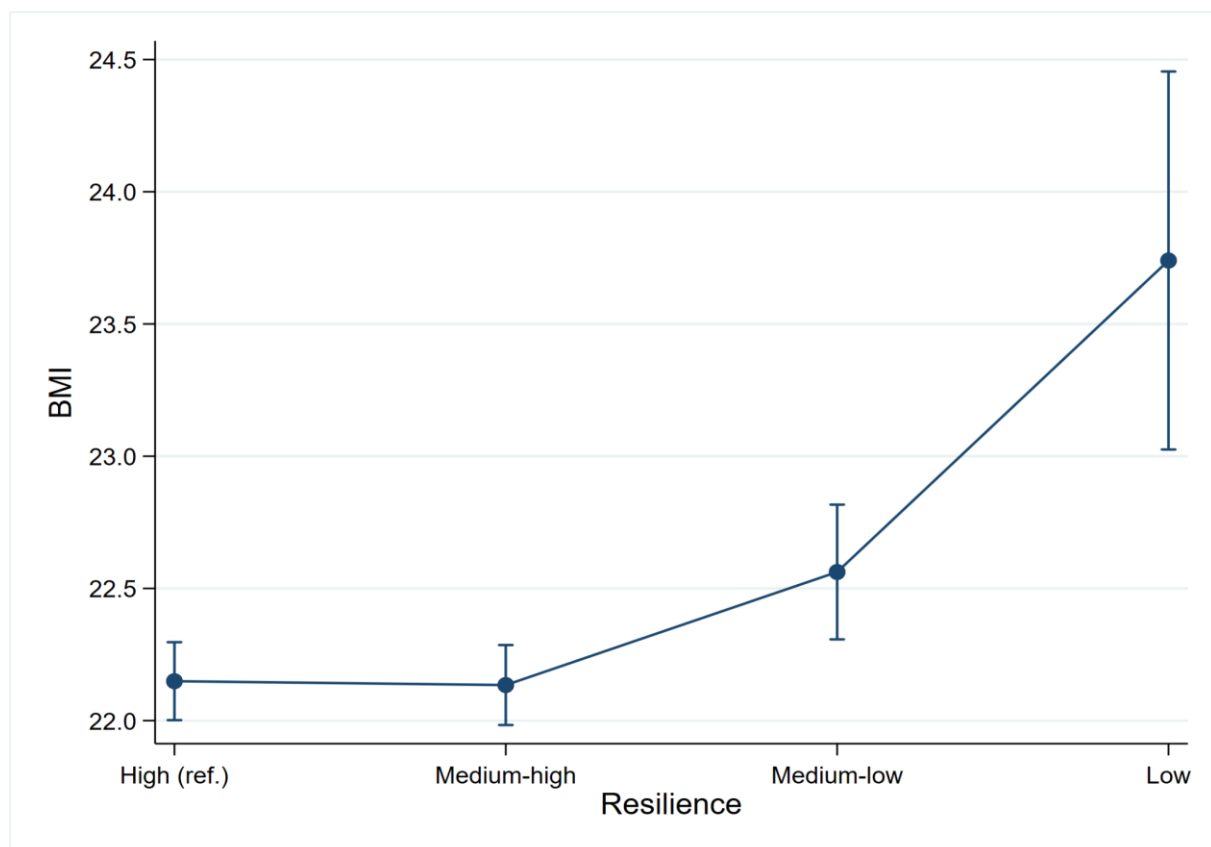


Figure 6: Associations between BMI and resilience categories

3.2.1 Results of the moderation hypothesis

Linear predictions of BMI in economic categories at different resilience categories

The linear predictions of the mean BMI across different resilience categories are presented in BMI values and 95% CIs in table 3 and illustrated in figure 7. The predicted BMI values showed a higher variance in adolescents with a worse financial situation at different resilience categories (BMI 22.3 to 24.2 at high- to low resilience), compared to the differences shown for participants with better- or the same financial situation as others. Predicted BMI for adolescents with better financial situation remained the same at all resilience categories (BMI 22.1), and only small variance in the financial category; same as others (BMI from 22.0 to 22.8 at high- to low resilience).

Table 3: Predicted mean BMI at different levels of resilience and economy categories.

Financial situation	Predicted mean BMI at different levels of resilience (95% CI)			
	High	Medium-high	Medium-low	Low
Same as others	22.0 (21.8 to 22.2)	22.3 (22.1 to 22.4)	22.5 (22.2 to 22.8)	22.8 (22.3 to 23.2)
Better financial situation	22.1 (21.8 to 22.4)	22.1 (21.8 to 22.4)	22.1 (21.5 to 22.7)	22.1 (21.2 to 23.0)
Worse financial situation	22.3 (21.6 to 23.0)	22.9 (22.6 to 23.3)	23.5 (23.0 to 24.1)	24.2 (23.1 to 25.2)

BMI body mass index, CI confidence interval.

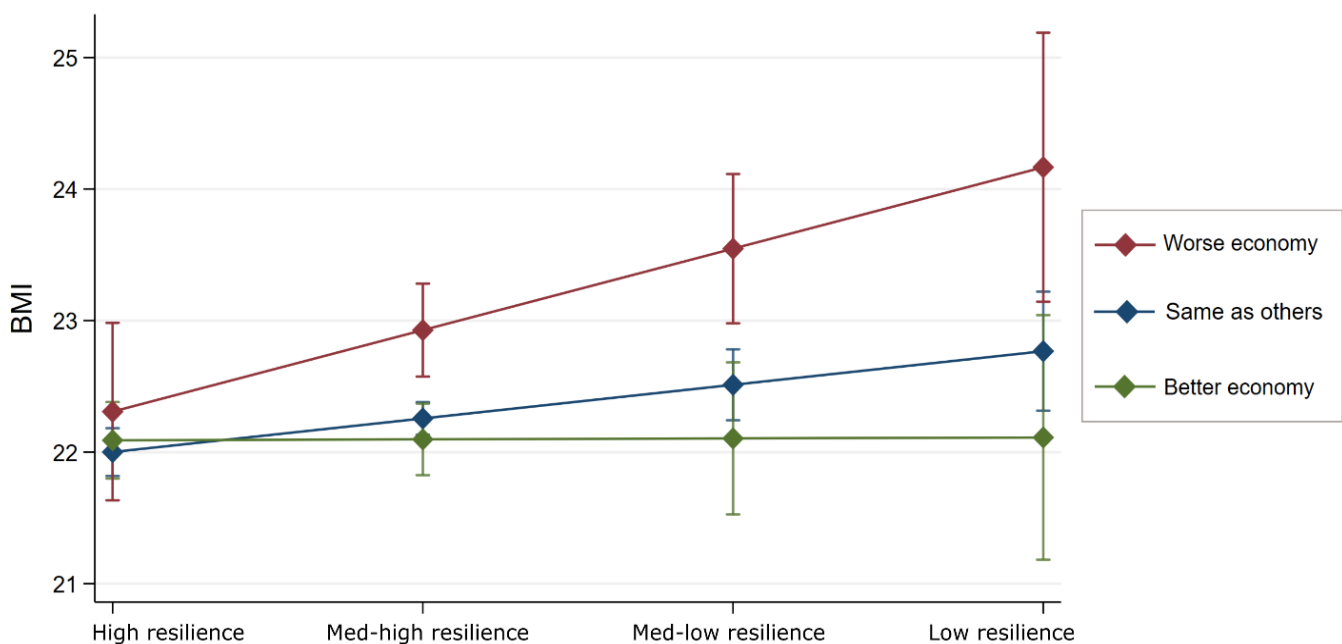


Figure 7: Predicted BMI (95% CI) according to categories of family economy and resilience.

BMI and interacted effects of economic categories at resilience percentiles.

The marginal effects indicate that the influence of low resilience is greater for adolescents from a worse economic situation, with a significant expected increase in mean BMI from approximately the 50th percentile and above (figure 8). This includes adolescents in the category *worse economy* with a resilience score between 2.1 and 5. The results of the marginal effects at resilience percentiles are presented in figure 8, as expected mean change in BMI for the categories better- and worse economy compared to the reference category.

The expected variations in BMI for adolescents with high resilience was close to zero, but not significant for either of the economic categories, as the confidence intervals for the effects at the 5th, 10th and 25th percentile crossed the zero-effect line at 0.0. The marginal effects for the group with a better economic situation were not significant at any level of resilience.

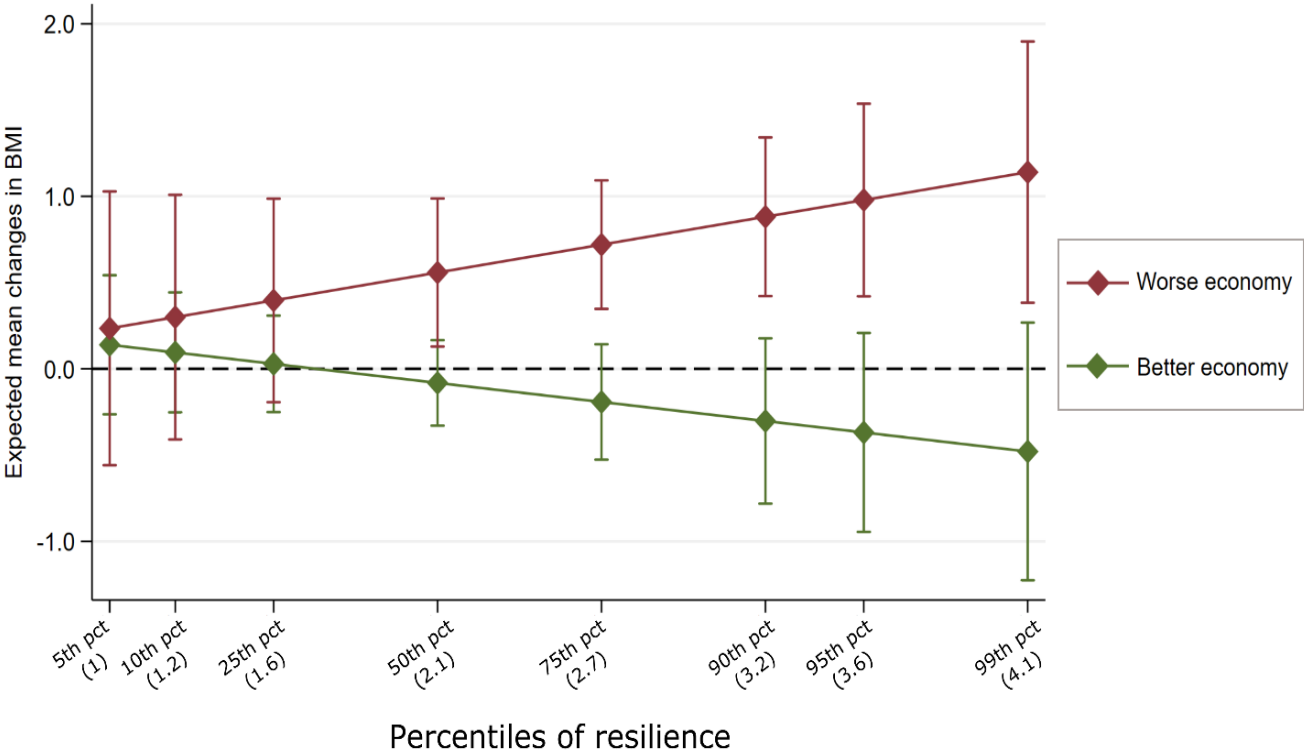


Figure 8: *Interacted effects on BMI at resilience percentiles, for different economic categories. Values on the x-axis present expected mean change in BMI (units) compared to the economic reference category, same as others.*

4 Discussion

4.1 Main findings and results

The main findings in this study showed that adolescents reporting a family economy as *worse than others had* a higher mean BMI compared to adolescents who perceived their family economy as better or the same. The results extend the knowledge on the association between lower family income and higher BMI in adolescents. Secondly, the study also showed significant results of higher BMI at lower levels of resilience, in an increasing exposure-response relationship, with increasing mean differences in BMI as the resilience score in adolescents lowers.

The results also confirmed the moderation hypothesis between resilience and economic situation, indicating that adolescents from low-income families with lower levels of resilience had the highest associated risk for overweight and obesity. On the contrary, only small variations in BMI were found at high levels of resilience, regardless of financial situation in the family, suggesting that resilience may serve as a protective factor against the negative effects of low family income on BMI.

4.2 Methodological discussion - strengths and limitations

Before evaluating and discussing the results of this study further, methodological strengths and limitations should be considered.

Design and study population

This study has several strengths in regards to design and study population. The epidemiological data from the YoungHUNT4 Survey consist of a large number of subjects, in a representative sample of adolescents in Norway (35). The data collection through detailed and thorough questionnaires and health examinations during school hours ensured a high participation rate, which reduced selection bias and enhanced the study's internal validity. Still, 983 participants had missing data on at least one of the variables of interest, resulting in a 13% loss of data (excluded variable not included). The subjects with missing values were excluded from the analysis, resulting in 6515 participants for the main analysis, which still is a substantial amount for an observational study. For consideration, the potential bias of the missing data not being completely at random should be discussed (37, 38). For instance, the questionnaire questions regarding resilience could potentially be emotionally loaded for individuals struggling with poor family cohesion or the lack of close friends, even though the questionnaires were anonymous. In similarity, the same assumptions can be made regarding participants from lower socioeconomic background, who may be more likely to have missing data on family income. However, these speculations were not considered to substantially affect

the results of this study, and if the mentioned assumptions did occur it would only underestimate the findings.

The cross-sectional design of both YoungHUNT4 and this study allowed standardized methods and inclusion of several variables, examining associations between the variables of a large sample (39). However, the study also has limitations that must be taken into account when interpreting the results. The cross-sectional design limits the ability to determine the direction of causality between the exposure and outcome variables, and it is not possible to determine that low income or low resilience are the causes of higher BMI in adolescents. Still, the cross-sectional design allowed the establishment of the associated relationship between the variables, and the precision of the associations found in this study is a considerable strength, and indicates that it is very unlikely that the results are due to chance. This provides additional knowledge about the possible mechanisms in play regarding overweight and obesity in adolescents and creates valid reasoning to examine the associated moderated relationships further in future in depth studies.

Study variables

The accuracy of measured height and weight was ensured through anthropometric measurements by health personnel for the majority of the study population, but for apprentices (n=169) this was self-reported in the questionnaires. This may result in inaccurate data on BMI for the apprentices in the study, but several studies have concluded that self-reported measurements are overall reasonably accurate (40). Adolescents' self-reported perception of their family's economic situation may include some uncertainty in whether their perception reflects the actual economic conditions, and could therefore be susceptible to information bias and misclassification. On the other hand, both children and adolescents are often able to pick up on parents' economical stress cues, despite parents' effort in trying to conceal this from their children. In a study by Mistry and Elenbaas (2021), they found strong associations between adolescents' perceptions of their social- and financial status and their parents' reports of income and education, which indicate a high validity of the economic variable in this study (41, 42). The resilience variable in this study is based on the validated Resilience Scale for Adolescents (READ) by Hjemdal et al. (2006), which had been proven reliable and an accurate measurement in several other studies (26, 43, 44). All variables on resilience in YoungHUNT4 were included in this study, representing personal- and social competence, social support and family cohesion, measured in the adolescent's agreement to 9 statements from 1 to 5 (totally agree to totally disagree). One consideration to keep in mind regarding this 5-point Likert scale, is the possibility of individual variations of

interpretation of the scale, as one individual's "agree" can be another individual's "average".

The thorough questionnaires and validity of the included variables are major strengths in this study, as well as the inclusion of covariates and adjustment for age and sex to reduce the impact of these confounding factors on the results. It is important to note that there may be other confounding variables that were not included in the analysis. The R-squared value in both regression models (table 2) estimated that approximately 10% of the variation in BMI can be explained by the included variables in this study. In relation to BMI, it is important to consider the complexity of the underlying causes and determinants, which is highly multifactorial. The inclusion of other possible confounding factors such as physical activity and dietary habits, could potentially have influenced the observed associations. However, associations between lower socioeconomic status and both lower levels of physical activity and poor dietary habits have been found to be closely related in several studies, and to avoid the inclusion of too many covariates and overfitting the model, these factors were not included (45, 46). Overfitting the model can result in unreliable and misleading results, if the model is too complex and includes too many variables.

4.3 Discussion of results and comparison with existing literature

Associations between BMI and financial status in the family

The results of this study showed significant associations between reported lower family income and higher BMI in adolescents, indicating that family income may be an important determinant and risk factor for overweight and obesity early in life. These findings are consistent with previous research on both socioeconomic status and low family income, as established factors of increased risk for overweight and obesity (12, 15-18). Several mechanisms may affect this relationship. For example, individuals with lower socioeconomic status are more likely to have lower levels of health literacy, and may therefore be more prone to make unfavorable health choices (20). This can have major impacts on the choices we make in everyday life, especially regarding diet, which affects our health in numerous ways, beyond total energy intake. Food quality plays an important role in the composition of nutrients. The increased availability of ultra-processed food with high energy density and poor nutrient profiles are becoming more and more accessible, convenient, cheap and desirable, making it increasingly challenging to make healthy food choices, especially with lower health literacy (47-49). The dietary habits of families with lower levels of health literacy (and socioeconomic status) are more likely to consist of higher amounts of refined sugar, saturated fat and salt, as well as less fruit and vegetables, fiber and protein (45, 50). Thus, adolescents from lower

socioeconomic backgrounds may have limited access to healthy food options and the opportunities of organized physical activity may be more limited compared to peers from higher/ average income families (45). The lifestyle habits obtained through childhood and adolescents are often seen to persist into adult life as well, which makes preventative strategies at early stages important (21, 22).

Associations between BMI and resilience in adolescents

The resilience of the participants in this study was relatively high, and the majority (83%) of the population reported either a high- or medium high resilience score. No significant differences between these groups were found in this study, but the results indicate a significantly higher BMI in both the lower categories, for adolescents with medium low- and low resilience scores (17% of the population). This suggests that there is a higher risk of overweight and obesity related to lower levels of resilience, including family cohesion and support, social competence and low self-efficacy in adolescents. This has also been suggested in previous research, where Skrove et al (2013) found significant associations between perceived body mass and higher levels of emotional symptoms in adolescents with low levels of social competence and family cohesion (26). A systematic review also suggested a strong positive relationship between poor family functioning and higher prevalence of overweight and obesity in children and adolescents (29). The included studies in this review did not use the same measurements for resilience (READ), but the characteristics bear similarity, and indicate the same mechanisms. It is however important to emphasize that the causal direction of this association can not be determined, and the effect of being overweight or obese in childhood or adolescence could arguably lead to lower self-esteem or self-efficacy, for instance (51).

Interacted effects on BMI through family economy and resilience

The associated risk of higher BMI in adolescents from low-income families were moderated by different levels of resilience. Specifically, adolescents from low-income families with both low- and medium-low resilience were significantly associated with higher BMI, and therefore at higher risk for overweight and obesity. This suggests that higher levels of resilience may serve as a protective factor on BMI despite the presence of poor prerequisites from low family income. Even though the interaction effects of worse economy at high levels of resilience were not significant, due to large confidence intervals crossing the zero-effect line at the 5th to 25th percentile in figure 7, these findings indicate an interesting tendency. Variations will always be present in large datasets, and in this analytic method the output is given in mean change in BMI compared to the reference group with same financial situation as others. The significance cut-off is therefore more prone to be affected by natural variance the closer this change

is to zero. The results shown in both figures 6 and 7 suggest that high levels of resilience may buffer the negative effects of low family income, as the categorical difference in BMI is minor at the highest level of resilience, across all levels of family income. On the contrary, adolescents from low-income families are the most affected by their resilience level, indicating that social networks and the resilience factors are especially important to prevent the development of overweight and obesity in this group.

There are several possible mechanisms that could potentially influence the relationship between BMI, economic status and resilience. Firstly, children and adolescents from lower-income families may face a range of challenges that could affect their psychological resilience, such as exposure to chronic stress, inadequate social support and access to resources, which potentially also could lead to social disadvantages. These factors may impact their ability to cope with adversity, and could therefore increase their susceptibility to negative health outcomes such as overweight and obesity. Furthermore, higher resilience from sufficient social support and social network may protect against the same effects from stress and adversity, and facilitate adaptive coping behaviors and promote greater self-efficacy (52).

4.4 Relevance to future research and preventative strategies

There is a high global consensus of preventative strategies being the best approach for management and reduction of the increasing prevalence of overweight and obesity, and several reports highlight that children and adolescents should be our main focus (2, 21, 30, 31). The European obesity report (2022) emphasizes that the approaches to reduce overweight and obesity should focus on both social, physical, cultural, economic and political factors, with a particular focus on income and socioeconomic inequalities (2). Social equalization and greater socioeconomic mobility for children and adolescents is also one of the main goals in the latest public health report in Norway, to reduce the generational patterns of social inequities and create a better prospect for good health for everyone.

The importance of parental support, family cohesion, close friends and social network should be emphasized in the preventative strategies, as these resilience factors enhance a safe and stable foundation for development and growth in childhood and adolescence. This study indicates that the presence of these resilience components gives better prospects in maintaining a healthy body weight, despite socioeconomic risk factors. Still, it would be interesting to examine if the different components of the resilience variable included in this study influence BMI in adolescents the same way, or if some components account for more than others. A better understanding of individual effects of family cohesion, social competence and self-efficacy could be beneficial to be able to add more

specific action points to the national strategy of reducing social inequalities and in development of effective interventions that target the root causes of health disparities (53). Further research should aim to explore the moderation of these relationships, and longitudinal studies could be considered to establish causality.

5 Conclusion

The aim of this study was to examine the associations between BMI in adolescents and financial situation, and to investigate if this association was moderated by resilience. The results of this cross-sectional study suggest that both lower family income and lower resilience is associated with higher BMI in adolescents, after adjusting for the effects of age and sex. The results confirmed the moderation hypothesis between resilience and economic situation, indicating that adolescents from low-income families with lower levels of resilience had the highest associated risk for overweight and obesity. This also suggests that resilience may serve as a protective factor against the negative effects of low family income on BMI. However, these findings do not imply causation, and other factors may also contribute to the observed association as the multifactorial causes behind BMI are influenced by several aspects, including social, environmental, and biological factors. Still, the precision of the associations found in this study indicates that it is very unlikely that the results are due to chance, and it might be beneficial to gain a better understanding on how specific resilience factors can serve as protective factors. In public health strategies aiming to reduce social inequalities in health, this could be especially valuable to children and adolescents from low-income families, as increased resilience possibly could increase the chances of a good outcome in health despite the risk of being from a lower socioeconomic background.

In conclusion, the study adds to the existing literature on the relationship between family economy and BMI, and highlights the importance of resilience and social network in adolescence for promoting and maintaining a healthy body weight. Further research should aim to explore the casualty of this association and examine possible effects of separate resilience factors, to gain a better understanding of the mechanisms of resilience.

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