Mental health in adolescence and early adulthood

Exploring the impact of social status and life course determinants

PhD dissertation

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Health
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2025

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Acknowledgements

First and foremost, I would like to thank the participants of the VestLiv cohort for their willingness to participate. Without them, this dissertation would not have been possible. I would like to express my sincere gratitude to

Karin Biering, for believing in me and fighting to give me the opportunity to pursue my PhD under exceptional guidance. From working together to secure funding and access to data to our conversations about the outdoors and life in general, you have always shown great drive and enthusiasm. You made it clear to me that personal life always comes before work and that prioritizing it does not make one less efficient in the academic world. You have treated me as a colleague rather than as a student, creating a safe learning environment where we could both pose clever and, occasionally, more or less stupid questions. You have been honest about both your abilities and limitations, which, in my opinion, is a great strength of character (And thank you for lending me the "No Hat"—I think you might need it back!)

Oleguer Plana-Ripoll, for welcoming me as a guest PhD student in your research group and for your invaluable guidance in epidemiological methods. You are a truly brilliant teacher, researcher, and leader. Thank you for your transparency and openness in everything you do. It has been an inspiration to be part of your journey—from starting your own research group to becoming a professor—as well as having you accompany me on my journey to becoming a researcher.

Ute Bültmann, for making my stay in Groningen a pleasant experience and for your insightful scientific discussions, especially regarding trajectories in Study II. You are a fascinating person with countless talents and an incredible depth of knowledge both within and beyond academia. Conversations with you are always inspiring, whether we are discussing epidemiology, sociology, politics, language, or music.

Trine Nøhr Winding, for helpful guidance on the VestLiv cohort. Your engaging manner, positive attitude, and sense of humor are always a pleasure to be around.

Finn Breinholt Larsen, for your indispensable guidance on methodology on Fixed Effect methods in Study III.

Morten Fenger-Grøn, for our valuable discussion about statistical methods, especially inverse probability weights and multiple imputations.

My colleagues at the Department of Occupational and Environmental Medicine for fostering an open, welcoming, and friendly work environment. Especially the Young Researchers group for your encouragement, shared frustrations and successes, and insightful discussions: Pernille Bach Steen, Mathias Rønnow, Sofie Breinholt Damgren, Sarah Holm Junge Jensen, Vivi Just-Nørgaard, and Caroline Lindholm Pedersen. I would also like to thank my co-pilots on the highway from Aarhus to Herning, Johanne Holk Lund and Anna Helene Meldgaard Pedersen, for the laughter, the inspiring (and sometimes trivial) conversations after long workdays, as well as the debriefings and naps when needed.

The members of the PSEMAU group for valuable scientific discussions about social and psychiatric epidemiology and for showing genuine interest in me and my project. Especially thanks to Lisbeth Mølgaard Laustsen and Danni Chen for sharing all ups and downs during our parallel PhD journeys – from the start to the very end.

My family and friends for their unwavering support and efforts to understand what this weird academic world is about.

My loving husband, Leo, for never questioning my abilities, supporting me throughout this process, patiently listening to my thoughts and ideas, engaging in discussions about complex systems thinking, offering new perspectives, and taking great responsibility at home while I was away fulfilling my academic responsibilities.

My wonderful children, Oliver and Emma, just by being yourselves, you remind me every day why we must make an effort to build a better future for the next generations.

Grants

This PhD project was made possible through financial support from:

- Sygeforsikring Danmark (Grant number 2021-0105)
- KV fonden
- William Demant
- Dansk Ramazzini Center
- AU Travel grant

None of the funding organization had any influence on the designs, analyses, or interpretations of the results.

Contents

0. Preface

Motivation

Mental health should not be a privilege for the most resourceful people.

I attended a primary school where we came from very different backgrounds. I became aware that just by having the parents I had, with the resources they had, I had more opportunities in several aspects of life than some of my friends did. I experienced feelings of unfairness. It was unfair that I had access to adult attention, food, and love while my good friend was not safe in his home, which was being used as a drug den. It was unfair that my classmates had to provide food on their own when their mother was lost in the bottle and could not provide for her children. It was not my friends' fault that they had to use their energy to meet their basic needs, making it difficult for them to focus in school. This was my first motivation for fighting social inequality.

Later, in secondary school, I experienced how mental health could be a challenge during the transition from adolescence to adulthood. Through personal experiences, those of my friends, and stories about distant acquaintances, I began to wonder: Should it really be this hard to be an adolescent? The feeling of unfairness struck again. No one should experience this level of pain. One thing my friends in secondary school and I had in common was that we had close social relationships and resourceful families in multiple ways. We had people around us who knew how to react to problems, cope, and find help in the complex Danish welfare system—or the possibility to finance help if needed. But how would my friends from primary school do if they faced the same problems?

During my training as a physiotherapist, I interned at the Psychiatric Hospital in Risskov. I had the privilege of listening to patients share their stories. I noticed that patients with the same mental disorder diagnoses had very different levels of functioning in their daily lives. I also noticed that patients with strong social relationships and resourceful family and friends often had more stability in their lives, were able to do more in their everyday routines, and generally received treatment earlier because their loved ones noticed when they were on a bad path before they did themselves and helped them seek treatment.

During my master's degree, I had the privilege of being accepted into the Research Honors Program and getting the opportunity to initiate a real research project for the first time. I was not in doubt. I typed into Google: "Social inequality in health research Jutland" (My willingness to travel to study social inequality was limited to Jutland.) The VestLiv cohort came up. Johan, an experienced professor, and Trine, now my co-supervisor, from the Department of Occupational Medicine, agreed to meet. When I walked into the meeting, I felt nervous speaking to a professor for the first time. However, when Johan confirmed that I was doing the project out of pure interest and not for financial reasons, he softened up and asked me what I wanted to study within social inequality in health. Without hesitation, I said, "Mental health." I came under Karin's wing, and three and a half years later—after a master's thesis, maternity leave, and countless funding applications—I started my PhD project.

List of Papers

This PhD dissertation is based on the following three papers, referred to by Roman numerals (Study I-III):

Study I: Sørensen CLB, Plana-Ripoll O, Bültmann U, Winding TN, Steen PB, Biering K. Social inequality in mental disorder diagnoses and psychotropic medication use among 15-year-old adolescents in Denmark from 2002–2022. *Social Psychiatry and Psychiatric Epidemiology*. Ahead of print. doi:10.1007/s00127-025-02943-y

Study II: Sørensen CLB, Plana-Ripoll O, Bültmann U, Winding TN, Steen PB, Biering K. Developmental trajectories in mental health through adolescence and adulthood: does socio-economic status matter? *Epidemiology and Psychiatric Sciences*. 2025;34:e33. doi:10.1017/S2045796025100073

Study III: Sørensen CLB, Larsen FB, Plana-Ripoll O, Bültmann U, Winding TN, Steen PB, Biering K. Estimating the associations between personal, health, lifestyle, and social factors on depressive symptoms from adolescence to adulthood: A fixed effect approach using panel data. *European Journal of Public Health.* Under review

Additional papers during my enrollment as PhD student

Sørensen CLB, Grønborg TK, Biering K. Test-retest reliability and factor structure of the Danish 6-item version of the Hopkins Symptom Checklist-core depression (SCL-6) in adolescents. BMC Pediatr. 2025 Mar 17;25(1):201. doi: 10.1186/s12887-025-05510-1. PMID: 40091030; PMCID: PMC11912736.

Chen D, Ejlskov L, Laustsen LM, Weye N, **Sørensen CLB**, Momen NC, Dreier JW, Zheng Y, Damgaard AJ, McGrath JJ, Sørensen HT, Plana-Ripoll O. The Role of Socioeconomic Position in the Association Between Mental Disorders and Mortality: A Systematic Review and Meta-Analysis. JAMA Psychiatry. 2024 Feb 1;81(2):125-134. doi: 10.1001/jamapsychiatry.2023.4316. PMID: 37966825; PMCID: PMC10652216.

Thorup L, Zulfikari M, **Sørensen CLB**, Biering K. "Body image and depressive symptoms in Danish adolescents: A cross-sectional national study". J Affect Disord. 2024 Nov 15;365:65-72. doi: 10.1016/j.jad.2024.08.016. Epub 2024 Aug 15. PMID: 39153549.

Sørensen CLB, Grønborg TK, Biering K. Test-retest reliability and factor structure of the Danish 6-item version of the Hopkins Symptom Checklist-core depression (SCL-6) in adolescents. BMC Pediatr. 2025 Mar 17;25(1):201. doi: 10.1186/s12887-025-05510-1. PMID: 40091030; PMCID: PMC11912736.

Thorup L, **Sørensen CLB**, Biering K. The Association between Work-Life Conflict and Mental Health-A Cohort Study. J Occup Environ Med. 2025 May 1;67(5):313-321. doi: 10.1097/JOM.0000000000003313. Epub 2025 Jan 10. PMID: 39793020.

Biering K, Schougaard LMV, Steen PB, Dørken EV, Glasscock D, **Sørensen CLB**. Translation, cross-cultural adaptation, and reliability of the Center for Epidemiological Studies Depression Scale for Children (CES-DC) in Danish adolescents. *Under review* in BMC Pediatrics.

Steen PB, Dalgaard VL, Andersen JH, **Sørensen CLB**, Bültmann U, Biering K. Perceived Stress Trajectories from Adolescence to early Adulthood: The Role of Sex and Social Status. *Under review* in Journal of Public Health.

Abbreviations

ATC: Anatomical Therapeutic Chemical Classification System

BIC: Bayesian Information Criterion

BMI: Body Mass Index

CES-D(C): Center for Epidemiological Studies Depression Scale (for Children)

CI: Confidence interval

CPR: unique identification numbers from the Danish Civil Registration System

DAG: Directed Acyclic Graph

FE: Fixed Effects

GBTM: Group Based Trajectory Modelling

GP: General Practitioner

ICD-10: 10th version of the International Classification of Diseases

IPW: Inverse Probability Weights

ISCED: International Standard Classification of Education

MI: Multiple Imputations

N: Number

NMI: Nordic Morbidity Index

OECD: The Organization for Economic Co-operation and Development

OR: Odds Ratio

POLS: Pooled Ordinary Least Squares

ROR: Relative Odds Ratio

SES: Socioeconomic status

WHO: World Health Organization

1. Introduction

Poor mental health is a concern globally. The World Health Organization (WHO) estimates that approximately 970 million people globally have a mental disorder, and 20% of children and adolescents are affected by mental disorders (1). Generally, the prevalence of mental health issues among adolescents has increased, raising concerns about the long-term consequences and the role of social inequalities in shaping mental health.

The following section summarizes the literature on the transition from adolescence to adulthood, mental health from a life course perspective, and time trends in mental health. Moreover, social determinants and other determinants of mental health are presented, along with the different definitions of mental health. Finally, the public health problem of poor mental health in adolescence is described through the lens of complex systems thinking.

1.1 Emerging adulthood – the transition from adolescence to adulthood

The transition from adolescence to adulthood has long been a central topic in developmental psychology and is widely recognized as a sensitive period for mental health. As early as 1950, German-American psychologist Erik Homburger Erikson emphasized the importance of identity formation during this developmental stage. He argued that confusion and instability in one's sense of self during this period could contribute significantly to poor mental health outcomes (2). From the 1950s to 2000, developmental psychology increasingly recognized adolescence and early adulthood as distinct and important life stages. Researchers such as the psychologist Daniel Levinson and the sociologist Glen Elder have emphasized transitional periods and the influence of social and historical contexts on development (3, 4). Simultaneously, the field of developmental psychopathology emerged, highlighting how biological, psychological, and social factors interact over time to shape mental health (5).

Building on this foundation, American psychologist Jeffrey Arnett introduced the concept of emerging adulthood in 2000, focusing on the age span of approximately 18–25 years. Arnett proposed that this stage represents a distinct developmental period demographically, subjectively, and in terms of identity exploration. His observations were based primarily on qualitative interviews with young people in their twenties and broader reviews of demographic and sociological data. He noted that the transition to adulthood has become increasingly prolonged due to societal shifts, such as later ages of marriage and parenthood and extended periods of education. As a result, emerging

adulthood is neither fully adolescence nor full-fledged adulthood. Emerging adulthood is a period with a lot of changes and choices, without the dependency of childhood and adolescence or the responsibilities of adulthood. As Arnett writes, "*Emerging adulthood is a time of life when many different directions remain possible, when little about the future has been decided for certain, when the scope of independent exploration of life's possibilities is greater for most people than it will be at any other period of the life course*" (6).

Subsequent research has linked identity formation during emerging adulthood to mental health outcomes. In particular, two aspects of identity development—commitment and exploration— are strongly associated with psychological well-being and distress (7). Arnett and colleagues have also highlighted the practical implications of distinguishing between adolescents, emerging adults, and adults in the context of mental health services. Emerging adults occupy a unique legal and psychological space: they are no longer minors and can refuse treatment, yet their experiences of instability and uncertainty may be normative—potentially even healthy—and not necessarily indicative of mental disorders, as similar symptoms might be in older adults (8).

Overall, the developmental stages of adolescence, emerging adulthood, and adulthood have distinct psychological and social characteristics. Recognizing these differences—and applying a life course perspective that considers how mental health evolves across these stages—is essential for understanding mental health trajectories over time.

1.2 A life course perspective on mental health

As described, the transitional period from adolescence to adulthood is marked by significant psychological, social, and biological changes. Mental health problems that emerge in adolescence and emerging adulthood can have lasting consequences, including educational challenges, labor market difficulties, and an increased risk of poor mental health outcomes in adulthood (9, 10). Therefore, mental health problems during this period are of great concern (10-12). The timing of poor mental health in the life course has changed, as the age of onset for mental disorder diagnoses has declined since the 1970s (13). According to Plana-Ripoll et al., this decline may reflect a combination of factors, including administrative changes in the healthcare system, demographic shifts, and changes in public and professional awareness and attitudes toward mental disorders (13).

Longitudinal studies of depressive symptom trajectories have provided insights into mental health development during the transitional period of adolescence and adulthood. A systematic review found that most adolescents (60-80%) had consistently low level of depressive symptoms, while 5-12% had persistently high level of symptoms, and 1-5% exhibited fluctuating symptoms between ages 15-25 (14). Key risk factors for persistent high levels of symptoms included being female, having a dopamine receptor phenotype, and belonging to a sexual or ethnic minority group. Conversely, strong parental support was associated with consistently low symptom levels (14). A study by Minh et al. conducted in Canada and the U.S. identified similar depressive trajectories but found that childhood socioeconomic status (SES) played a larger role in the U.S. compared to Canada, suggesting that national policies and social structures may influence how SES affects mental health (15). These findings underscore that depressive symptom trajectories are shaped not only by individual or familial factors but also by broader societal and structural conditions.

The role of SES in mental health is particularly dynamic and complex during the transition from adolescence to adulthood. Depression in emerging adulthood has been linked to later unemployment, suggesting that poor mental health early in adulthood can have long-term socioeconomic consequences (8). However, these negative outcomes may be mitigated by factors such as parental support, illustrating the importance of the social context in shaping life trajectories during this period (8). In this light, studying mental health trajectories within a Nordic welfare context, such as Denmark, is particularly relevant. The country's universal healthcare, access to education, and extensive social safety nets may mitigate some of the risks associated with low SES. Understanding how depressive symptoms unfold in such settings can provide critical insights into the potential of welfare policies to reduce mental health inequalities across the life course.

1.3 Time trends of mental health

Increasing levels of poor mental health are a global concern (1). For example, the U.S. experienced a 39.8% increase in patients with mental health diagnoses from 2019 to 2023 (16). Globally, self-reported measures of depressive symptoms also suggest rising rates, with point prevalence increasing from 24% in 2001–2010 to 37% in 2011–2020 (12). Similar trends have been documented in Denmark in recent decades, including rising rates of mental disorder diagnoses, increased use of psychotropic medication, and higher prevalence of self-reported mental health problems (13, 17-19). Notably, these increases have been particularly prevalent among adolescents and emerging adults (13, 18-21). For example, antidepressant use among 0-17-year-olds more than doubled from 2.15

users per 1,000 inhabitants in 2002 to 5.04 users per 1,000 in 2022 (20). This increase parallels the rising incidence rates of mental disorder diagnoses in 15-20-year-olds (21). For most mental disorder diagnoses, incidence rates among younger individuals were markedly higher in more recent birth cohorts than in previous generations (21). Thus, a shift in the time trends of mental health has occurred, but the explanations for this shift are poorly understood.

Several explanations have been proposed for the observed increase in mental health problems. Some suggest that lower diagnostic thresholds and increased mental health awareness (22). Others point to broader societal shifts toward "psychologization", where every day struggles are more often framed in clinical terms (23, 24). However, others argue that the rise reflects a genuine increase in mental health problems driven by growing pressures—academic, social, and cultural—that particularly affect young people (23, 25). These explanations are not mutually exclusive; rather, they likely capture different facets of a complex and multifaceted phenomenon.

Although these explanations differ, they share a common theme: the roles of social context and inequality. Whether through access to care, exposure to stressors, or broader societal changes, social determinants appear to shape the experience and recognition of mental health problems. Therefore, studying these social determinants in relation to mental health in adolescence and adulthood is essential, not only for understanding the underlying mechanisms of mental health problems but also for informing targeted prevention efforts and guiding effective policy responses.

1.4 Social determinants of mental health

In Denmark, the increasing prevalence of adolescent mental health problems has occurred alongside increasing social inequality. The Gini coefficient, a commonly used measure of income inequality that ranges from 0 (indicating perfect equality, where everyone has the same income) to 100 (indicating perfect inequality, where one person has all the income), increased from 24 in 2002 to 30 in 2022 (26). This increase is also reflected in the growing income ratio between the richest 10% and the poorest 10%, which rose from 2.67 in 2002 to 3.24 in 2022, meaning that the top 10% earned more than three times as much as the bottom 10% in 2022 (26). Educational mobility has also declined; in 2021, 60% of children from the poorest quintile who lacked vocational training remained in the poorest quintile compared to 39% in 1995 (27). Although the incidence of mental disorders has been studied extensively, SES-specific patterns of mental health incidence remain unknown in Denmark (28). A Canadian study investigating SES-specific trends in acute mental

health service use from 2004 to 2019 found that absolute income inequality decreased for hospitalizations due to mood disorders, while it increased for hospitalizations due to substance-related disorders and for emergency visits across all mental disorder (29). This highlights the need to understand how SES and adolescent mental health are connected and whether these associations have changed over time. Moreover, findings from different countries suggest that contextual factors may influence both the magnitude and nature of SES–mental health associations, underscoring the importance of country-specific research (30).

The association between SES and adolescent mental health is well documented. Several reviews have concluded that children and adolescents growing up in socioeconomically disadvantaged conditions face an elevated risk of developing mental health problems, and that persistent or worsening disadvantage over time increases this risk (30-34). However, SES is a multidimensional construct that is typically measured using either objective or subjective indicators, each capturing distinct aspects of social stratification. Objective indicators such as family income, parental education, and occupational class reflect different types of resources. Income signals access to material and economic resources, education reflects cognitive and cultural capital, and occupational class relates to both structural position and work-related exposures (35, 36). Geyer argues that occupational class captures the long-term effects of workplace organization and conditions, factors known to influence health independently of income or education (36). Moreover, research has shown that young employees in the public sector have a higher risk of sickness absence due to common mental disorders than those in the private sector, highlighting the complex interplay between workplace environment and mental health (37).

In contrast, subjective social status (SSS) captures how individuals perceive their position relative to others. These perceptions may encompass feelings of respect, social inclusion, or financial stress and may reflect the psychosocial mechanisms through which inequality "gets under the skin" (34, 35, 38). For adolescents, SSS may also be shaped by peer comparisons at school or in their communities and may therefore relate to social experiences such as exclusion or admiration (38, 39).

Importantly, different SES measures often show only weak to moderate correlations with each other, suggesting that they should not be used interchangeably (36, 40). Studies have shown that the strength and nature of the association between SES and adolescent mental health vary depending on which indicator is used (31, 34, 38-40). Some studies have found SSS to be a stronger and more

consistent predictor of poor mental health than objective indicators (35, 38) , while others have reported stronger associations for parental education or income (40).

Timing matters—not only in terms of when SES is measured, but also when mental health outcomes are assessed. Longitudinal research indicates that early life socioeconomic disadvantage can have lasting effects, although the strength of the associations may vary depending on the developmental timing of both exposure and outcome (31, 40). For example, Poulsen et al. found that the timing of exposure to low income and low parental education in early versus late childhood had differential impacts on depressive symptoms across Danish adolescence and young adulthood. Some findings also suggest that subjective SES in adolescence predicts depressive symptoms well into adulthood, although its influence may attenuate over time (39).

Taken together, these findings underscore the importance of using multiple SES indicators—both objective and subjective—measured over time when studying social inequalities in mental health. This can reveal different mechanisms and offer a more comprehensive understanding of how social stratification affects adolescent and adult mental health.

1.5 Definitions of poor mental health

Most existing research has investigated mental health in terms of mental disorder diagnoses or self-reported mental health in separate studies, while studies on psychotropic medication use are limited (13, 18, 19, 21, 28, 41). In Denmark, mental disorder diagnoses are only recorded in the registers if an individual has an inpatient or outpatient contact with a hospital; therefore, these records primarily reflect the most severe cases of mental health problems (42). Danish hospital registers are known to underrepresent mild to moderate mental disorders, which are often managed by general practitioners (GPs) or private psychiatrists and are therefore not captured in hospital-based registers (43). On the other hand, self-reported mental health measures represent symptoms that might not meet the threshold for a formal mental disorder diagnosis and thus represent a different aspect of mental health (44).

Psychotropic medication can be prescribed by GPs, private practice psychiatrists, and doctors from private hospitals; therefore, this measure can capture a wider range of mental health problems than diagnoses from public hospitals alone (45). However, psychotropic medications are sometimes prescribed for other indications, such as sleep disturbances, chronic pain, or menopausal symptoms,

which means that their use does not always reflect the presence of a mental disorder. This makes it more difficult to interpret this measure solely as an indicator of poor mental health. Consequently, studying multiple measures of mental health within the same population is necessary to provide a more comprehensive understanding of its different aspects and severity. Combining register-based diagnoses, self-reported symptoms, and prescription data allows researchers to address the limitations of each data source and obtain a more nuanced picture of the population's mental health.

1.6 Risk and protective factors of mental health

Mental health arises from the dynamic interplay of biological, psychological, and social influences. The biopsychosocial model offers a comprehensive framework for understanding how various factors shape mental health outcomes across development (46). Some of these factors, such as genetic vulnerability (47), are non-modifiable, while others, including coping skills, peer relationships, and school environments, are modifiable and therefore particularly relevant in a preventive context. Importantly, many modifiable factors can act as either risk or protective influences, depending on their presence or absence. This section highlights a selection of well-established risk and protective factors, focusing on adolescence. This list is not exhaustive but illustrates the diversity of mechanisms that contribute to mental health.

Biological factors include, among others, genetic predisposition, pubertal timing, and grey matter volume, all of which increase vulnerability to mental health problems (47, 48). Chronic physical illnesses or disabilities also contribute to psychological distress (49).

Psychological factors involve cognitive, emotional, and behavioral patterns. Experiences of adverse childhood experiences or stressful life events—such as abuse or neglect—are strongly associated with later mental health outcomes (47, 50-52). Other risk factors include poor coping strategies, low self-esteem, and emotion regulation, while protective psychological traits include strong self-efficacy, effective coping mechanisms, and a positive self-concept, which can help buffer against poor mental health (53-56). Also behavioral factors related to lifestyle can be both protective or risk factors, such as physical activity, smoking, diet, sleep, and alcohol use (54, 57-59).

Social factors are especially influential in adolescence. As mentioned earlier, socioeconomic disadvantage is a well-documented risk factor (30-34). Family dynamics also matter: high conflict,

low parental involvement, or lack of emotional support are associated with poor mental health, while warm, consistent parenting promotes well-being (51, 60-62). Additionally, a family history of mental disorders constitutes a risk factor for poor mental health (63). Social support in general is similarly important (51, 53, 54, 62, 64-66). Bullying, including cyberbullying, is linked to an increased risk of depression and anxiety, whereas supportive peer networks and a sense of belonging can protect against such outcomes (67, 68). School environments also play a role; academic pressure and lack of support can increase the risk, while a positive school climate can serve as a buffer (62, 66, 69).

In summary, mental health is influenced by a complex network of biological, psychological, and social factors. Many of these are modifiable and offer key targets for prevention strategies. Moreover, the same factor can serve as either a risk or protective influence, depending on its context, frequency, timing, and intensity. This complexity underscores the importance of a holistic, multisystem approach to understanding and addressing mental health issues.

1.7 Systems thinking approach to study mental health determinants

Many of the aforementioned studies on mental health determinants have focused on single risk factors, often through reductionistic approaches that are difficult to translate into public health interventions. However, some studies have outlined that mental health is influenced by a dynamic interplay of several underlying causes rather than isolated factors (70-72). Traditional models tend to oversimplify these relationships, overlooking the interaction of multiple factors over time. Öngör and Paulus argued that mental disorders should be understood as complex dynamic systems rather than linear cause-and-effect relationships. This perspective emphasizes the need for a complex systems approach to mental health research (73). Complex systems thinking approaches problem-solving by considering issues as elements within broader, interconnected systems. It emphasizes the importance of understanding how different parts of a system interact, influence one another, and collectively shape the system's overall behavior (74).

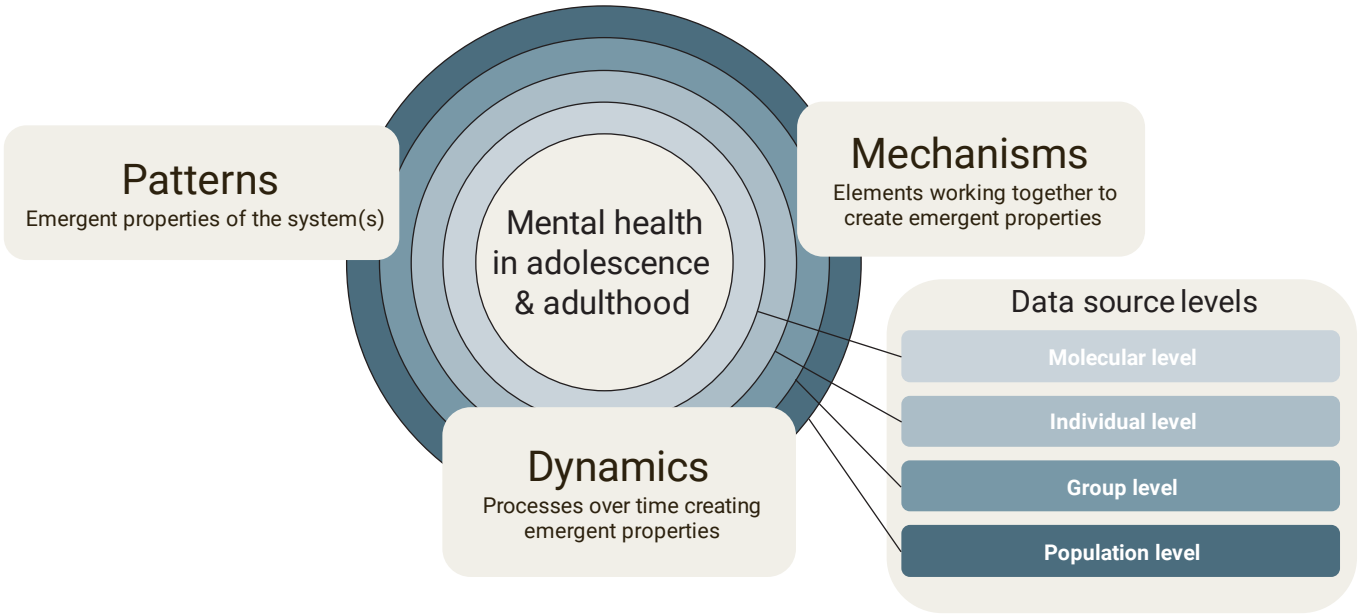
1.7.1 Health Complexity framework

Despite its growing relevance, systems thinking remains unfamiliar to many epidemiologists and health researchers, making it challenging to frame existing research from this perspective (75). However, many methods already used in epidemiology can contribute meaningfully to a systems perspective when their findings are interpreted within a broader conceptual framework. To support this conceptual shift, Rod et al. developed the Health Complexity Framework to help researchers

identify how their work contributes to understanding complex public health challenges and facilitate the translation of research findings into effective interventions (75). The framework distinguishes between the levels at which data are collected, from the molecular to the population level, and organizes the complexity of health problems into three key dimensions (Figure 1):

1. Patterns: How health patterns emerge from complex systems.
2. Mechanisms: The mechanisms that shape these patterns.
3. Dynamics: How mechanisms and patterns evolve over time.

Figure 1: The Health Complexity Framework adapted from Rod et al. (75)



1.7.2 Longitudinal cohort designs and complexity

To understand mental health as a dynamic and emergent phenomenon, study designs must capture both individual development over time and broader societal shifts that shape these trajectories. In this context, nationwide cohort studies offer a particularly valuable foundation for research. Denmark's unique data infrastructure, which links population registers across decades, makes it possible to examine time trends and emerging patterns in mental health at the population level. These trends may reflect evolving societal dynamics, such as changes in inequality, education, and healthcare access, which interact to shape the collective mental health of youth cohorts.

At the individual level, longitudinal cohort studies enable researchers to follow the same individuals over key developmental stages, such as adolescence, emerging adulthood, and adulthood. This allows for the investigation of dynamics, including how health-related patterns and mechanisms evolve over time. Survey-based cohorts further enrich this by collecting detailed information on a wide range of determinants. This richness makes it possible to explore the interactions and interdependencies among multiple biological, psychological, and social factors, which are core to a complex systems approach. By integrating both register and survey data, cohort studies are particularly well-suited to identify the emergent properties of mental health, offering insight into how diverse factors combine to produce population-level outcomes across the life course.

1.8 Synthesis and aims

The transitional periods of adolescence, emerging adulthood, and adulthood are particularly important when studying mental health, as each stage represents distinct life phases with varying implications for mental health and the consequences of poor mental health. Applying a life course perspective is therefore especially important. Recent research has shown a temporal shift toward an earlier age of onset in newer cohorts, making this issue increasingly urgent.

Trajectory studies of mental health provide valuable insights into its development during these life stages, making it relevant to study this in a Danish context. Mental health problems have increased across multiple indicators, including mental disorder diagnoses, psychotropic medication use, and self-reported mental health. Simultaneously, social inequality has increased. While the association between SES and mental health is well documented, the temporal trends in this association remain unclear.

Most studies have focused on a single SES indicator, typically an objective measure such as income, education, or occupational class, in relation to mental health. However, to fully capture the multifaceted nature of social inequality, it is essential to consider both objective and subjective SES measures, as they reflect different dimensions of social positions. Similarly, many studies assess only one aspect of mental health; however, considering multiple measures within the same population allows for a broader understanding of the different constructs of mental health. Finally, rather than analyzing individual mental health determinants in isolation, we need approaches that capture the complex and dynamic interplay of multiple underlying determinants of poor mental health status.

To address these knowledge gaps, this dissertation interprets the findings through the lens of the Health Complexity Framework to improve their translation into public health initiatives. The overarching goal of this study is to inform targeted age-sensitive mental health prevention strategies.

The specific objectives are to:

I) Examine time trends in social inequality in adolescent mental health from 2002 to 2022, using family income and parental education as SES indicators and mental disorder diagnoses and psychotropic medication use as outcome measures among 15-year-olds.

II) Investigate the SES patterns in mental health from adolescence to adulthood (aged 15-32) by examining the mean, prevalence, cumulative incidence, and trajectories of several mental health measures, including depressive symptoms, mental disorder diagnosis, and psychotropic medication use.

III) Investigate the association between age-specific changes in explanatory factors, encompassing personal, health, lifestyle, and social factors, and changes in depressive symptoms in individuals aged 15-32.

2. Methods

In the following section, the setting, study populations, study designs, data sources, variables, and statistical analyses for the three studies are described. An overview of the studies is presented in Table 1.

Table 1: Overview of the studies

	Study I	**Study II**	**Study III**
Topic	Time trends in social inequality in adolescent mental health	Life course perspective on mental health	Life course perspective on mental health determinants
Study design	Multiple cross-sectional cohort studies	Longitudinal cohort study	Longitudinal cohort study
Population(s)	15-year-olds living in Denmark in the period 2002-2022	VestLiv participants (aged 15-32)	VestLiv participants (aged 15-32)
Data sources			
Surveys	Yes	Yes	Yes
Registers	Yes	Yes	Yes
Outcome(s)	Mental disorder diagnoses Psychotropic medication use	Mental disorder diagnoses Psychotropic medication use Depressive symptoms	Depressive symptoms
Exposure(s)	Parental educational level Family income	Parental educational level Family income SSS in school SSS in society	Coping Self-esteem Sense of coherence Stress Psychosomatic symptoms Self-rated health Physical activity Smoking BMI Bullying
Additional variables	Sex Origin Cohabitation Family's mental health Family's multimorbidity Own multimorbidity	Sex Origin Cohabitation Family's mental health Family's multimorbidity Own multimorbidity School pressure Teachers' social support Classmates' social support Bullying Parents' support	Sex Origin Parental educational level Family income SSS in school SSS in society Mental disorder diagnoses Psychotropic medication use
Primary statistical analyses	Logistic regression	Group based trajectory modelling	Fixed effect regression
Handling of missing data			
IPW	Yes	Yes	Yes
MI	Yes	Yes	Yes

Note: BMI=Body Mass Index, SSS=Subjective Social Status, IPW=Inverse Probability Weights, MI=Multiple Imputations

2.1 Settings, study populations, and study designs

2.1.1 15-year-olds in Denmark (Study I)

The population consisted of all registered residents in Denmark who turned 15 years in the period between 2002-2022, identified through unique identification numbers (CPR) from the Danish Civil Registration System (76). Study I is a nationwide register-based cohort study comprising cross-sectional analyses of the associations between adolescents' SES, defined by family equivalized income and Parental educational level, and mental health outcomes, defined by mental disorder diagnoses and psychotropic medication use. The analyses cover seven three-year periods from 2002 to 2022.

2.1.2 VestLiv cohort (Study II & III)

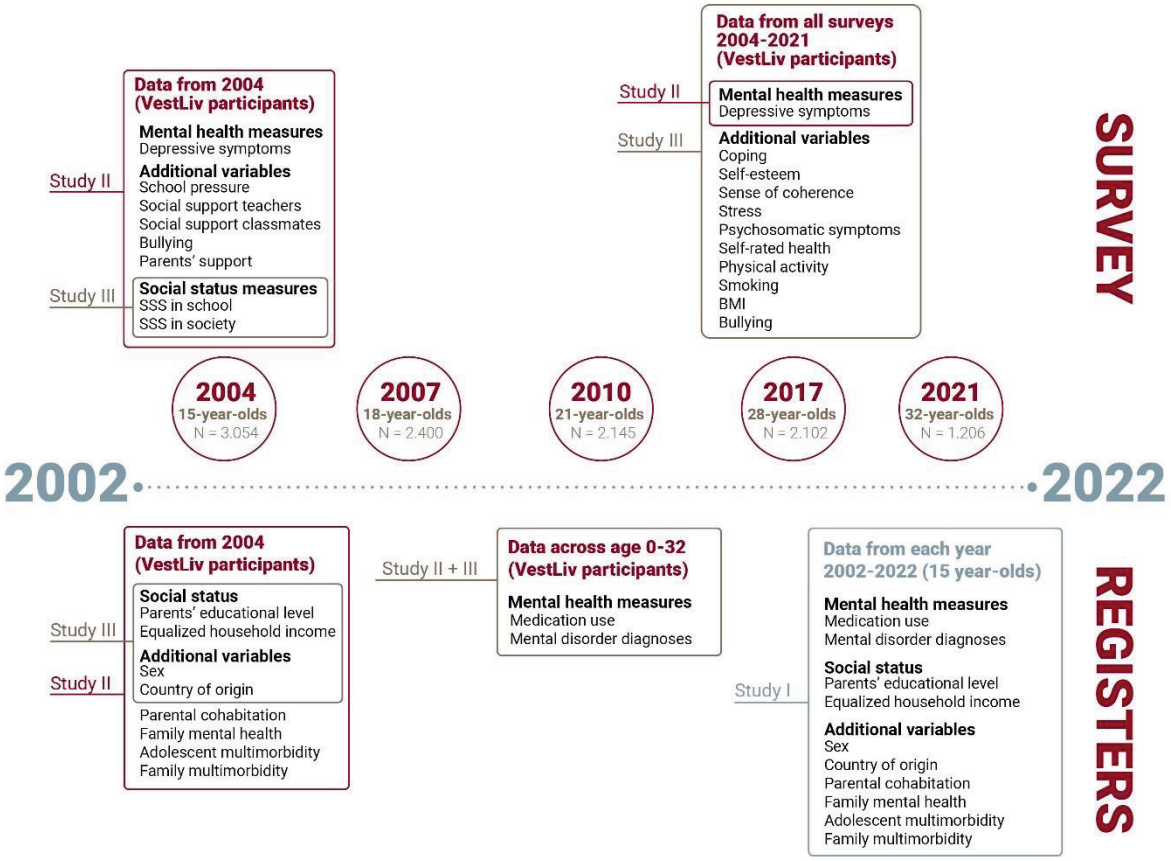
The VestLiv Cohort is a longitudinal cohort study following a population of adolescents born in 1989 and living in the western part of Denmark in 2004 (the former Ringkjøbing County). A total of 3,681 adolescents were invited to participate, and 3,054 (83%) responded at age 15, with subsequent follow-ups at ages 18 (65%), 21 (58%), 28 (57%), and 32 (33%) (77).

The initial survey was conducted in April 2004 using paper-based questionnaires completed during school hours, with researchers visiting all schools in the area. Adolescents who were absent received the questionnaire via post. All public and private schools in the area participated, except for special-needs schools. In 2007, follow-ups were distributed via email and post, whereas the 2010, 2017, and 2021 follow-ups were sent electronically. All individuals from the original cohort were invited to each follow-up, regardless of prior participation, unless they actively withdrew from the study. The surveys covered health, family, social life, school, work, and well-being and were linked to a range of register data from Statistics Denmark using the CPR numbers (76). Study II and III are both longitudinal cohort studies.

2.2 Data sources and variables

The data originated from the national Danish registers and the VestLiv cohort surveys. In the following section, the origin, temporal context, and definitions of mental health outcomes, social status measures, and additional variables are described in detail. An overview of the variables, data sources, and timing of data extraction is presented in Figure 2.

Figure 2: Overview of variables, data sources, and timing of data extraction in Studies I, II, and III.



2.2.1 Outcomes

2.2.1.1 Mental disorder diagnoses

Mental disorder diagnoses are defined by the Danish modification of the 10th version of the International Classification of Diseases (ICD-10) codes F10-F69 and F80-F99, thus excluding F00-F09 (organic diagnosis) and F70-79 (intellectual disabilities), as these conditions either have late-onset or are congenital, often originating in early childhood. Mental disorder diagnoses from the psychiatric and somatic units from 1995 to 2022 were identified in the Danish National Patient Registry (42, 78). Outpatient data were unavailable before 1995; therefore, we included only data from 1995 onwards. Both primary and secondary diagnoses were included.

Study I: The mental disorder diagnoses are presented in 8 diagnostic groups: substance use disorders (F10-F19); schizophrenia, schizotypal, and delusional disorders (F20-29)—hereafter referred to as "psychotic disorders"; mood disorders (F30-39); neurotic, stress-related, and somatoform disorders (F40-48)—hereafter referred to as "anxiety-related disorders"; eating disorders (F50-59); personality disorders (F60-69); developmental disorders (F80-89); behavioural disorders (F90-98); and a joint

category of "Any mental disorder". Diagnoses were recorded from birth or 1995 until six months after the 15th birthday.

Studies II & III: Diagnoses, defined using the same criteria for "Any mental disorder" as in Study I, are categorized as present/not present in the following age groups: early childhood (0-5), childhood (6-12), adolescence (13-17), adulthood (18-32), and in the study period (15-32). Study II also presents diagnoses for each year of age in the range of 15-32 years.

2.2.1.2 Psychotropic medication use

Psychotropic medication use was identified using Anatomical Therapeutic Chemical (ATC) codes: N05A (excluding N05AN), N05B, N05C, N06A, N06B, N06C (excluding N06AX01 & N06AX02), N07BB, and N07BC. Data were retrieved from the Danish National Prescription Register (79). Indication codes are used to ensure that medications are prescribed for mental health–related purposes.

Study I: Psychotropic medication use was recorded from six months before to six months after the 15th birthday of the adolescent.

Studies II and III: Psychotropic medication use was categorized as present/not present within these age groups: young childhood (0-4), childhood (5-12), adolescence (13-17), adulthood (18-32), and in the study period (15-32). Study II also presents psychotropic medication use for each specific year of age (15-32 years).

2.2.1.3 Depressive symptoms

In the VestLiv cohort, depressive symptoms were assessed using the 4-item version of the Centre for Epidemiological Studies Depression Scale for Children (CES-DC4) at ages 15, 18, and 21, and the adult version (CES-D4) at ages 28 and 32. The four items of the scale are each scored from 0-3, resulting in a sum score from 0-12, with higher scores indicating more depressive symptoms (44).

Studies II & III: Depressive symptoms were the primary outcome, measured continuously.

2.2.2 Social status measures

2.2.2.1 Family income

Equalized family income is a measure of disposable household income weighted by the number of family members. A family is defined as people living at the same address, and the income measure is adjusted according to the number of adults and children in the household. The variable was obtained from the Register of Family Income (80).

Study I: We calculated the mean equalised family income for the year before, the year of, and the year after the adolescent's 15th birthday. Using a three-year average reduces potential information bias from temporary income fluctuations, such as financial losses due to poor investment years (81). If data were available for fewer than three years, the available years were used. The equalised family income was then categorised according to the OECD definition into low (lowest 20%), middle (60%), and high (highest 20%) income groups for each birth cohort, before the cohorts were grouped in three-year periods (82).
Studies II & III: The population consisted of participants from the VestLiv cohort. We calculated the mean equalised family income for the year of the initial survey (2004), the year before, and the year after the survey. If data were available for less than three years, this data was used. Categorisation into low-, middle-, and high-income groups was handled according to the OECD definition, as in Study I.

2.2.2.2 Educational level

Parents' highest educational level is categorized according to the Danish version of the International Standard Classification of Education (ISCED) into three groups: short (up to secondary school; ISCED 0-2), middle (upper secondary school, vocational education, or short-cycle tertiary education; ISCED 3-5), and long (bachelor's degree or higher; ISCED 6-8) (83). Parents were defined as legal guardians identified through the family ID from the Population Register, and educational data were obtained from the Register of the Highest Completed Education (84, 85).
Studies I, II & III: Parental education data were collected at the date of the adolescents' 15th year (Study I) or the date of the initial survey (Studies II and III).

2.2.2.3 Subjective Social Status

In the VestLiv cohort, SSS was measured at age 15 in two domains, school and society, using the MacArthur Scale of Subjective Social Status – Youth Version (MacArthur scale). Adolescents ranked themselves on a 10-step ladder, representing the social hierarchy in their class (SSS in school) and their family's position in society (SSS in society) (86). Three SSS groups were defined: low (steps 1-4), middle (steps 5-8), and high (steps 9-10).
Studies II & III: The categorized SSS in school and society were included in the analyses.

2.2.3 Additional variables

2.2.3.1 Additional variables from registers

The register-based covariates included sex, country of origin, parental cohabitation, family history of mental disorders, adolescent multimorbidity, and family multimorbidity. The variables sex and origin were used in all three studies, while the rest of the register-based covariates were used in Studies I and II.

Sex was classified as male or female. Country of origin was categorized as born in Denmark or born outside Denmark. Parental cohabitation was defined as legal parents living in the same household as the adolescent from birth until the 15th birthday (Study I) or the date of the initial survey (Study II). This measure was dichotomized as parental cohabitation since birth versus no parental cohabitation. Data on sex, origin, and cohabitation were obtained from the Population Register (84).

Family history of mental disorders was defined as the presence of a mental disorder diagnosis or prescription of psychotropic medication in siblings or parents. Siblings were defined as individuals under 25 years old living in the same household as the adolescent at the time of their 15th birthday (Study I) or initial survey (Study II). Parents were defined as legal guardians. Mental disorder diagnoses were assessed from birth (or from 1995) until the adolescent's 15th birthday (Study I) or initial survey (Study II). Psychotropic medication use was measured six months before and after the adolescent's 15th birthday (Study I) or the initial survey (Study II). The presence of a family mental disorder was coded dichotomously (yes/no) based on diagnoses and/or the use of psychotropic medications. The definitions and data sources for mental disorder diagnoses and psychotropic medication use are detailed in Sections 2.2.1.1 and 2.2.1.2.

Multimorbidity in adolescents, siblings, and parents was assessed using a modified version of the Nordic Multimorbidity Index (NMI). The NMI includes 50 multimorbidity predictors weighted from -2 to 22 (87). The index date was defined as the 15th birthday (Study I) or the initial survey date (Study II). The predictors were based on ICD-10 codes in the 5 years before the index date and ATC codes in the 6 months before the index date. Mental disorder-related ICD-10 codes (F10, F17) and psychotropic medication ATC codes (N05A, N05BA, N05CD, N05CF, N06A, N07BC) were excluded from the NMI, as they were part of the outcome measure for adolescents and the family mental disorder covariate (87). Data were retrieved from the National Patient Registry and the Danish National Prescription Register (78, 79).

2.2.3.1 Additional variables from surveys

In Study II, five covariates from the 2004 survey were included: school pressure, social support from teachers, social support from classmates, bullying, and parental support.

- School pressure was measured using two items developed by Flemming Balvig (scored 0-2) and one item from the Health Behavior in School-aged Children (HBSC) survey (scored 0-3), resulting in a total score of 0-7. Higher scores indicate greater school pressure (88, 89).
- Social support from teachers was assessed using one item from the OECD PISA project (scored 0-3) (61). The measure was dichotomized (0-1 = support; 2-3 = no support) (90).
- Social support from classmates was measured using two items from the HBSC survey (scored 0-4 each). The measure was dichotomized (0-4 = no support; 5-8 = support) (89).
- Bullying was assessed using one item from HBSC (89). The score of 1-5 was dichotomized as not bullied (1 = "Never") or bullied (2 = "Sometimes", 3 = "Monthly", 4 = "Weekly", 5 = "Daily").
- Parental support was measured using a shortened version of the Parental Bonding Instrument (PBI) with four items (scored 0-3) per parent (total score 0-12). A continuous measure was used, averaging total scores across parents when applicable, otherwise using a single parent's score. Higher scores indicate greater support (91).

In Study III, explanatory variables were categorized into four groups: *Personal, Social, Health*, and *Lifestyle Factors*.

Personal factors included coping, self-esteem, and sense of coherence.

- In all five surveys, coping was measured using seven items from "Brief COPE scale", each scored 1-4 (7-28 total score) (92). Questions in the subscale "Avoidant coping" were discarded, as they represent undesirable coping strategies.
- Self-esteem was measured using six items from Rosenberg's self-esteem scale each scored 1-4 (6-24 total score) in all five surveys (55).
- Sense of coherence was measured using four items from the adapted version of Antonovsky's Orientation to Life Questionnaire, short form (SOC-13), fitted for adolescents. Each item was scored from 1-5, resulting in a sum score of 4-20. One question had a slightly different wording in the 2004 survey compared to the rest of the surveys (93, 94).

Health factors included stress, self-rated health, and psychosomatic symptoms.

- Stress was measured using four items from the Perceived Stress Scale (PSS) scored 0-4 (total score 0-16) (95, 96). The version for adolescents was used at ages 15, 18, and 28, and the version for adults was used at ages 28 and 31.
- In all surveys, self-rated health was measured with one item from SF-36 scored 1-5 (97).
- Psychosomatic symptoms were measured using five items from the Hopkins Symptom Checklist 90 in all surveys. Each item was scored 1-4, resulting in a sum score of 5-20 total score (98).

Lifestyle factors included physical activity, Body Mass Index (BMI), and smoking.

- Physical activity was measured with 1 item from Youth Risk Behaviour Survey 2003 with a score of 1-6 (99). In the surveys in 2017-2021, the most extreme category of 7+ hours was divided into two categories–7-10 hours and 11+. These were categorised together to ensure the same scoring in all surveys.
- Smoking was measured with 1 item from Youth Risk Behaviour Survey 2003 scored 1-4 (99). In the surveys 2007-2021 the answer "No" was divided into "No, never smoked" and "No, but smoked previously". These were handled as "No" to ensure the same scoring for all surveys.
- BMI was calculated based on self-reported height and weight (BMI = weight/height^2).

Social factors included bullying (68).

- Bullying was measured using one item from the HBSC with a score of 1-5. In 2004, 2007, and 2010, the question concerned bullying at school/education (89). In 2007, 2017, and 2021, the question concerned bullying at work. In 2007, the answer with the highest score for either bullying at work or education was used.

2.3 Statistical analyses

2.3.1 Handling of missing data

Multiple imputations (MI) using chained equations were applied in all three studies to address the missing data, as described below.

Study I: MI was performed with 10 iterations to account for missing data on income and education level. The number of iterations was chosen based on the rule of thumb that the number of iterations should be at least equal to the percentage of missing cases (100). The imputation models incorporated year, sex, adolescents' multimorbidity, parents' multimorbidity, siblings'

multimorbidity, adolescents' psychotropic medication use, adolescents' mental disorder diagnosis and diagnosis group, siblings' and parents' mental disorder, parental cohabitation, parental educational level, and family income expressed as a mean of 2.5 years before and 2.5 years after the 15th birthday of the adolescent.

Study II: MI was performed with 100 iterations to compensate for missing values in SES measures and covariates from the 2004 survey. At the time, we were not aware of the rule of thumb regarding the number of iterations and instead used 100 imputations, as done in previous studies (101). While depressive symptoms were included in the imputation of covariates, MI was not applied to the outcome, as imputing the outcome based on the same model as the covariates did not add information to the analysis (102, 103).

Study III: MI was performed using 56 iterations. As mentioned earlier, the number of iterations was determined based on the rule of thumb that it should match the highest percentage of missing data in any variable included in the models (100). MI was applied to address missing values in the explanatory variables and depressive symptoms across all surveys. The models incorporated information from different surveys along with data from registers on sex, SES, psychotropic medication use, and mental disorder diagnoses (81). Unlike in Study II, MI was applied to the outcome of depressive symptoms in Study III to ensure a consistent population size across surveys, which is an essential requirement for modelling within-person changes over time.

2.3.2 Handling of non-participation

To account for the unequal probability of participation in the VestLiv cohort, inverse probability weights (IPW) were applied in Studies II and III (104). The selection of covariates in the IPW models was based on Directed Acyclic Graphs (DAGs) (104).

Study II: The probability of being sampled in 2004, 2007, and 2010 was estimated based on sex, parents' mental disorder diagnoses, adolescents' mental disorder diagnoses, parental educational level, and equalized family income. For the 2007 and 2010 surveys, the sum score of depressive symptoms from previous surveys and participation in previous surveys were also included. The probability of being sampled in 2017 and 2021 was calculated using sex, parents' mental disorder diagnoses, adolescents' mental disorder diagnoses, adolescents' psychotropic medication use, own educational level, equalized family income, labor market participation, the sum score of depressive symptoms from earlier surveys, and participation in earlier surveys.

Study III: The analytical sample was restricted to individuals who completed at least three of the five questionnaires. Because selection was not linked to individual surveys (as in Study II), a single IPW

was calculated using data spanning the entire cohort period (ages 15–32). The probability of being included in the analytical sample was estimated based on sex, parents' mental disorder diagnoses, adolescents' mental disorder diagnoses, adolescents' psychotropic medication use, adolescents' country of origin, mean depressive symptoms across surveys, and several SES measures (parental educational level, own educational level, own labor market participation, and equalized family income).

2.3.3 Descriptive statistics

Descriptive statistics were reported using counts and percentages for categorical variables and means with 95% confidence intervals (CI) for continuous variables across all three studies.

Study I: Characteristics were presented for each of the seven 3-year cohorts spanning 2002–2022.

Study II: Characteristics were presented for the different samples used in the study: the mental disorder diagnosis sample, the medication use sample, the trajectory sample, and the samples for each of the five surveys. To prevent reverse causality, individuals with prior psychotropic medication use before age 15 years were excluded from the medication prevalence analyses, and those with mental disorder diagnoses before age 15 years were excluded from the cumulative incidence analyses. The mean sum score of depressive symptoms across all surveys, prevalence of psychotropic medication use (ages 15–32), and cumulative incidence of mental disorder diagnoses (ages 15–32) were calculated with 95% CIs for each SES measure. Due to the small sample sizes, psychotropic medication use at ages 15–17 was combined into a single category.

Study III: Characteristics of the analytical sample were described using information from the 2004 survey (age 15) with counts and percentages. Depressive symptoms were described for the characteristics at each age point, as well as the mean changes in depressive symptoms between age points. Additionally, the mean values and prevalence of the explanatory variables and their within-person changes between age points were reported. Since variation in explanatory variables was essential for evaluating their association with changes in depressive symptoms, it was examined whether variables had less than 10% mean change between age points, and inclusion had to be reconsidered in the models (105).

2.3.4 Analytical approaches

2.3.4.1 Study I

Odds ratios (OR) with 95% CI were estimated using logistic regression to assess the association between equalized family income and mental health measures. These models were adjusted for

country of origin, adolescent multimorbidity, sibling multimorbidity, parental multimorbidity, sibling mental disorders, parental mental disorders, and cohabitation.

For analyses of parental education level and mental health measures, ORs were estimated using logistic regression adjusted for country of origin, parental NMI, and parental mental disorders. Covariate selection was based on the existing literature and the drawing of DAGs.

Sensitivity analyses were performed using mental disorder diagnoses from age 7 onwards instead of from birth or 1995 to account for the unavailability of registered data in early life in the earliest cohorts.

2.3.4.2 Study II

Mental health trajectories from ages 15 to 32 were identified using group-based trajectory modelling (GBTM) applied to depressive symptom scores (CES-D(C)4) (28, 106). The modelling process involved the following three steps:

1. The optimal number of trajectory groups was determined using Bayesian Information Criterion (BIC), ensuring that all groups had a minimum size of 5%.
2. The best-fitting trajectory shapes (linear, quadratic, or cubic) were selected based on the lowest BIC, group sizes above 5%, average posterior probability of assignment (APPA) >70% for each group, and odds of correct classification (OCC) >5.0 (106).
3. Individuals were assigned to the trajectory group with the highest probability, and descriptive statistics were calculated for each group. Logistic regression was then used to estimate relative odds ratios (ROR) of membership in each trajectory group compared to a reference trajectory group.

2.3.4.3 Study III

Fixed-effects (FE) regression models were used to assess within-individual associations between changes in explanatory variables and depressive symptoms between the ages of 15 and 32. Depressive symptom scores served as the dependent variable, while the explanatory variables were independent variables. FE estimates were compared with pooled ordinary least squares (POLS) estimates using the Hausman test to confirm the model's suitability (105, 107).

Since FE regression relies on within-individual changes, all time-invariant confounders were inherently controlled for. Additionally, the models included all explanatory variables to account for mutual effects and were adjusted for the survey to control for cohort aging and temporal trends (107, 108). Dominance analysis was applied to assess the relative importance of the explanatory variables. This method decomposes and compares the contribution of each independent variable to the

explained variance in depressive symptoms by analyzing the intra-individual variance within the FE model (109, 110). Analyses of asymmetric changes were conducted to explore whether the associations between explanatory variables and depressive symptoms differed depending on the direction of change. A modified first-difference method developed by Paul D. Allison was used for both the FE and asymmetry analyses (107, 108).

2.3.5 Programming

All analyses were conducted on Statistics Denmark's secure server. Study I was performed using Stata version 17, whereas Studies II and III were conducted using Stata version 18 (111). Some plots were generated in R Studio (Version 4.4.1).

2.4 Approvals

The study was originally approved by the Danish Data Protection Agency and later registered in the regional database of research studies (Case no.: 1-16-02-547-15). No approval from the ethical committee was required as the study used register and survey data only (112).

3. Results

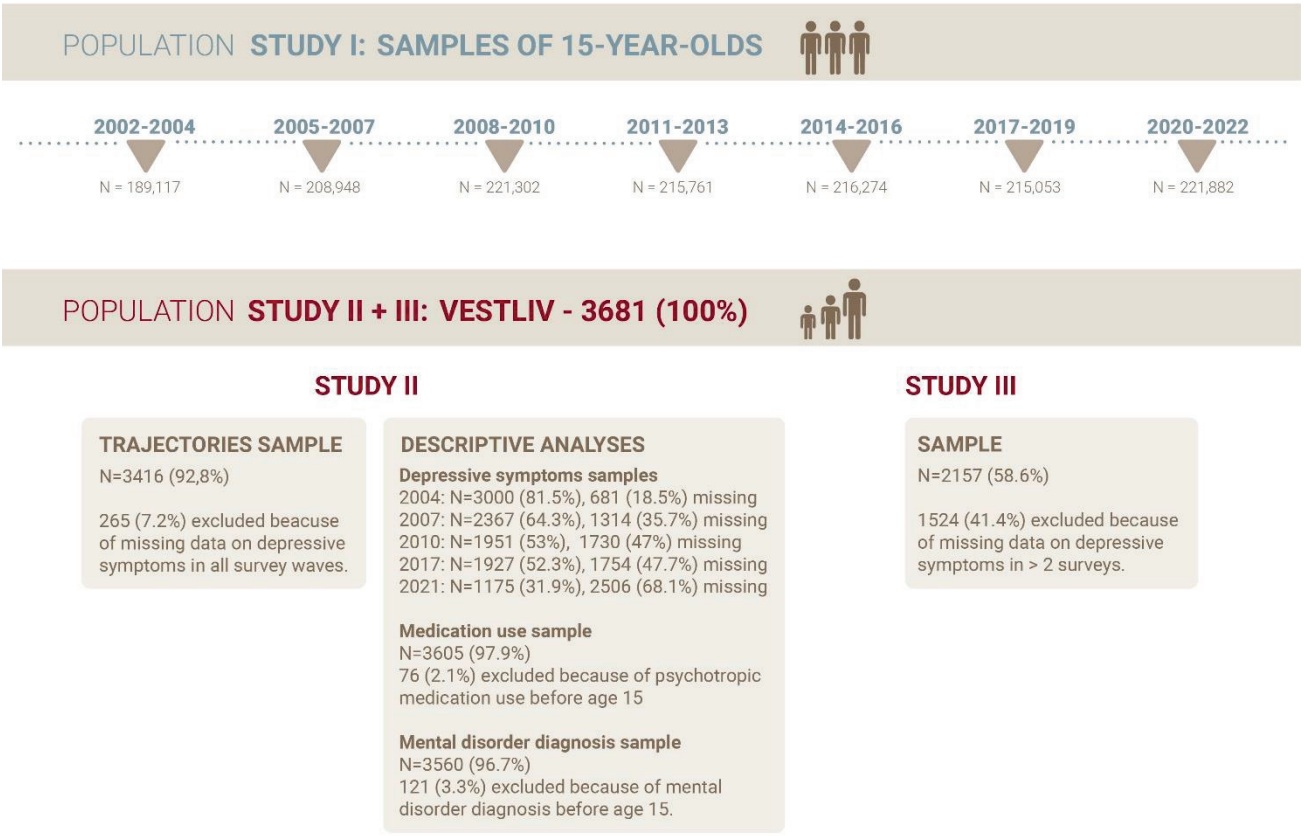
This section presents the main findings from the three studies. Full results and detailed tables are available in the article manuscripts included in the appendix. An overview of the study populations is provided in Figure 3.

In Study I, adolescents were grouped into 3-year periods, with sample sizes ranging from 189,117 to 221,882 individuals.

In Studies II and III, analyses were based on the VestLiv cohort, which included 3,681 individuals. In Study II, the samples answering depressive symptoms in the surveys declined over time—from 82% in 2004 to 32% in 2021. Among participants, 97.9% had no history of psychotropic medication use before age 15 and were included in the medication use analyses, while 96.7% had no recorded mental disorder diagnosis before age 15 and were included in the diagnosis analyses. For the trajectory analyses, 92.8% of participants responded to at least one depressive symptoms questionnaire and were thus included.

In Study III, 2,157 VestLiv participants who completed the depressive symptoms questionnaire in at least three survey waves were included in the analytical sample.

Figure 3: Overview of included populations



3.1 Time trends in social inequality in adolescent mental health (Study I)

This study aimed to examine time trends in social inequality in adolescent mental health from 2002 to 2022, using family income and parental education as SES indicators and mental disorder diagnoses and psychotropic medication use as mental health measures among 15-year-olds.

3.1.1 Descriptive results

Descriptive analyses of adolescents grouped into 3-year periods revealed an increase in the prevalence of any mental disorder diagnosis over the past two decades, rising from 6% in 2002–2004 to 19% in 2020–2022 (Table 2). Notably, the trends varied by diagnostic category. The largest increases were observed for behavioral disorders (+5 percentage points), developmental disorders (+3.9 percentage points), and anxiety-related disorders (+3.3 percentage points), whereas the prevalence of other disorders remained relatively stable (e.g. personality disorders) or declined (e.g. substance use disorders). Similarly, the prevalence of psychotropic medication use increased from 2% to 9% during this period. Over this period, there was also a shift in parental educational attainment, with a growing proportion of parents completing longer education programs.

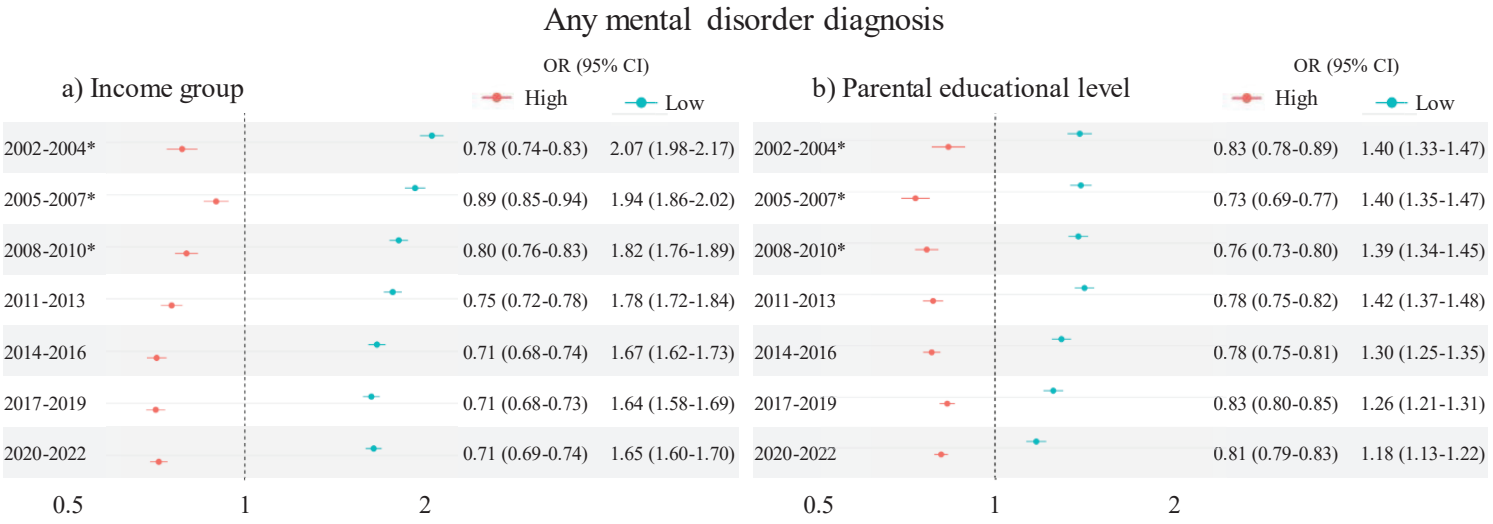
Table 2: Characteristics of 15-year-olds grouped in 3-year periods

Cohort		2002-2004* N=189,117	2015-2007* N=208,948	2008-2010* N=221,302	2011-2013 N=215,761	2014-2016 N=216,274	2017-2019 N=215,053	2020-2022 N=221,882
Mental disorder diagnosis	Any mental disorder	11890 (6.3%)	17097 (8.2%)	23168 (10.5%)	26758 (12.4%)	33466 (15.5%)	36967 (17.2%)	43080 (19.4%)
	Substance use disorders	1390 (0.7%)	1548 (0.7%)	1581 (0.7%)	905 (0.4%)	740 (0.3%)	556 (0.3%)	571 (0.3%)
	Psychotic disorders	254 (0.1%)	334 (0.2%)	414 (0.2%)	531 (0.2%)	663 (0.3%)	731 (0.3%)	805 (0.4%)
	Mood disorders	552 (0.3%)	785 (0.4%)	1101 (0.5%)	1348 (0.6%)	1749 (0.8%)	1626 (0.8%)	1581 (0.7%)
	Anxiety-related disorders	2252 (1.2%)	3643 (1.7%)	4617 (2.1%)	5722 (2.7%)	7491 (3.5%)	8750 (4.1%)	9892 (4.5%)
	Eating disorders	587 (0.3%)	771 (0.4%)	1086 (0.5%)	1377 (0.6%)	1688 (0.8%)	1947 (0.9%)	2454 (1.1%)
	Personality disorders	376 (0.2%)	369 (0.2%)	399 (0.2%)	367 (0.2%)	442 (0.2%)	346 (0.2%)	325 (0.1%)
	Developmental disorders	2099 (1.1%)	3307 (1.6%)	5023 (2.3%)	6167 (2.9%)	8177 (3.8%)	9559 (4.4%)	11179 (5.0%)
	Behavioral disorders	4380 (2.3%)	6340 (3.0%)	8947 (4.0%)	10341 (4.8%)	12516 (5.8%)	13452 (6.3%)	16273 (7.3%)
Medication use	Age 14.5-15.5	2951 (1.6%)	5246 (2.5%)	9483 (4.3%)	11559 (5.4%)	13691 (6.3%)	15133 (7.0%)	19766 (8.9%)
Household income	High	37540 (19.9%)	41459 (19.8%)	43686 (19.7%)	42456 (19.7%)	42252 (19.5%)	41927 (19.5%)	43148 (19.4%)
	Middle	112828 (59.7%)	124657 (59.7%)	131829 (59.6%)	128580 (59.6%)	129047 (59.7%)	128274 (59.6%)	132161 (59.6%)
	Low	38750 (20.5%)	42832 (20.5%)	45787 (20.7%)	44725 (20.7%)	44975 (20.8%)	44852 (20.9%)	46573 (21.0%)
Educational level	High	21266 (11.2%)	25454 (12.2%)	29497 (13.3%)	33376 (15.5%)	39349 (18.2%)	46216 (21.5%)	54153 (24.4%)
	Middle	136610 (72.2%)	152973 (73.2%)	163028 (73.7%)	156705 (72.6%)	153254 (70.9%)	147020 (68.4%)	147439 (66.4%)
	Low	31241 (16.5%)	30521 (14.6%)	28778 (13.0%)	25679 (11.9%)	23671 (10.9%)	21817 (10.1%)	20290 (9.1%)

*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.
Note: data on 0.6% of educational level and <0.1% of household income are imputed. Results presented in this table are selected and adapted from the full tables reported in the manuscript

3.1.2 Associations between SES measures and mental disorder diagnoses

The analysis of the associations between income and mental disorder diagnoses revealed that adolescents from low-income groups consistently had higher odds of any mental disorder diagnosis than the middle-income reference groups. Conversely, adolescents from high-income families had consistently lower odds across all periods (Figure 4a), and similar trends were observed for parental educational level. Adolescents with parents in the long-education groups had consistently lower odds of any mental disorder diagnosis compared with the middle group, while those with parents in the short-education groups had higher odds overall (Figure 4b). While the strength of the associations between high income over time or long education and lower odds of diagnosis compared with the middle groups remained relatively stable, the associations for low income or short education and diagnosis appeared to weaken over time.



*Mental disorder diagnosis not available since birth, but only available from year 1995

Note: Models a) are adjusted for country of origin, adolescent's chronic illness, siblings' chronic illness, parents' chronic illness, siblings' mental disorder, parents' mental disorder, and cohabitation and b) are adjusted for country of origin, parents' chronic illness and parents' mental disorder

Figure 4: Odds ratios (OR) of any mental disorder diagnosis by a) income group and b) parental educational level.

Diagnosis-specific income analyses revealed distinct trends over time (Figure 5). Among adolescents in the high-income group, the ORs relative to the middle-income group remained relatively stable across most diagnoses, consistently indicating lower odds of mental disorder diagnosis. Exceptions included mood disorders, where the difference diminished in the most recent cohort, and eating disorders, for which the ORs were comparable throughout the study period. For the low-income group, the odds of being diagnosed with most mental disorders were higher than those in the middle-income group across all time periods. However, these associations weakened over time for several

diagnoses, including psychotic, mood, personality, developmental, and behavioral disorders. In contrast, the association strengthened for substance use disorders. For eating disorders, the odds for the low- and middle-income groups remained comparable across the entire period.

In the analyses of parental educational level and specific mental disorder diagnoses (Figure 6), the direction and strength of the associations varied across diagnostic categories. Notably, associations with mood and eating disorders reversed over time, with the highest odds observed in the long-education group and the lowest in the short-education group in later cohorts. Some associations remained stable over time (psychotic, personality, and developmental disorders), while others declined (anxiety-related, developmental, and behavioral disorders) or increased (substance use disorders).

3.1.3 Associations between SES measures and psychotropic medication use

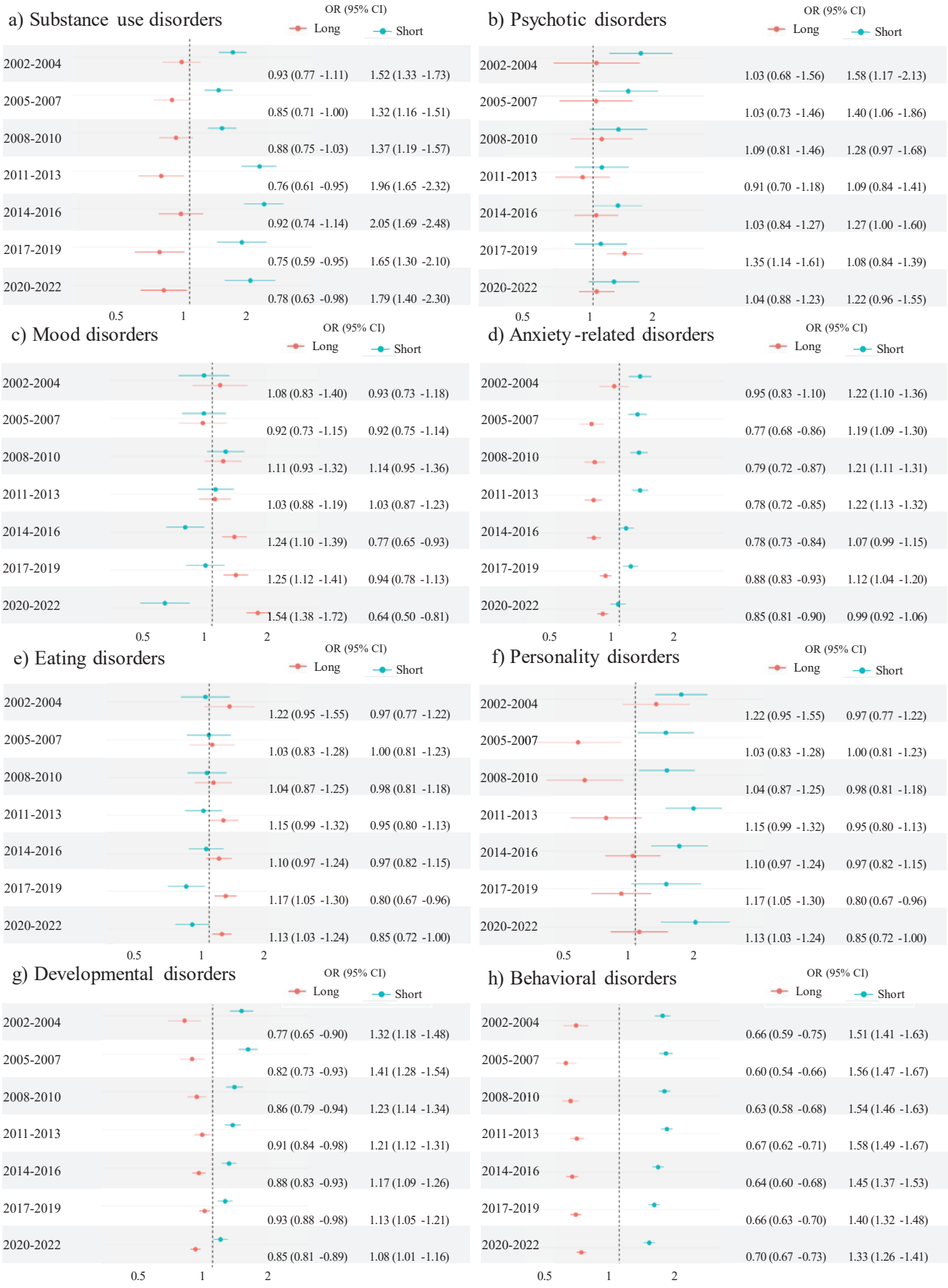
Analyses of psychotropic medication use and SES showed that adolescents in the low-income group consistently had higher odds of psychotropic medication use than those in the middle-income group (Figure 7). In contrast, adolescents in the high-income group had lower odds in the earliest cohorts, but this difference diminished in the most recent periods. Regarding educational level, the short-education group generally had higher odds of psychotropic medication use, while the long-education group had lower odds compared to the middle group. The strength of these associations increased until approximately 2011–2013 and then decreased.

Figure 5: Odds ratios (OR) of specific mental disorder diagnoses by income group.

*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.

Note: Models are adjusted for country of origin, adolescent's chronic illness, siblings' chronic illness, parents' chronic il lness, siblings' mental disorder, parents' mental disorder, and cohabitation

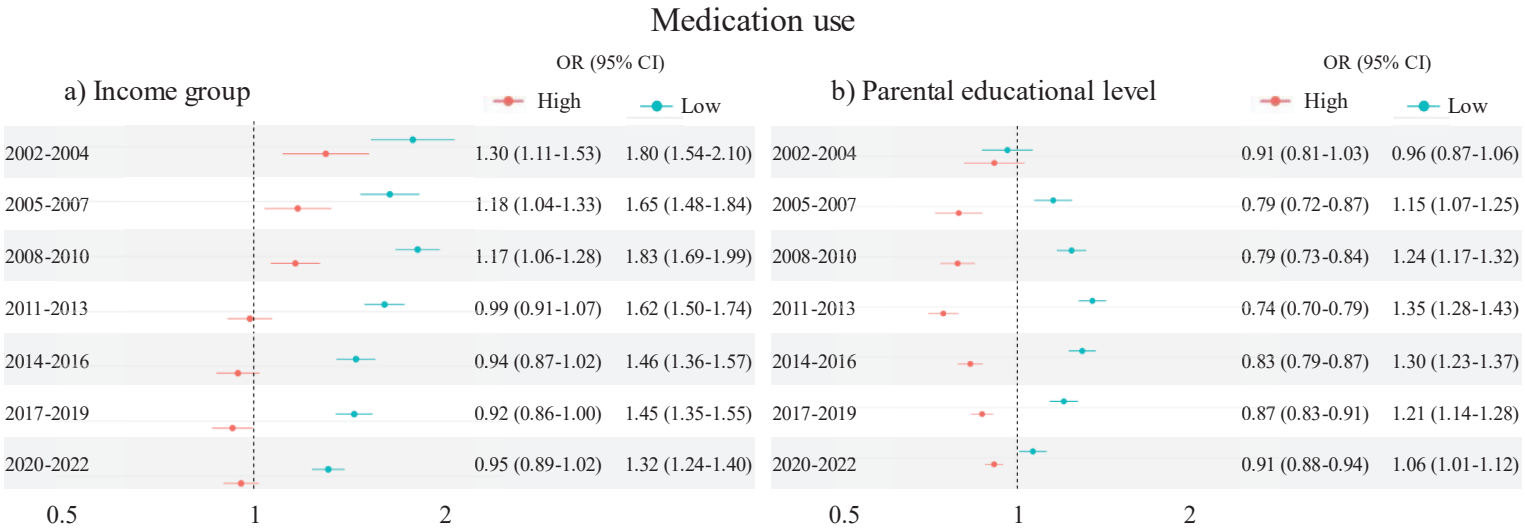
Figure 6: Odds ratios (OR) of specific mental disorder diagnoses by parental educational level.



*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.

Note: Models are adjusted for country of origin, parents' chronic illness and parents' mental disorder

Figure 7: Odds Ratios (OR) of psychotropic medication use by a) income group and b) parental educational level.



Note: Models a) are adjusted for country of origin, adolescent's chronic illness, siblings' chronic illness, parents' chronic illness, siblings' mental disorder, parents' mental disorder, and cohabitation and b) are adjusted for country of origin, parents' chronic illness and parents' mental disorder

3.2 Trajectories of depressive symptoms in adolescence and early adulthood (Study II)

This study aimed to investigate SES patterns in mental health from adolescence to adulthood (aged 15-32) by examining the mean, prevalence, cumulative incidence, and trajectories of several mental health measures, including depressive symptoms, mental disorder diagnosis, and psychotropic medication use.

3.2.1 Population

Across participants in the different surveys of the VestLiv cohort, approximately 30% used psychotropic medication and around 20% had a mental disorder diagnosis as represented in the 2004 survey (Table 3). Parental education levels were distributed as follows: 6% in the long-education group, 75% in the middle group, and 16% in the short-education group. Regarding SSS, 40% reported high SSS in school and 30% in society, while few (approximately 5% in school and 2% in society) reported low status. Similar results were present in the mental disorder diagnosis sample, the medication use sample, and the trajectory sample.

Table 3: Characteristics of samples (imputed and weighted data)

Variables		2004 N=3000	Mental disorder diagnosis sample N=3520	Medication use sample N=3605	Trajectory sample N=3416
Depressive symptoms (Mean (95% CI))	15 years	2.20 (2.12-2.28)	2.21 (2.13-2.29)	2.20 (2.12-2.28)	2.20 (2.09-2.32)
	N (missing)	2902 (618)	2954 (651)	3000 (416)	1698 (229)
	18 years	2.86 (2.76-2.95)	2.85 (2.76-2.94)	2.82 (2.72-2.92)	2.86 (2.74-2.99)
	N (missing)	2294 (1226)	2336 (1269)	2367 (1049)	1461 (466)
	21 years	2.45 (2.34-2.55)	2.45 (2.35-2.56)	2.54 (2.42-2.65)	2.48 (2.35-2.61)
	N (missing)	1885 (1635)	1924 (1681)	1951 (1465)	1302 (625)
	28 years	2.54 (2.44-2.63)	2.55 (2.45-2.64)	2.65 (2.54-2.75)	2.68 (2.57-2.80)
	N (missing)	1866 (1654)	1895 (1710)	1927 (1489)	1927 (0)
	32 years	2.52 (2.40-2.64)	2.53 (2.41-2.64)	2.59 (2.46-2.73)	2.49 (2.36-2.62)
	N (missing)	2294 (1226)	2336 (1269)	2367 (1049)	946 (981)
Medication use (N (%))	Child (age 4-12)	23 (1%)	0 (0%)	41 (1%)	24 (1%)
	Adolescence (age 12-17)	79 (2%)	74 (2%)	113 (3%)	61 (3%)
	Adult (age 17-32)	942 (27%)	983 (27%)	985 (29%)	533 (28%)
	Study period (age 0-32)	1038 (29%)	1058 (29%)	1084 (32%)	590 (31%)
Mental disorder diagnosis (N (%))	Child (age 4-12)	0 (0%)	80 (2%)	126 (4%)	59 (3%)
	Adolescence (age 12-17)	117 (3%)	155 (4%)	172 (5%)	73 (4%)
	Adult (age 17-32)	576 (16%)	605 (17%)	611 (18%)	366 (19%)
	Study period (age 0-32)	602 (17%)	707 (20%)	743 (22%)	410 (21%)
SSS* in school (N (%))	High	1446 (41%)	1476 (41%)	1387 (41%)	763 (40%)
	Middle	1923 (55%)	1971 (55%)	1868 (55%)	1077 (56%)
	Low	151 (4%)	158 (4%)	161 (5%)	87 (5%)
SSS* in society (N (%))	High	1070 (30%)	1087 (30%)	1024 (30%)	529 (27%)
	Middle	2391 (68%)	2455 (68%)	2328 (68%)	1363 (71%)
	Low	59 (2%)	63 (2%)	64 (2%)	35 (2%)
Household income (N (%))	High	714 (20%)	721 (20%)	628 (18%)	371 (19%)
	Middle	2124 (60%)	2172 (60%)	2022 (59%)	1174 (61%)
	Low	682 (19%)	712 (20%)	767 (22%)	382 (20%)
Educational level (N (%))	High	208 (6%)	214 (6%)	171 (5%)	117 (6%)
	Middle	2758 (78%)	2815 (78%)	2599 (76%)	1489 (77%)
	Low	554 (16%)	576 (16%)	646 (19%)	320 (17%)

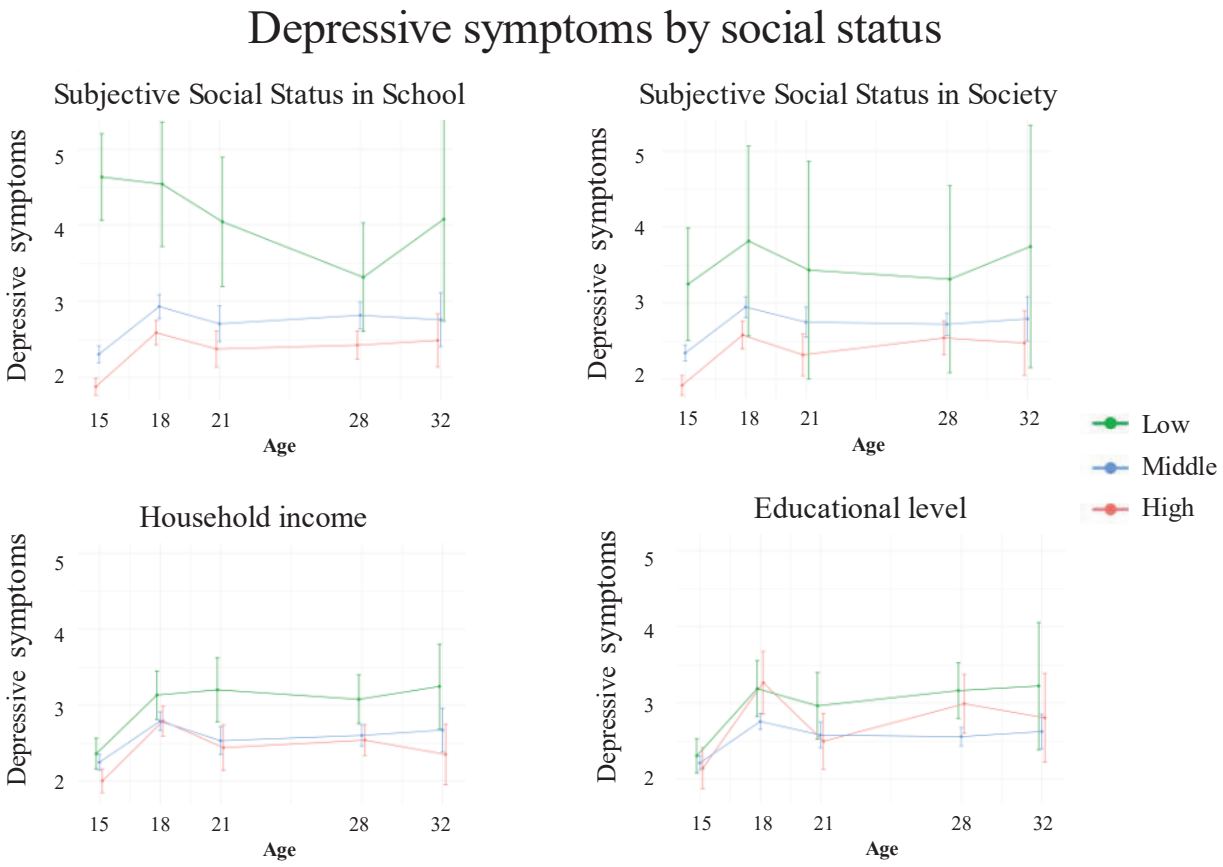
Notes: SSS = Subjective Social Status. Results presented in this table are selected and adapted from the full tables reported in the manuscript.

Attrition analyses showed that non-responders were more often male, had lower SES measures, and were more likely to use psychotropic medications or have a diagnosis. Using IPW and MI to adjust the sample distributions improved the representation of non-responders but did not completely eliminate differences in characteristics.

3.2.2 Descriptive results

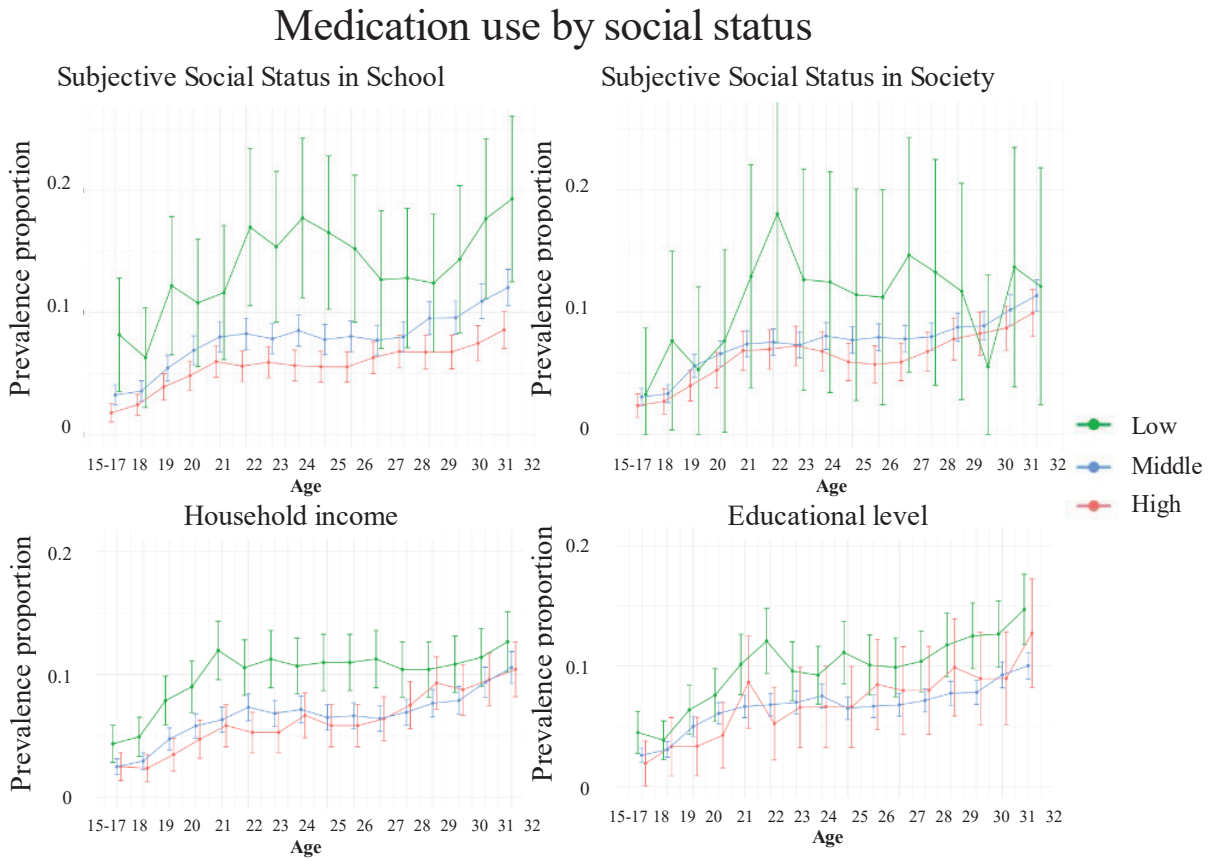
Descriptive analyses showed that adolescents from the four low-SES groups—SSS in school, SSS in society, household income, and parental educational level—consistently reported higher mean scores for depressive symptoms (Figure 8). Depressive symptoms had a possible total score ranging from 0 to 12, with higher scores indicating more severe symptoms. The strongest SES gradient was observed for the subjective SES measures, which were based on adolescents placing themselves on a 10-step ladder representing their perceived position in the school context (SSS in school) and their family's position in society (SSS in society). In contrast, the mean scores across the parental educational level groups were more similar.

Figure 8: Mean scores of depressive symptoms stratified by SES measures.



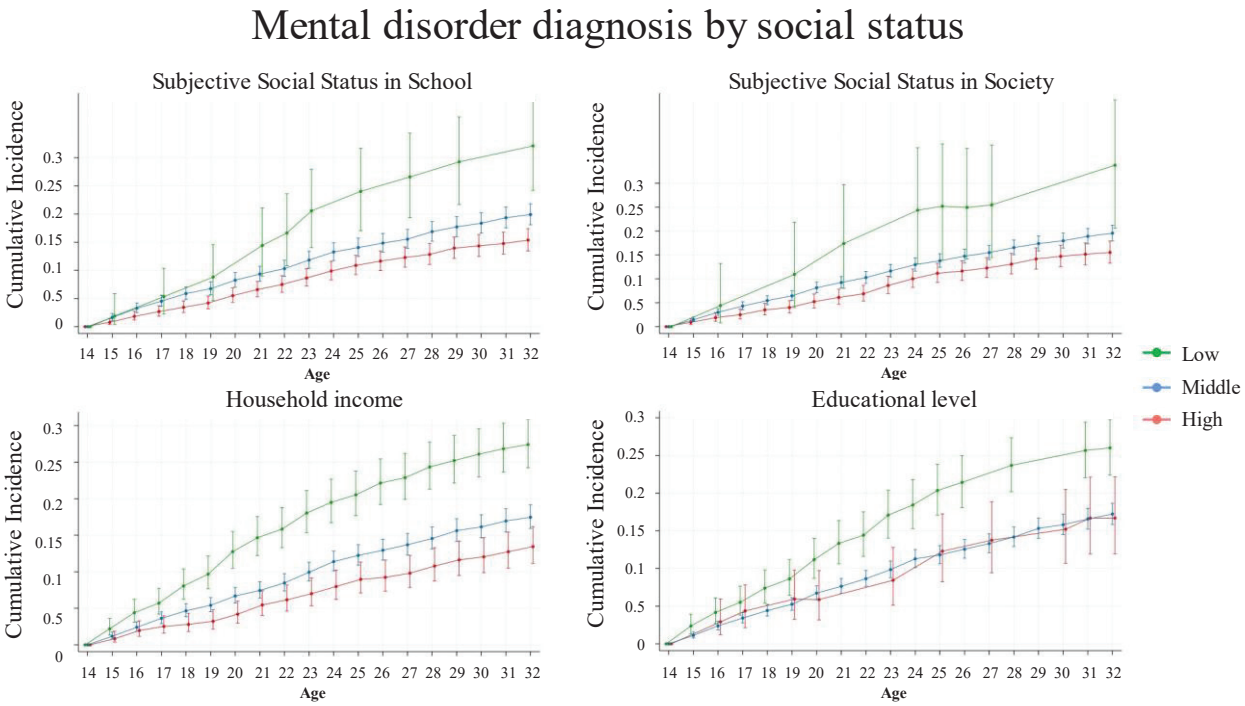
A similar trend was observed for psychotropic medication use, with the highest prevalence proportions found in the low-SES groups, particularly for the SSS measures, while the prevalences across the parental education groups were relatively similar (Figure 9).

Figure 9: Prevalence of psychotropic medication use stratified by SES measures.



For the cumulative incidence of the first mental disorder diagnosis—presented as proportions—the highest rates were again seen in the low-SES groups (Figure 10). In this analysis, the short-education group had higher incidence than the middle- and long-education groups.

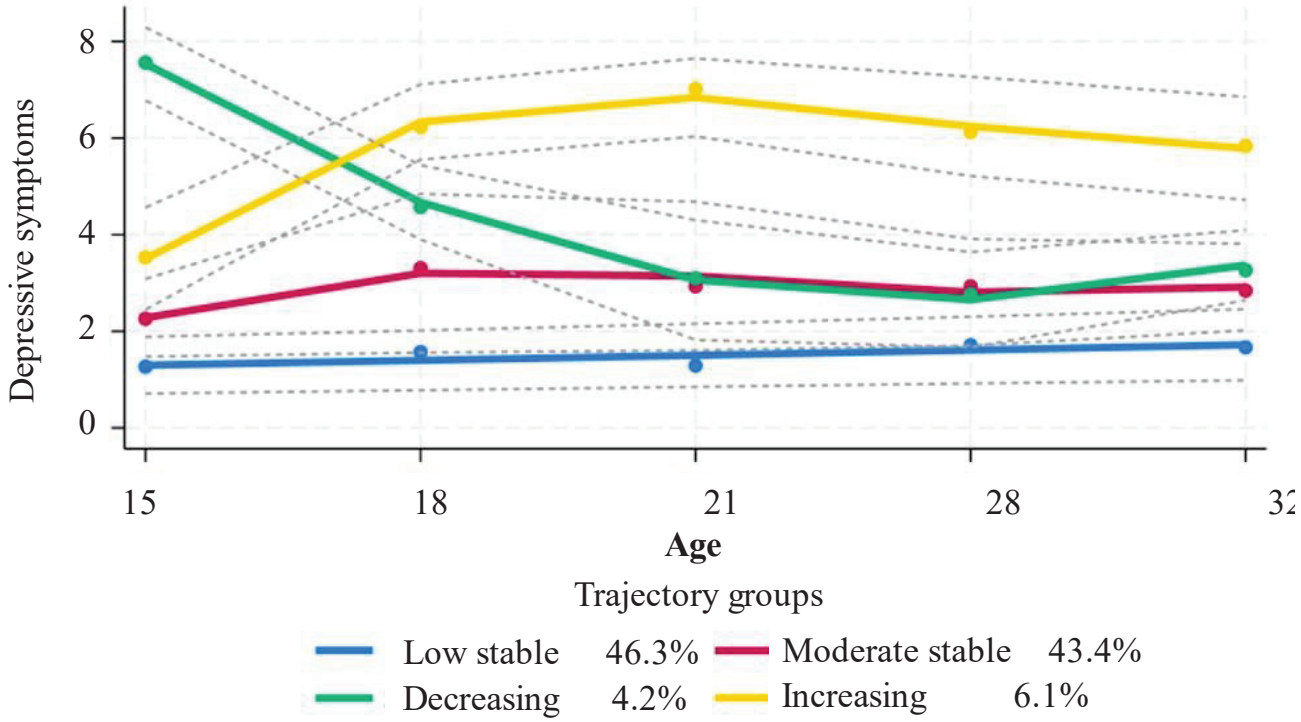
Figure 10: Cumulative incidence (proportion) of first mental disorder diagnosis stratified by SES measures.



3.2.3 Developmental trajectories

Four distinct trajectory groups best described the development of depressive symptoms over time based on the BIC and group size. The selection of the trajectory shapes was based on BIC, group size, APPA, and OCC. The best-fitting shapes of the trajectories were linear, cubic, and quadratic shapes. Two OCC values fell below the recommended threshold of 5, and one APPA value fell below the recommended threshold of 70. The four trajectory groups identified were low stable, moderate stable, decreasing, and increasing (Figure 11).

Figure 11: Depressive symptoms trajectories with 95% confidence intervals (dotted lines) and mean values (dots) at ages 15-32 years.

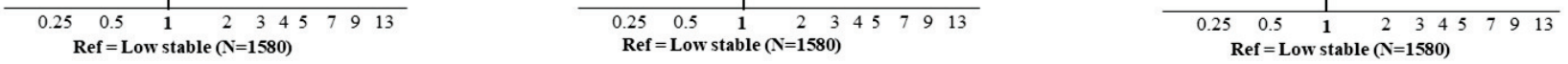


After assigning adolescents to the trajectory group to which they were most likely to belong, two-level comparisons were conducted using RORs. These comparisons involved comparing each trajectory group to the low stable group (reference trajectory) and comparing each individual characteristic (e.g. sex, social support, SES measure) to its reference category (Table 4).

The results showed that individuals who were female, had other mental health outcomes (either psychotropic medication use or a mental disorder diagnosis as an adult or during the study period), had low SSS in school, had parents who were not living together, or lacked social support (from classmates, teachers, or parents) had higher RORs of belonging to any of the other trajectory groups compared to the low stable group. In contrast, individuals with high SSS in society had a higher ROR of belonging to the low stable group than to any of the other trajectory groups.

Table 4: Relative Odds Ratios (ROR) with 95% confidence intervals (95% CI) of membership to the different trajectory groups compared to the low stable groups for each characteristic.

Variables		Trajectory groups: **Moderate stable** (N=1484) ROR (95% CI)	**Decreasing** (N=143) ROR (95% CI)	**Increasing** (N=209) ROR (95% CI)
Sex	Females (Ref. = Males)	1.56 (1.34-1.82)	3.15 (2.13-4.65)	3.15 (2.13-4.65)
Medication use	Child (age 4-12) (Ref = No)	1.69 (0.75-3.83)	N/A*	N/A
	Adolescence (age 12-17) (Ref = No)	1.00 (0.61-1.65)	2.64 (1.22-5.72)	2.64 (1.22-5.72)
	Adult (age 17-32) (Ref = No)	1.62 (1.35-1.94)	3.14 (2.16-4.57)	3.14 (2.16-4.57)
	Study period (age 0-32) (Ref = No)	1.52 (1.28-1.82)	2.71 (1.86-3.93)	2.71 (1.86-3.93)
Mental disorder diagnosis	Child (age 4-12) (Ref = No)	0.90 (0.53-1.53)	1.52 (0.56-4.08)	1.52 (0.56-4.08)
	Adolescence (age 12-17) (Ref = No)	1.48 (1.00-2.18)	1.69 (0.77-3.68)	1.69 (0.77-3.68)
	Adult (age 17-32) (Ref = No)	1.53 (1.22-1.92)	3.38 (2.25-5.09)	3.38 (2.25-5.09)
	Study period (age 0-32) (Ref = No)	1.40 (1.14-1.72)	3.05 (2.06-4.52)	3.05 (2.06-4.52)
SSS in school**	Low (Ref =Middle)	2.21 (1.21-4.02)	12.75 (6.46-25.19)	4.28 (1.99-9.24)
	High (Ref =Middle)	0.74 (0.62-0.88)	0.84 (0.55-1.27)	0.40 (0.24-0.66)
SSS in society**	Low (Ref =Middle)	0.78 (0.37-1.65)	2.16 (0.76-6.17)	1.93 (0.67-5.54)
	High (Ref =Middle)	0.74 (0.62-0.88)	0.64 (0.43-0.97)	0.48 (0.31-0.75)
Income	Low (Ref =Middle)	1.09 (0.88-1.33)	0.98 (0.61-1.59)	2.11 (1.45-3.06)
	High (Ref =Middle)	0.92 (0.76-1.11)	0.62 (0.38-1.02)	0.75 (0.49-1.16)
Educational level	Low (Ref =Middle)	1.18 (0.94-1.48)	1.46 (0.89-2.40)	2.24 (1.50-3.34)
	High (Ref =Middle)	1.46 (1.06-2.00)	1.53 (0.76-3.09)	1.42 (0.77-2.61)
Origin	Other (Ref = Denmark)	1.11 (0.79-1.57)	1.73 (1.19-2.52)	1.53 (0.76-3.09)
Cohabitation	No (Ref = Yes)	1.46 (1.24-1.73)	4.20 (2.86-6.17)	1.73 (1.19-2.52)
Bullied	Yes (Ref = No)	1.77 (1.44-2.17)	11.21 (6.82-18.42)	4.20 (2.86-6.17)
Support classmates	No (Ref = Yes)	1.63 (1.08-2.45)	3.58 (2.35-5.44)	11.21 (6.82-18.42)
Support teacher	No (Ref = Yes)	1.64 (1.28-2.09)	3.58 (2.35-5.44)	3.58 (2.35-5.44)
School pressure	Continous (Ref = 0)	1.21 (1.12-1.30)	1.43 (1.21-1.69)	1.32 (1.13-1.54)
Parents' support	Continous (Ref = 0)	0.86 (0.82-0.89)	0.64 (0.58-0.70)	0.76 (0.69-0.83)
NMI* **	Continous (Ref = 0)	1.09 (0.95-1.26)	1.08 (0.82-1.41)	0.95 (0.72-1.24)



*No observations of medication use in childhood in the decreasing and increasing group, ** SSS = Subjective Social Status, ***NMI = Nordic Morbidity Index
Note: Data are imputed and weighted

3.3 Effects of personal, health, lifestyle, and social factors on depressive symptoms (Study III)

This study aimed to investigate the association between age-specific changes in explanatory factors, encompassing personal, health, lifestyle, and social factors, and changes in depressive symptoms in individuals aged 15-32.

3.3.1 Population

The characteristics of the analytical sample used in Study III (Table 5) were largely similar to those described in Study II (Table 3). The mean depressive symptom scores peaked at age 18, and the mean absolute change in depressive symptoms ranged from 1.64 to 2.04 across age intervals. Mean depressive symptoms were consistently higher in the low-income groups and in adolescents with low SSS in both school and society across all ages. In contrast, the mean scores were relatively similar across the groups of parental educational levels.

Table 5: Characteristics of the analytical sample at baseline (2004) with mean depressive symptoms scores (CES-D(C)4)

		Depressive symptoms (Mean (95% CI))				
	N (%)	**15**	**18**	**21**	**28**	**32**
Total	2157 (100%)	2.23 (2.12-2.33)	2.85 (2.73-2.97)	2.50 (2.37-2.62)	2.65 (2.54-2.76)	2.69 (2.55-2.83)
Parental education						
Long	128 (6%)	2.29 (1.94-2.64)	3.27 (2.83-3.70)	2.49 (2.10-2.89)	2.93 (2.56-3.30)	2.89 (2.46-3.33)
Middle	1670 (77%)	2.21 (2.10-2.32)	2.79 (2.67-2.91)	2.46 (2.33-2.58)	2.58 (2.47-2.69)	2.62 (2.47-2.76)
Short	359 (17%)	2.28 (1.92-2.64)	2.98 (2.60-3.35)	2.67 (2.28-3.06)	2.87 (2.48-3.26)	2.96 (2.54-3.38)
Household income						
High	413 (19%)	2.02 (1.82-2.22)	2.86 (2.63-3.09)	2.19 (1.96-2.42)	2.50 (2.29-2.70)	2.46 (2.22-2.71)
Middle	1333 (62%)	2.25 (2.11-2.38)	2.79 (2.65-2.92)	2.45 (2.31-2.59)	2.58 (2.44-2.72)	2.64 (2.49-2.79)
Low	411 (19%)	2.37 (2.06-2.68)	3.05 (2.72-3.38)	2.96 (2.61-3.31)	3.03 (2.71-3.34)	3.09 (2.73-3.46)
SSS* in society						
High	107 (5%)	4.72 (3.83-5.62)	4.60 (3.85-5.35)	4.15 (3.41-4.88)	3.56 (2.92-4.20)	3.78 (3.12-4.44)
Middle	1142 (53%)	2.27 (2.13-2.41)	2.96 (2.80-3.13)	2.58 (2.41-2.74)	2.78 (2.61-2.94)	2.80 (2.61-2.99)
Low	908 (42%)	1.88 (1.73-2.02)	2.50 (2.35-2.66)	2.20 (2.04-2.36)	2.37 (2.22-2.53)	2.42 (2.23-2.61)
SSS* in school						
High	46 (2%)	3.76 (2.85-4.67)	3.59 (2.56-4.62)	3.93 (2.66-5.20)	3.88 (2.59-5.18)	3.53 (2.42-4.63)
Middle	1469 (68%)	2.30 (2.16-2.43)	2.95 (2.80-3.10)	2.60 (2.45-2.75)	2.67 (2.53-2.81)	2.77 (2.61-2.94)
Low	642 (30%)	1.96 (1.77-2.15)	2.57 (2.38-2.75)	2.15 (1.96-2.34)	2.50 (2.31-2.69)	2.44 (2.23-2.65)
Mental disorder diagnosis						
Older child (5-12 years)	64 (3%)	2.24 (1.42-3.07)	2.51 (1.68-3.35)	2.68 (1.84-3.52)	3.20 (2.26-4.15)	2.70 (1.71-3.69)
Adolescent (13-17 years)	106 (5%)	3.08 (2.38-3.79)	4.19 (3.48-4.90)	3.47 (2.71-4.23)	3.59 (2.84-4.34)	3.00 (2.14-3.86)
Adult (18-32 years)	373 (17%)	2.88 (2.55-3.21)	3.60 (3.25-3.95)	3.53 (3.14-3.91)	3.67 (3.35-3.99)	3.85 (3.45-4.25)
Study period (5-32 years)	451 (21%)	2.76 (2.46-3.06)	3.51 (3.18-3.83)	3.32 (2.98-3.67)	3.42 (3.12-3.72)	3.48 (3.10-3.85)
None in study period	1706 (79%)	2.09 (1.97-2.20)	2.68 (2.56-2.79)	2.28 (2.16-2.39)	2.44 (2.33-2.56)	2.48 (2.35-2.62)
Medication use						
Older child (5-12 years)	22 (1%)	1.81 (0.64-2.98)	2.88 (0.82-4.94)	3.56 (1.25-5.87)	2.65 (0.90-4.40)	3.13 (0.70-5.55)
Adolescent (13-17 years)	66 (3%)	3.24 (2.46-4.02)	3.87 (2.99-4.76)	3.61 (2.70-4.51)	3.09 (2.26-3.92)	3.04 (2.06-4.01)
Adult (18-32 years)	601 (28%)	2.80 (2.54-3.05)	3.49 (3.21-3.76)	3.38 (3.09-3.67)	3.56 (3.30-3.81)	3.54 (3.24-3.84)
Study period (5-32 years)	667 (31%)	2.71 (2.47-2.95)	3.40 (3.15-3.66)	3.27 (3.00-3.55)	3.43 (3.19-3.67)	3.41 (3.13-3.70)
None in study period	1490 (69%)	2.01 (1.90-2.12)	2.60 (2.49-2.72)	2.15 (2.03-2.26)	2.30 (2.18-2.41)	2.37 (2.22-2.51)

*SSS = Subjective Social Status Results presented in this table are selected and adapted from the full tables reported in the manuscript.

The range of absolute mean changes in depressive symptoms was from 1.53 (among those with long parental education between ages 28 and 32) to 2.78 (among those with high SSS in society between ages 15 and 18) (Table 6).

Table 6: Absolute change in depressive symptoms between time points

	Absolute change in depressive symptoms (Mean (95% CI))			
	15-18	**18-21**	**21-28**	**28-32**
Total	2.04 (1.95-2.14)	1.95 (1.85-2.04)	1.87 (1.78-1.96)	1.64 (1.55-1.74)
Parental education	2.15 (1.83-2.47)	2.23 (1.89-2.57)	1.92 (1.62-2.21)	1.53 (1.23-1.82)
Long	2.00 (1.90-2.10)	1.92 (1.82-2.01)	1.85 (1.76-1.94)	1.63 (1.53-1.72)
Middle				
Short	2.22 (1.91-2.52)	1.97 (1.66-2.29)	1.96 (1.68-2.24)	1.78 (1.50-2.05)
Household income	2.10 (1.91-2.30)	1.85 (1.67-2.02)	1.73 (1.56-1.89)	1.54 (1.38-1.70)
High	2.04 (1.93-2.15)	1.98 (1.87-2.10)	1.88 (1.77-1.98)	1.63 (1.52-1.75)
Middle				
Low	2.00 (1.74-2.25)	1.92 (1.68-2.16)	1.99 (1.75-2.23)	1.78 (1.56-2.00)
SSS* in society	2.78 (2.22-3.33)	2.27 (1.73-2.80)	2.35 (1.88-2.82)	1.96 (1.51-2.42)
High	2.12 (1.98-2.25)	1.99 (1.85-2.12)	1.90 (1.78-2.01)	1.69 (1.57-1.81)
Middle				
Low	1.87 (1.74-2.00)	1.86 (1.72-1.99)	1.78 (1.65-1.90)	1.55 (1.42-1.68)
SSS* in school	2.13 (1.46-2.81)	2.15 (1.37-2.94)	2.17 (1.49-2.84)	1.77 (0.94-2.61)
High	2.10 (1.98-2.21)	1.97 (1.85-2.09)	1.90 (1.79-2.00)	1.68 (1.57-1.79)
Middle				
Low	1.92 (1.77-2.07)	1.88 (1.73-2.03)	1.79 (1.64-1.93)	1.55 (1.42-1.69)
Mental disorder diagnosis	1.82 (1.18-2.45)	1.78 (1.15-2.41)	1.86 (1.20-2.51)	1.53 (0.91-2.16)
Older child (5-12 years)	2.94 (2.36-3.52)	2.19 (1.65-2.73)	1.98 (1.50-2.46)	1.98 (1.45-2.52)
Adolescent (13-17 years)	2.51 (2.25-2.78)	2.15 (1.88-2.42)	2.15 (1.92-2.38)	1.95 (1.72-2.18)
Adult (18-32 years)	2.49 (2.24-2.75)	2.13 (1.88-2.38)	2.05 (1.83-2.27)	1.86 (1.65-2.08)
Study period (5-32 years)				
None in study period	1.93 (1.83-2.02)	1.90 (1.80-1.99)	1.82 (1.73-1.92)	1.59 (1.48-1.69)
Medication use	2.22 (0.56-3.88)	1.94 (0.75-3.13)	2.39 (1.13-3.64)	1.67 (0.50-2.84)
Older child (5-12 years)	2.64 (2.03-3.25)	2.69 (2.15-3.22)	2.33 (1.83-2.83)	1.73 (1.21-2.25)
Adolescent (13-17 years)	2.41 (2.22-2.59)	2.27 (2.08-2.46)	2.16 (1.99-2.33)	1.86 (1.69-2.03)
Adult (18-32 years)	2.36 (2.18-2.53)	2.26 (2.08-2.43)	2.15 (1.99-2.31)	1.83 (1.67-2.00)
Study period (5-32 years)				
None in study period	1.92 (1.82-2.03)	1.83 (1.73-1.93)	1.74 (1.65-1.84)	1.55 (1.45-1.65)

Notes: SSS = Subjective Social Status. Results presented in this table are selected and adapted from the full tables reported in the manuscript.

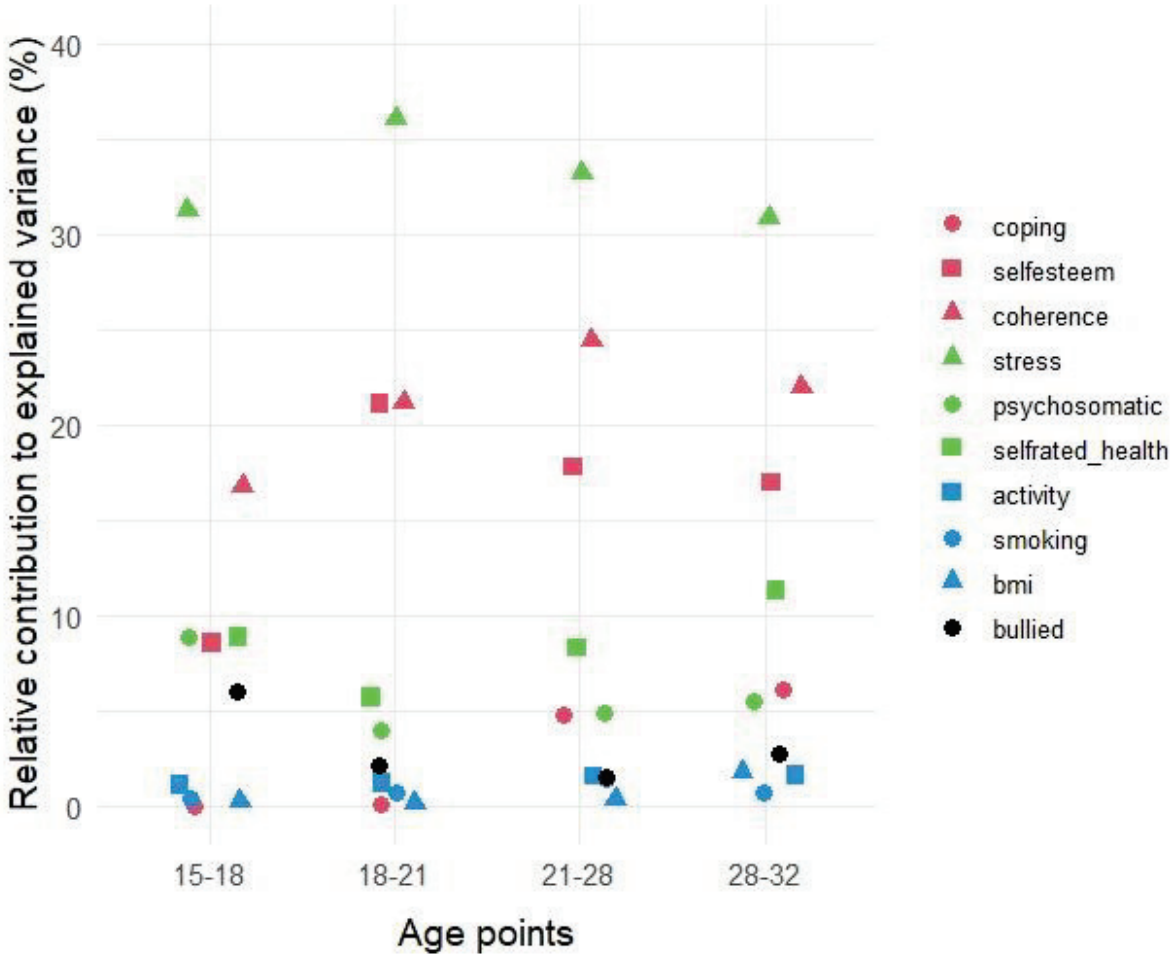
While IPW reduced differences in characteristics between the analytical and excluded samples, some discrepancies remained for sex, origin, parental educational level, household income, and mental health measures. All explanatory variables met the inclusion criteria for the FE analyses, as they exhibited more than a 10% change across all age points.

3.3.2 FE analyses and dominance

The FE models explained between 25% and 29% of the total variance in depressive symptoms and were all found to perform better than the POLS models. Across all age-points, changes in health

(green) and personal (red) factors contributed the most to the explained variance in depressive symptoms, whereas lifestyle (blue) and social (black) factors explained relatively less (Figure 12). More specifically, changes in stress symptoms and sense of coherence were the strongest contributors to variance, consistently ranking first and second in terms of dominance, respectively. Self-esteem ranked third in dominance at most intervals, except between ages 15 and 18, where self-rated health and psychosomatic symptoms were more important. A general pattern emerged, showing that the relative importance (dominance) of different explanatory variables varied across the life course of the participants. For example, changes in bullying explained >5% of the variance at ages 15–18, but contributed <2% in later age intervals.

Figure 12: Results from the dominance analyses showing the relative contribution to the explained variance of depressive symptoms for personal (red), health (green), lifestyle (blue), and social factors (black).



Note: points are slightly scattered to improve readability

3.3.3 Asymmetric effects

An asymmetrical effect was observed for psychosomatic symptoms between the ages of 15-18 (Table 7). Specifically, an increase in psychosomatic symptoms during this period was associated with a stronger increase in depressive symptoms (0.24 (95%CI: 0.15-0.33)), compared to a reduction in psychosomatic symptoms, which was only weakly associated with a decrease in depressive symptoms (0.08 (95%CI: -0.18-0.01).

The results also provide insights into the magnitude of these associations. Reductions in stress showed the strongest association with reductions in depressive symptoms across all age intervals, except for ages 21-28. In addition, other factors that were strongly associated with reductions in depressive symptoms included bullying (ages 15–18), self-esteem (ages 18–21), self-esteem and sense of coherence (ages 21–28), and self-esteem (ages 28–32).For increases in depressive symptoms, the strongest associations were found for increases in bullying and psychosomatic symptoms (ages 15–18), stress and sense of coherence (ages 18–21), self-rated health (ages 21–28), and both self-rated health and bullying (ages 28–32).

Table 7: Results from asymmetrical change analyses

	Change in depressive symptoms (mean (95% CI))			
	Age 15-18	**Age 18-21**	**Age 21-28**	**Age 28-32**
Personal factors				
Coping	p=0.16	p=0.59	p=0.59	p=0.53
1 positive change	-0.02 (-0.05;0.01)	0.01 (-0.04;0.06)	0.03 (-0.02;0.09)	0.03 (-0.02;0.09)
1 negative change	-0.03 (-0.08;0.02)	0.00 (-0.02;0.03)	-0.01 (-0.06;0.04)	-0.01 (-0.06;0.04)
Self-esteem	p=0.49	p=0.15	p=0.69	p=0.55
1 positive change	0.09 (0.01;0.16)	0.08 (0.01;0.16)	0.10 (0.03;0.16)	0.09 (0.02;0.15)
1 negative change	-0.04 (-0.11;0.03)	-0.18 (-0.25;-0.12)	-0.11 (-0.18;-0.04)	-0.07 (-0.13;-0.01)
Sense of coherence	p=0.15	p=0.67	p=0.16	p=0.36
1 positive change	0.21 (0.13;0.29)	0.17 (0.08;0.25)	0.11 (-0.00;0.21)	0.09 (-0.01;0.19)
1 negative change	-0.10 (-0.19;-0.02)	-0.15 (-0.23;-0.07)	-0.22 (-0.29;-0.15)	-0.16 (-0.23;-0.09)
Health factors				
Stress	p=0.18	p=0.31	p=0.62	p=0.56
1 positive change	0.20 (0.11;0.28)	0.18 (0.12;0.25)	0.21 (0.13;0.28)	0.20 (0.13;0.26)
1 negative change	-0.30 (-0.38;-0.22)	-0.25 (-0.34;-0.17)	-0.17 (-0.26;-0.09)	-0.20 (-0.26;-0.15)
Psychosomatic symptoms	p=0.03	p=0.63	p=0.44	p=0.54
1 positive change	0.24 (0.15;0.33)	0.09 (0.00;0.18)	0.09 (-0.00;0.17)	0.11 (0.01;0.22)
1 negative change	-0.08 (-0.18;0.01)	-0.08 (-0.17;0.01)	-0.03 (-0.13;0.07)	-0.11 (-0.20;-0.03)
Self-rated health	p=0.55	p=0.65	p=0.62	p=0.58
1 positive change	0.13 (-0.06;0.32)	0.12 (-0.14;0.38)	0.26 (0.08;0.44)	0.26 (0.10;0.42)
1 negative change	-0.25 (-0.54;0.03)	-0.16 (-0.33;0.01)	-0.24 (-0.47;-0.01)	-0.29 (-0.51;-0.07)
Lifestyle factors				
Physical activity	p=0.18	p=0.45	p=0.62	p=0.56
1 positive change	-0.09 (-0.22;0.04)	0.09 (-0.03;0.21)	0.02 (-0.13;0.18)	0.03 (-0.07;0.13)
1 negative change	-0.10 (-0.30;0.09)	-0.00 (-0.15;0.14)	0.03 (-0.11;0.17)	0.01 (-0.13;0.14)
Smoking	p=0.68	p=0.34	p=0.35	p=0.51
1 positive change	-0.06 (-0.19;0.08)	-0.04 (-0.20;0.12)	0.12 (-0.08;0.32)	-0.07 (-0.32;0.18)
1 negative change	0.02 (-0.39;0.43)	0.20 (-0.02;0.41)	0.01 (-0.12;0.14)	0.11 (-0.00;0.22)
BMI	p=0.43	p=0.45	p=0.59	p=0.57
1 positive change	0.01 (-0.05;0.07)	0.03 (-0.03;0.10)	-0.03 (-0.08;0.01)	-0.03 (-0.06;0.00)
1 negative change	-0.09 (-0.27;0.08)	0.04 (-0.11;0.19)	0.01 (-0.06;0.09)	0.03 (-0.04;0.09)
Social factors				
Bullying	p=0.73	p=0.33	p=0.51	p=0.35
1 positive change	0.29 (-0.03;0.60)	-0.14 (-0.52;0.24)	-0.03 (-0.37;0.32)	0.22 (-0.01;0.45)
1 negative change	-0.31 (-0.52;-0.11)	-0.17 (-0.51;0.17)	0.03 (-0.26;0.33)	-0.03 (-0.31;0.25)

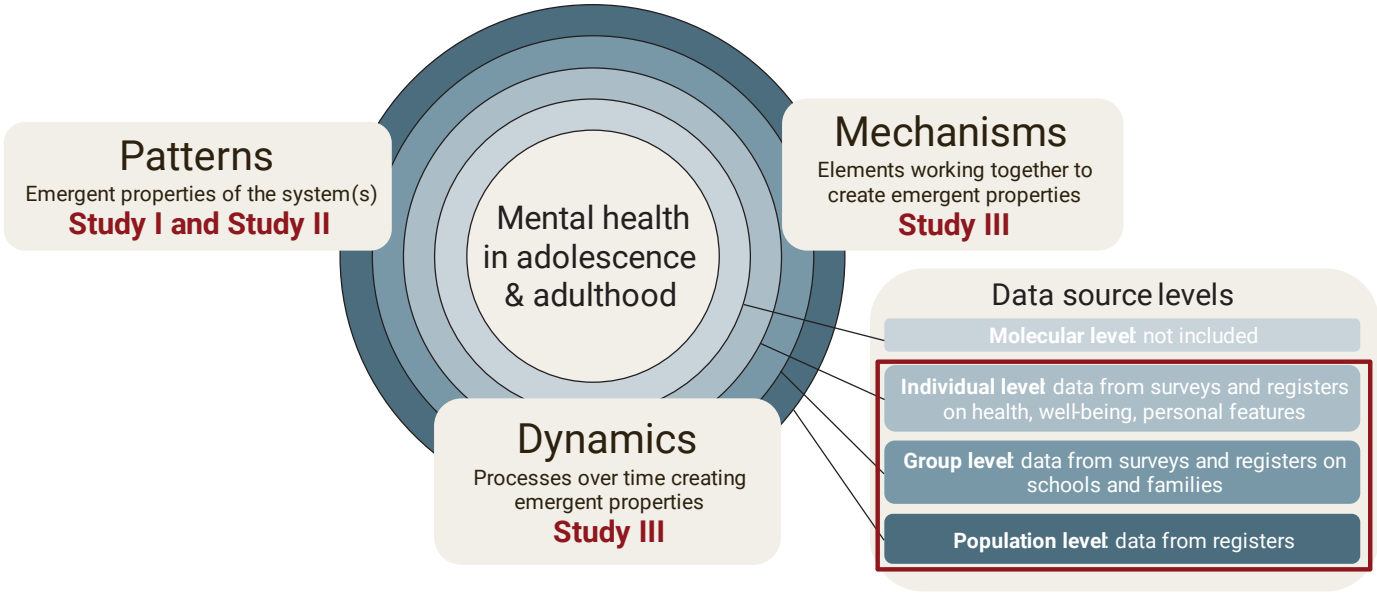
4. Discussion

This section presents the main findings, a discussion of the results of the three studies conceptualized with existing literature, and a discussion of the methods used.

4.1 Main findings conceptualized in the Health Complexity Framework

The findings of this dissertation can be conceptualized using the Health Complexity Framework, which views mental health as a dynamic, multi-level phenomenon shaped by interacting individual, social, and systemic factors over time. Each study contributes to different dimensions of this framework: patterns, mechanisms, and dynamics (Figure 13). The analyses incorporated data across multiple levels: individual-level information on health, well-being, and personal characteristics; group-level data on social and family relations; and population-level indicators—all derived from nationwide registers and surveys.

Figure 13: The Health Complexity Framework adapted from Rod et al. and applied to the three studies of the thesis (75)



Patterns were addressed in Studies I and II.

Study I showed increasing prevalences of mental disorder diagnoses and psychotropic medication use among 15-year-olds from 2002 to 2022. While low-income and short-education groups consistently experienced the highest mental health burdens, the strength of these associations weakened over time—particularly for income—suggesting shifting vulnerability. In contrast, the associations remained stable for adolescents in the high-income and long-education groups.

However, this general trend masks substantial variation across diagnostic categories. For psychotropic medication use, the association with income diminished over the study period, whereas the association with educational level strengthened until 2011–2013 and then declined.

Study II expanded the examination of patterns across the life course. Individuals with low SES experienced higher mean levels of depressive symptoms, greater use of psychotropic medication, and higher cumulative incidence of mental disorder diagnoses between ages 15 and 32-most pronounced for SSS in school and society. Four distinct depressive symptom trajectories from adolescence to adulthood was identified: low stable, moderate stable, decreasing, and increasing. Socioeconomic disadvantage—particularly SSS in school and society—was associated with increased risk of following less favorable trajectories. The odds of belonging to any trajectory other than the low stable group were higher among females, individuals with comorbid mental health outcomes, those with low social status, and those lacking social support. Notably, social support was associated with a greater likelihood of following more favorable symptom trajectories.

Mechanisms and dynamics were primarily explored in Study III.
Changes in personal, health, and social factors were associated with changes in depressive symptoms across five age periods. Stress symptoms and sense of coherence consistently explained the largest part of variance, but the relative importance of factors shifted with age. Overall, changes in personal and health-related factors showed the strongest associations with changes in depressive symptoms throughout the study period.

Applying the Health Complexity Framework revealed that mental health is not a fixed or linear outcome, but rather an emergent property of complex, age-dependent, and multi-level interactions. This perspective highlights the need for nuanced, developmentally sensitive, and multi-dimensional approaches in both public health surveillance and intervention strategies.

4.2 Findings contextualized by existing literature

4.2.1 Time trends in social inequality in adolescent mental health (Study I)

The findings of Study I align with previous research documenting a rise in poor mental health among adolescents (13, 19, 21, 113, 114) and consistent associations between SES and adolescent mental health (30-33, 38, 115, 116). This is the first study to examine time trends in social inequality in mental health.

While the GINI coefficient indicates rising social inequality in Denmark over recent decades (26), we observed a somewhat unexpected decline in the strength of associations between income and adolescent mental health problems. This pattern does not appear to be explained by the shifting income definitions over time. A sensitivity analysis showed that the relative mean income in high-income groups increased, while it decreased in low-income groups compared to the middle-income group, suggesting that the categorization itself did not mask inequality trends.

A changing distribution of parental education levels may partly explain the weakening association between education and mental health. Over time, more parents attained higher levels of education, possibly narrowing the distinctions between the middle- and low-education groups in terms of resources and opportunities. The somewhat different patterns observed for income and education may also reflect the nature of the SES indicators themselves: income was measured as a three-year average around the time the adolescent entered the study and may therefore reflect the family's current SES circumstances, whereas educational attainment is typically established earlier in adulthood—often before having children—and may be less sensitive to more recent life changes.

The underlying causes of the increase in adolescent mental health problems remain widely debated. Some argue that a lower diagnostic threshold and a possible trend toward overdiagnosis, particularly for conditions such as ADHD, have contributed to the observed increase (22). Others point to a broader societal shift toward "psychologization", where everyday challenges are increasingly interpreted through a psychological lens, potentially inflating the number of diagnoses (23, 24). These trends may be more prominent among adolescents from higher SES backgrounds, who are often more engaged in public discourse and are better positioned to navigate healthcare systems (117, 118).

Another line of argument suggests that the rise in mental health problems reflects real changes in adolescents' lived experiences, including heightened academic, social, and cultural pressures (23, 25). Qualitative studies suggest that these pressures may exacerbate vulnerability in low-SES adolescents due to their challenging financial and social conditions. However, they also indicate the emergence of new types of vulnerability among middle- and high-SES youth, who may experience unique forms of pressure related to performance and expectations (23).

The diagnosis-specific results revealed diverse patterns over time. For instance, the increasing association between low SES and substance use disorders may reflect hereditary factors (48).

Although our models were adjusted for family history of mental illness, undiagnosed conditions, particularly among parents, may have influenced the results. Given the downward shift in the average age of onset for mental disorders (21), undiagnosed parental conditions may affect both SES indicators and adolescent mental health outcomes, and the degree of undiagnosed conditions may differ depending on the diagnosis. Conversely, for mood and eating disorders, the observed decline or reversal in SES associations over time may be driven by differences in health-seeking behavior. Parents with high SES are more likely to recognize symptoms, seek professional help, and advocate for diagnosis and treatment (117, 118).

Regarding psychotropic medication use, a policy change in 2014 prohibited GPs from prescribing antidepressants to individuals under 25 years of age, allowing only psychiatrists to prescribe this medication (43, 119). While overall psychotropic medication use continued to rise after this change, likely due to increased prescriptions by psychiatrists, this shift may have disproportionately affected low-SES adolescents. These individuals may face more barriers in accessing psychiatric specialists than higher-SES adolescents, who often have greater healthcare literacy and better access to services. Such access advantages may include employer-paid private health insurance, which has become increasingly common in Denmark. From 2003 to 2023, the number of people covered by private health insurance rose steeply from 229,000 to 2.9 million, now encompassing almost all private sector employees and a growing share of public sector workers (120). However, this development may further exacerbate inequalities, as the most vulnerable—such as individuals with unstable or no attachment to the labor market—are often excluded from such schemes despite the universal public healthcare system.

4.2.2 Trajectories of depressive symptoms in adolescence and early adulthood (Study II)

To our knowledge, no previous study has examined SES-specific mental health outcomes from adolescence to adulthood. However, prior Danish studies have investigated the cumulative incidence of mental disorder diagnoses as proportions. For example, one study reported a cumulative incidence of any mental disorder of 0.15 (95% CI: 0.15–0.15) in a younger cohort, while another reported lifetime cumulative incidences of 0.31 (95% CI: 0.31–0.31) for males and 0.34 (95% CI: 0.34–0.35) for females by age 80 years (28, 121). The present study found a cumulative incidence of 0.19 (95% CI:0.17-0.20), which is somewhat in line with estimates for the younger cohort. Differences in incidence rates across studies are likely explained by cohort age, as older cohorts naturally accumulate more diagnoses over time. Additionally, the geographic context of the present study may

partly explain these findings. The VestLiv cohort covers a rural population, and previous research has shown that individuals living farther from psychiatric hospitals are less likely to receive diagnoses (28, 122, 123). There has also been a temporal trend toward earlier onset of mental disorders, meaning that more recent cohorts may accumulate diagnoses earlier in life (124). Finally, due to limitations in the register, this study only included diagnoses from age 6 years onwards, potentially missing early childhood diagnoses such as developmental and behavioral disorders (13, 42).

Regarding depressive symptom trajectories, this study identified four distinct groups, which aligns with a review showing that most studies identify three to four trajectories, typically including low stable and moderate stable groups (14). However, unlike many prior studies that report a high-stable trajectory, this pattern was not observed in the present data. While combinations such as decreasing, increasing, and low stable trajectories have previously been reported (15, 125-128), the specific combination of these with a moderate stable group is less frequent (129, 130). Consistent with the existing literature, this study found that being female and having low SES were associated with an increased likelihood of belonging to trajectories characterized by higher depressive symptoms (14, 15, 125, 128, 129, 131). However, much prior research has focused on childhood SES, whereas this study used measures from adolescence. Measuring SES earlier in life may result in even stronger associations, as suggested by previous research (40).

4.2.3 Effects of personal, health, lifestyle, and social factors on depressive symptoms (Study III)

Our study identified stress symptoms, sense of coherence, self-esteem, self-rated health, and psychosomatic symptoms as the most influential factors in explaining the variance in depressive symptoms between 15 and 32 years of age. All of these have previously been recognized as risk factors for poor mental health (55, 56, 132-135). However, research on whether the strength of these associations varies across the life course is limited. Notably, low self-esteem has been shown to have a greater impact on mental health when it occurs during identity formation (55). This is in line with the theory of emerging adulthood (ages 18-25), a period in which identity formation is a central developmental task (6), and with our findings, in which self-esteem had the greatest dominance at ages 18–21 and remained influential at ages 21–28 and 28–32.

Longitudinal studies on self-rated health have primarily focused on older populations, making direct comparisons with the present study challenging (135). Nonetheless, our findings support the importance of self-rated health in relation to depressive symptoms in young adulthood. Similarly, our

results regarding psychosomatic symptoms are consistent with previous research showing that such symptoms in adolescence are predictive of poor mental health in early adulthood (133). Moreover, lifestyle factors—defined as physical activity, smoking, and BMI—contributed only minimally to the explained variance in depressive symptoms, which is in contrast to earlier research identifying these factors as determinants of mental health (54, 59). A potential explanation for this discrepancy is that previous studies have examined lifestyle factors as isolated exposures, whereas the present study applied a systems-oriented approach that considered multiple interrelated influences simultaneously.

Interestingly, bullying did not emerge as a central factor in dominance analyses. However, the asymmetric analyses revealed strong associations between changes in bullying and changes in depressive symptoms, particularly for increases in bullying at ages 15–18 and 28–32, and for decreases at ages 15–18 and 18–21. While the long-term consequences of bullying are well-established, its age-specific impact remains underexplored (68).

It is important to note that even though some factors showed stronger dominance or associations with depressive symptoms, the minimal detectable change for the CES-DC4 has been estimated to 3.85 points (95% CI: 2.91–4.80) (136). This suggests that targeting a single explanatory factor may not be sufficient to produce clinically meaningful changes in depressive symptoms. Therefore, preventive strategies should adopt a multifactorial approach that addresses several contributing factors simultaneously.

Although social factors did not play a central role in the dominance models, future research should include a broader set of variables—particularly those related to social connections, social support, and loneliness, which have shown strong links to mental health across different life stages (51, 53, 54, 62, 64-66, 137). Moreover, investigating potential interactions or moderating effects between variables was beyond the scope of this study but is an important area for future research. For example, coping strategies may buffer the negative effects of stress on mental health (138).

4.3 Methodological considerations

This section discusses the general methodological considerations for the three studies in this thesis, including issues related to selection bias, misclassification, confounding, and generalization.

4.3.1 Strengths and limitations of methods

In Study I, a key limitation is the lack of data on mental disorder diagnoses before 1995, which affects diagnostic coverage for the oldest included cohort. Consequently, full lifetime diagnostic information is not available for 15-year-olds in the 2002–2009 cohorts, complicating comparisons across cohorts. However, a sensitivity analysis using diagnoses from age 7 years onwards showed similar results and did not alter the study's conclusions. It should also be noted that this study captured only the most severe cases of poor mental health from the registers. Data from primary care are not available; therefore, diagnoses made by GPs are not included. Weye et al. (45) found that only 15% of individuals who met the cutoff for self-reported depression, based on the Major Depression Inventory, had a corresponding diagnosis in the psychiatric registers, while 51% had received psychotropic medication.

In Study II, the finding that low SSS was more strongly associated with mental health outcomes than low income or short education may partly reflect the small size of the low SSS groups, which comprised only 5% of the sample and may represent the most socially disadvantaged group. To test whether group size influenced the results, we reclassified the low-income group to include only the lowest 5% of incomes, which did not change the results. However, this comparison can be problematic, as previous research has shown that individuals in the lowest tax-reported income brackets can sometimes have substantial financial resources due to factors such as tax minimization, asset-based wealth, or temporary income fluctuations and may therefore be misclassified in register-based data (81). A strength of this study is the inclusion of multiple SES measures to capture different dimensions of social status. Low correlations between SES measures underscore the importance of using multiple indicators when studying social inequalities. The combination of survey and register data allowed for a broad and nuanced analysis of the data. A limitation of this study is that the trajectory groups had an APPA value and two OCC values that were below the recommended thresholds. Although the APPA (65%) and OCC (2.7% and 3.6%) were only slightly below the suggested cutoffs (70% and 5%, respectively), these results should be interpreted cautiously.

In Study III, the longitudinal design spanning from adolescence to adulthood offers a unique opportunity to examine age-specific changes in depressive symptoms during this developmental transition. The availability of self-reported data on a wide range of explanatory variables enabled a comprehensive examination of how personal, health, lifestyle, and social factors are related to depressive symptoms. One limitation is the varying time intervals between surveys (three to seven

years), which complicates comparisons of change across models, as the duration between measurements may influence the magnitude of the observed changes. Finally, the sizes of the estimates in the asymmetric change analyses should be interpreted with caution, as the variables included in the models differ in their measurement scales; some are categorical, while others are continuous. A one-unit change in a categorical variable (e.g. from "not bullied" to "once or twice") represents a relatively larger shift when the variable includes only five categories compared to a one-unit change in a continuous variable that spans a broader range (e.g. one unit on the BMI scale). This difference in scale means that effect sizes are not directly comparable across variable types, and the relative magnitude should be interpreted within the context of each variable's measurement properties. However, this limitation only affects the interpretation of the asymmetric change analyses. In contrast, dominance analyses are not subject to this issue, as categorical variables are coded as such, and the results reflect each variable's relative contribution to the explained variance in depressive symptoms rather than relying on unit-based comparisons.

4.3.2 Causality

Across all three studies, causal interpretations are limited by the timing of measurements. In Studies I and II, SES and mental health indicators were assessed at the same time, making it impossible to determine whether socioeconomic disadvantage leads to poor mental health or whether mental health problems contribute to lower SES — leaving open the possibility of reverse causality. In Study III, changes in depressive symptoms and the potential explanatory factors were measured at the same time, making it difficult to know which came first. Future research should examine the timing of exposures and outcomes more closely to better assess causal relationships.

4.3.3 Selection bias

In Study I, the use of national register data provided near-complete coverage of Danish adolescents, thereby minimizing the risk of selection bias. Missing data were addressed using MI, which incorporates strong auxiliary variables. However, relying solely on register-based mental health indicators likely underrepresents milder cases, particularly among low-SES groups who may be less likely to access specialist care (117, 118). Conversely, individuals from high-SES families might be underrepresented if they used private psychiatric services not captured in the registers.

In Study II, the use of near-complete national register data in descriptive analyses of mental disorder diagnoses and psychotropic medication use similarly minimized the selection bias.

Studies II and III used data from the VestLiv cohort. Participation in the initial survey was high (81.5% in 2004). Missing data were handled using MI within each survey to retain as many participants as possible, and IPW was applied to adjust for non-participation, which was especially important in later surveys. Nonetheless, some differences in the characteristics between the analytical and excluded samples remained, suggesting that selection bias may not have been fully eliminated despite these efforts.

4.3.4 Misclassification

In Study I, all data were drawn from national registers, which can be subject to misclassifications. Psychotropic medication use was defined using prescription indication codes; however, some prescriptions lacked an indication and were coded as no psychotropic medication use, which could lead to an underestimation of medication use for mental disorder treatment. Regarding SES measures, approximately 0.6% of individuals had missing data on parental educational levels, primarily among those of non-Danish origin. Although multiple imputations were used to handle this, the potential for misclassification remains, particularly in this subgroup. Moreover, income data may be misclassified at lower ends of the distribution. As mentioned, previous research has shown that individuals in the lowest tax-reported income brackets may have substantial financial resources due to tax minimization strategies, asset-based wealth, or temporary income fluctuations and are therefore incorrectly categorized as low-income in register-based analyses. However, categorizing income into groups has been shown to reduce this bias (81).

In Studies II and III, misclassification may have arisen from survey-based measures. The CES-DC4, used to assess depressive symptoms, has demonstrated poor reliability and only acceptable structural validity in adolescents, while the short form has not been validated in adults (139). Therefore, depressive symptom levels should be interpreted with caution. The SSS was measured using the MacArthur Scale and categorized into low, middle, and high groups. Although similar cutoffs have been used in other studies (e.g. low: steps 1–3; middle: steps 4–7; high: steps 8–10) they differ slightly from those in the present study, where the cutoffs were set at low (steps 1–4), middle (5–8), and high (9–10) to better balance group sizes, as the low group was very small and the high group large with the cutoff previously used. The construct validity and optimal cutoffs of the MacArthur Scale warrant further investigation.

In Study III, the models were based on changes in variables across surveys; however, not all variables were measured identically across time points. Some slight variations in item wording reflect the necessary cultural and developmental adaptations for ages 15–32, but these changes may reduce the consistency of measurements over time and affect the changes in the variables.

4.3.5 Confounding

In Study I, the analyses were adjusted for various register-based variables, including demographic and family level information. However, factors not available in the registers, such as parenting style, neighborhood characteristics, or coping strategies, may still confound the results (140-142).

In Study II, no adjustments for confounding factors were applied. This was appropriate given the aim of describing SES-specific patterns in mental health and depressive symptom trajectories.

In Study III, a major strength is the use of FE models that control for all time-invariant confounding. Additionally, all explanatory variables were mutually adjusted, and the survey was included as a covariate to account for aging and secular trends. Despite this, the models explained 25–29% of the variance in depressive symptoms, suggesting that unmeasured factors likely contribute to changes in depressive symptoms.

4.3.6 Generalizability

Study I used national data; therefore, the findings are likely generalizable to the Danish population. In an international context, the results may also be applicable to countries with welfare systems similar to Denmark. However, these findings could underestimate the effects of low SES in contexts where socioeconomic disadvantage is more strongly associated with unmet basic needs.

In Study II, the findings regarding psychotropic medication use reflect prescribing practices prior to the 2014 regulation that restricted general practitioners from prescribing antidepressants to individuals under 25 years, reserving this right for psychiatrists (119). As the cohort studied was born in 1989 and thus aged out of this regulation by the time it was implemented, the findings may not be fully generalizable to younger cohorts affected by this policy change.

In Studies II and III, the analyses based on data from the VestLiv cohort, which is located in a rural region of Denmark, might have limited generalizability to more urban settings than the national population, as rural–urban differences in health and social dynamics could influence the observed

relationships. However, a previous study found that the social structure of the VestLiv cohort was comparable to that of the general Danish population (143).

5. Conclusion

This thesis contributes to a deeper understanding of how SES shapes the development and course of mental health from adolescence to adulthood. Drawing on national register data and longitudinal survey data, the three studies collectively illustrate the persistence of social inequality in mental health across developmental stages, while also highlighting how different aspects of SES—both objective and subjective— are related to mental health outcomes and trajectories over time.

Study I showed that social inequalities in adolescent mental health in Denmark have persisted over the past two decades, although the patterns have evolved. While increases were observed in the prevalence of mental disorder diagnoses and medication, the magnitude of inequality between the low- and middle-SES groups appears to have slightly decreased. In contrast, inequalities between the high- and middle-SES groups remained stable. Importantly, these trends differed by diagnosis, indicating that broader societal or systemic changes may influence specific mental health outcomes in distinct ways. This highlights the need for future research to examine diagnosis-specific mechanisms and policies that can mitigate these social disparities.

Study II extended the investigation into adulthood, showing that individuals with low SES—especially those with low SSS—faced more mental health outcomes. SSS emerged as a particularly sensitive indicator, potentially identifying vulnerable individuals who may be overlooked by indicators such as income and education. The study revealed that depressive symptom trajectories are socially patterned, with other mental health problems, low SES, female sex, and low social support being associated with trajectories with more depressive symptoms. These findings suggest that strengthening social support systems for vulnerable adolescents and young adults may help prevent the development or worsening of depressive symptoms over time.

Study III emphasized the importance of considering age-specific dynamics in the development of depressive symptoms. While changes in personal and health-related factors (e.g. stress, psychosomatic symptoms, and sense of coherence) were most strongly associated with changes in depressive symptoms, the influence of these factors varied across life stages. Bullying in adolescence was also associated with depressive symptoms; however, due to data limitations, the full scope of social influences could not be explored. Future research should adopt system-based approaches to better capture the complexities of social determinants over time.

6. Perspectives

The results of this dissertation hold several clinical and public health implications for mental health prevention and intervention across adolescence, emerging adulthood and adulthood.

First, the identification of socioeconomical vulnerable groups emphasizes the continued need for targeted prevention strategies. While some evidence points to a weakening of SES gradients in diagnoses and medication use, vulnerable adolescents remain at elevated risk, and certain diagnostic categories may require more focused attention. Clinicians and policymakers should be aware that socioeconomic disadvantage remains a powerful structural determinant of mental health and continues to affect young people unequally.

Second, the strong association between SSS and depressive symptom trajectories highlights the importance of addressing subjective social experiences in clinical settings. Feelings of inferiority, social marginalization, or exclusion may not be visible through traditional SES indicators but still have profound associations with mental health. Interventions that support adolescents' sense of belonging, self-worth, and social inclusion—such as school-based mental health programs and youth-centered therapeutic approaches—could help mitigate these risks.

Third, social support emerged as a factor that may buffer against increasing depressive symptoms. Clinically, this suggests that mental health professionals should assess the availability and quality of adolescents' support networks and actively work to strengthen them, including through school-oriented, family-oriented or peer-support interventions.

Fourth, findings from Study III underline that age-sensitive approaches are essential. Different factors—such as stress, self-esteem and sense of coherence—contribute differently to mental health at different ages. Interventions should therefore be developmentally tailored, flexible over time, and responsive to the changing needs of young people.

Finally, while the Health Complexity Framework was used as an interpretative lens for understanding the results, while it also carries practical implications. It suggests that effective mental health care must move beyond simple cause-effect models and instead embrace the evolving nature of mental health. The interplay between personal, social, and structural factors is dynamic, and targeting a single factor in isolation is unlikely to result in clinically meaningful improvements.

Instead, multifaceted approaches that address several interrelated determinants simultaneously—and adapt to changes over time—are needed to support young people's mental health in a more sustainable and effective way.

In conclusion, the studies underscore the need for a layered and responsive mental health system—one that integrates social context, developmental timing, and complexity into both diagnosis and intervention. Such an approach can more effectively support adolescents through their formative transitions and reduce the long-term burden of mental disorders.

Summary

Mental health problems in adolescence and adulthood are a growing public health concern with long-term consequences for individuals and society. This thesis explored how mental health developed from 15 to 32 years of age in relation to social inequalities and determinants. Using longitudinal survey and register data, it examined trends in social determinants, mental health trajectories, and the influence of personal, health, lifestyle, and social factors on mental health. The aim was to support targeted, age-sensitive preventive strategies.

Study I investigated whether socioeconomic (SES) inequality in adolescent mental health changed from 2002 to 2022. The study included all 15-year-olds in Denmark over this period and linked family income and parental education to mental disorder diagnoses and the use of psychotropic medication. The results showed an increasing prevalence of mental health problems across all groups. SES disparities persisted but tended to decrease over time, although the diagnosis-specific patterns varied.

Study II followed a 1989 birth cohort across five surveys from ages 15 to 32 to assess the influence of SES—both objective and subjective—on mental health development. Individuals with low SES at age 15 experienced worse mental health outcomes throughout the period, most prominently for individuals with a low subjective status. Four depressive symptom trajectories were identified: low stable, moderate stable, decreasing, and increasing trajectories. Low social status, being female, having other mental health outcomes, and low social support increased the likelihood of belonging to a trajectory other than the low stable trajectory.

Study III explored the associations between changes in personal, health, lifestyle, and social factors and changes in depressive symptoms at different stages of life. Using fixed-effects and dominance analyses, the results showed that stress symptoms were consistently the most important factor, while sense of coherence became more influential with age. Self-esteem, psychosomatic symptoms, and self-rated health also played key roles, with their relative importance shifting with age.

Together, these studies show that mental health is shaped by persistent social inequalities and dynamic individual factors. Interventions should be tailored to different life stages and prioritize individuals from socioeconomically disadvantaged backgrounds.

Dansk resumé

Mentale helbredsproblemer i ungdoms- og voksenårene er et stigende problem med langvarige konsekvenser. Afhandlingen undersøgte, hvordan mental sundhed udviklede sig fra 15- til 32-årsalderen med fokus på social ulighed. Ved brug af longitudinelle spørgeskema- og registerdata blev tendenser i social ulighed, mentale helbredsforløb og betydningen af personlige, sundhedsrelaterede, livsstilsrelaterede og sociale faktorer belyst. Formålet var at understøtte målrettede og alderssensitive forebyggelsesstrategier.

Studie I undersøgte, om den sociale ulighed i unges mentale sundhed havde ændret sig fra 2002 til 2022. Studiet inkluderede alle 15-årige i Danmark i perioden og koblede familieindkomst og forældres uddannelsesniveau til psykiatriske diagnoser og brug af psykofarmaka. Resultaterne viste en stigende forekomst af mentale helbredsproblemer i alle grupper. Social ulighed var vedvarende, men viste en tendens til at aftage over tid, med varierende mønstre afhængigt af diagnose.

Studie II fulgte en 1989-fødselskohorte gennem fem målinger fra 15- til 32-årsalderen og undersøgte, hvordan både objektiv og subjektiv social status påvirkede mental sundhed over tid. Personer med lav social status som 15-årige havde gennemgående dårligere mentalt helbred, mest udtalt for personer med lav subjektiv social status. Fire forløb af depressive symptomer blev identificeret: lav stabil, moderat stabil, faldende og stigende. Lav social status, at være kvinde, have tidligere mentale helbredsproblemer og lav social støtte øgede risikoen for at tilhøre de øvrige forløb frem for lav stabil.

Studie III undersøgte, hvordan ændringer i personlige, sundhedsrelaterede, livsstilsrelaterede og sociale faktorer hang sammen med ændringer i depressive symptomer i forskellige livsstadier. Med fixed effects- og dominansanalyser viste studiet, at stress-symptomer var den vigtigste forklarende faktor, mens oplevet sammenhæng (sense of coherence) blev vigtigere med alderen. Selvværd, psykosomatiske symptomer og selvvurderet helbred spillede også væsentlige roller, med skiftende betydning over tid.

Studierne viste, at mental sundhed blev formet af vedvarende sociale uligheder og dynamiske individuelle faktorer. Forebyggende indsatser burde tilpasses livsfaser og målrettes personer med socioøkonomisk ufordelagtige vilkår.

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Appendices

Study I

Study II

Study III

Study I

Social Psychiatry and Psychiatric Epidemiology
https://doi.org/10.1007/s00127-025-02943-y

RESEARCH

Social inequality in mental disorder diagnoses and psychotropic medication use among 15-year-old adolescents in Denmark from 2002–2022

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Received: 28 February 2025 / Accepted: 9 June 2025

Abstract

Purpose The aim of this study is to examine if the social inequality in adolescent mental health has changed in the past decades (2002–2022) by studying the associations between socioeconomic status (SES) and mental health measures in 15-year-old adolescents.

Methods This study is a register-based study consisting of seven cross-sectional analyses of associations between adolescents' SES, defined as family income and parents' educational level, and mental health, defined as mental disorder diagnosis and medication use. The population consists of all registered residents in Denmark who turned 15 years in the years 2002–2022. All data was obtained from Danish population-based registers. The prevalence of mental health measures was calculated, and the associations between SES and mental health were analysed with log-binomial regression.

Results The prevalence of mental disorder diagnoses and medication use of adolescents increased during the past two decades. Associations between SES and mental health were found between all measures during the period, however, a trend toward decreasing associations for low-SES groups and stable odds ratios for high-SES groups compared to the middle-SES were observed. Diagnosis-specific analyses—including eight diagnostic categories—revealed divergent trends, such as increasing associations for SES and substance use disorders and decreasing associations for SES and mood disorders.

Conclusion This study highlights persistent but evolving social inequalities in adolescent mental health in Denmark from 2002 to 2022. While the prevalence of mental health diagnoses increased, changes in inequality patterns were diagnosis-specific, suggesting that broader societal trends may influence types of mental disorders differently.

Keywords Mental health · Adolescence · Equality · Socioeconomic status · Social inequality

Background

Poor mental health is an increasing global concern, with the World Health Organization (WHO) estimating that approximately 20% of children and adolescents are affected by a mental health condition [1]. Denmark has seen similar trends over recent decades, as reflected by an increase in both the prevalence of mental disorder diagnoses and medication use among youth [2–4]. Notably, antidepressant use among 0–17-year-olds in Denmark more than doubled the past decades, from 2.15 users per 1,000 inhabitants in 2002 to 5.04 users per 1,000 in 2022 [5]. This increase has occurred despite a regulatory change in 2014 that restricted general practitioners from prescribing antidepressant medication to children and adolescents [6]. The increased medication use aligns with rising incidence rates of diagnosed

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mental disorders in 15–20-year-olds; for example, a study found that the incidence rates of mood disorders in younger ages (under age 30 years) were markedly higher in the most recent birth cohorts compared to older cohorts [7]. Several studies on both self-reported mental health and mental disorder diagnoses have confirmed this increasing trend over time, while studies on psychotropic medication use are lacking [3, 4, 7, 8].

Rising mental health issues have paralleled an increase in socioeconomic inequality in Denmark. The Gini coefficient, reflecting income distribution, rose from 24 in 2002 to 30 in 2022 [9]. Moreover, social mobility through education has also become more difficult: in 2021, 60% of children from the poorest quintile who lacked vocational training remained in the poorest quintile, compared to 39% in 1995 [10]. The association between low socioeconomic status (SES) and poor mental health in adolescents is well-documented [11–17]. This has been evident, both when SES is defined as income, reflecting the economic resources of the family, and parents' educational level, reflecting the cognitive skills and cultural capital [18]. However, it is also evident that the associations between SES and poor mental health differs depending on the measure of SES [11]. Given the importance of understanding the different aspects of SES in relation to adolescent mental health, further investigation is crucial. While existing studies tend to focus on specific aspects of SES, such as income or educational level, few incorporate population-based data [11–17]. Therefore, research that explores multiple SES factors within the same population-based sample remains limited. Moreover, although social inequality and adolescent mental health issues have increased simultaneously, little is known about the changes over time in the association between SES and mental health in adolescents.

This study aims to examine the association between social inequality in mental health using various SES measures (family income and parental educational level) and mental health measures (mental disorder diagnoses and medication use) in 15-year-old adolescents over the period from 2002 to 2022.

Methods

Study design, setting, and participants

This study is a register-based cohort study consisting of cross-sectional analyses of the associations between adolescents' SES, defined as family income and parents' educational level, and mental health, defined as mental disorder diagnoses and medication use, for seven 3-year-periods in the years 2002–2022.

The population consists of all registered residents in Denmark who turned 15 years in the years 2002–2022 identified through the Danish Civil Registration System [19].

Variables, data sources and measurement

Mental health measures

We defined mental disorder diagnoses by the Danish modification of the 10th version of the International Classification of Diseases (ICD-10) codes F10-F69 and F80-F99, thus excluding F00-F09 (organic diagnosis) and F70-79 (intellectual disabilities). The mental disorder diagnoses are presented in 8 diagnostic group: substance use disorders (F10-F19); schizophrenia, schizotypal, and delusional disorders (F20-29)—hereafter referred to as "psychotic disorders"; mood disorders (F30-39); neurotic, stress-related, and somatoform disorders (F40-48)—hereafter referred to as "anxiety-related disorders"; eating disorders (F50-59); personality disorders (F60-69); developmental disorders (F80-89); behavioural disorders (F90-98); and a joint category of "Any mental disorder". Mental disorder diagnoses from the psychiatric and somatic units from 1995–2022 are identified from the Danish National Patient Registry [20, 21]. The register does not cover outpatients before 1995 and therefore, the first cohorts of adolescents in 2002–2009 do not have complete data from birth and the results are not directly comparable with the later cohorts. Adolescents' mental disorder diagnoses are defined as the lifetime prevalence of any primary or secondary diagnosis recorded from birth until six months after the adolescent's 15th birthday.

Medication use was defined as prescriptions for psychotropic medication using Anatomical Therapeutic Chemical (ATC) codes N05A (excluding N05AN), N05AN, N05B, N05C, N06A, N06B, N06C (excluding N06AX01 and N06AX02), N07BB and N07BC), obtained from the Danish National Prescription Register [22]. The choices of ATC codes were based on advice from a senior psychiatrist on medication most often used for treating mental disorder diagnoses in Denmark, with exclusion of medication that often is used to treat other types of disorders. Medication use is defined as prescription filled in the period between half a year before and half a year after the adolescents'15th birthday.

SES measures

Equalized family income is a measure of the disposable income weighted by the number of people in the family obtained from the Register of Family Income [23]. The equalized family income was categorized according to the OECD definition of low (20% lowest), middle (60%) and

high (20% highest) income group [24]. The adolescents were grouped with adolescent born the same year. We used the mean of the equalized family income the year before the adolescents' 15th birthday, the year of the 15th birthday and the year after the 15th birthday. The mean of 3 years was used to reduce information bias related to negative income for one year, e.g. because of financial loss due to a poor investment year [25]. If information on less than 3 years income was available in the period, this information was used.

Parents' highest educational level is categorized according to the International Standard Classification of Education (ISCED) into educational level group of short (up to secondary school (ISCED: 0–2), middle (upper secondary school, vocational education or short-cycle tertiary education (ISCED: 3–5), and long (bachelor's degree or higher (ISCED: 6–8)) [26]. Data on parents' educational level—defined as the highest level completed by either parent—was obtained on the adolescents' 15th birthday obtained from Register of the Highest Completed Education [27]. The middle group was used as the reference category in both SES measures, as it represents the most typical group in the population and enables comparisons relative to the average adolescent [28].

Covariates

Covariates consist of sex, country of origin, parents living together, family's mental disorder, adolescents' multimorbidity, and family's multimorbidity. The adolescents' sex was defined as male or female according to their legal registered sex. The country of origin is coded as born in Denmark or born outside Denmark. Parents living together was defined as the legal parents living in the same household as the adolescent from birth until the time of the 15th birthday. The measure was dichotomized into parents living together since birth or parents not living together in the period since birth. Data on sex, origin, and parents were living together was obtained from the Population Register [29].

Family's mental disorder was defined as any mental disorder diagnosis since birth of the family member or from 1995 until the 15th year birthday of the adolescent or any prescription for psychopharmacological medication. Siblings were defined as children or adolescents (< 25 years old) living in the same household as the adolescents at the time of the 15th birthday. Parents was defined as legal parents. Mental disorder in siblings and parents was measured dichotomously, indicating whether or not mental disorder was present in the family. The medication use was measured half a year before and half a year after the 15th birthday. Multimorbidity of the adolescents, siblings and parents was defined by a modified version of the Nordic Multimorbidity Index (NMI). In the NMI, 50 predictors of multimorbidity are weighted from −2 to 22. The index date was defined as the 15th birthday of the adolescent and the predictors were based on ICD-10 codes in the period 5 years before the index date and ATC codes in the period 6 month before the index date. We excluded ICD-10 codes related to mental disorder diagnosis (F10 and F17) and ACT codes of psychopharmacological mediation (N05A, N05BA, N05CD, N05CF, N06A and N07BC), as they are part of the outcome for the adolescents, and part of the covariate of mental disorder in family for siblings and parents [30]. Data on health and medication was obtained from the National Patient Registry and Danish National Prescription Register [20, 22].

Missing data

To account for missing data on income and educational level, multiple imputations with chained equations and 10 iterations are used. The models were built on information about year, sex, multimorbidity of the adolescents, the parents and the siblings, psychotropic medication use of the adolescent, any mental disorder diagnosis and diagnosis group of the adolescent, mental disorder in siblings and parents, parents living together, parents' educational level, and family income 2.5 year before the 15th birthday and 2.5 year after.

Statistical methods

Descriptive statistics

The characteristics of the adolescents in terms of mental disorder diagnoses, medication use, SES groups defined by income, SES groups defined by parents' educational level, origin, parents living together, and NMI are presented in seven 3-year periods from 2002–2022. Mental disorder diagnoses and medication use are also presented sex-stratified and stratified by the SES measures (equalized family income and parents'highest educational level). For each mental disorder diagnosis, the mean age of onset is presented.

Main analyses

The odds ratios (OR) of the equalized family income and mental health measures, along with the 95% confidence intervals (CI), were estimated using logistic regression adjusted for country of origin, the adolescent's multimorbidity, siblings' multimorbidity, parents' multimorbidity, siblings' mental disorder, parents' mental disorder, and parents living together.

The ORs for the parents' highest educational level and mental health measures were estimated using logistic regression adjusted for country of origin, parents' chronic illness and parents' mental disorder. The selection of covariates for adjustment was based on existing literature and the construction of directed acyclic graphs (DAGs) (Supplementary Fig. 1 & 2).

Sensitivity analyses

The used thresholds for equalized family income were explored by expanding the time frame to the mean of 5 years instead of 3 years and use of tertiles to define low-, middle-, and high-income groups. Moreover, sensitivity analyses using only mental disorder diagnosis from age 7 instead of year 1995 or birth was calculated to explore the effect of the lack of data in the first years of life in the earliest cohorts.

The data were analysed on the secure server of Statistics Denmark. All analyses were conducted in Stata version 17 [31]. Plots and graphs were performed in R Studio (Version 4.4.1).

Results

Descriptive results of the characteristics of the included adolescents grouped in 3-year periods showed slightly higher prevalences of males compared to females throughout the period 2002–2022 (Table 1). The prevalence of adolescents with any mental disorder diagnosis has increased in the past decades from 6% in 2002–2004 to 19% in 2020–2022 with the highest prevalences of behavioural disorders (7%) and developmental disorders (5%). Generally, a tendency of earlier mean age-of-onset for some mental disorder diagnoses was observed, while the age-of-onset for mood disorders, eating disorders, and behavioural disorders was relatively stable. Likewise, the prevalence of medication use increased in the same period from 2% in 2002–2004 to 9% in 2020–2022. A sensitivity analysis showed that the prevalence of ADHD medication use increased in the first two cohorts and then remained stable, accounting for approximately 50% of all psychotropic prescriptions from 2008 onwards (Supplementary Table 1). The adolescents' parents have a longer education in the later years and there is an increasing prevalence of adolescents with origins outside of Denmark. Data were imputed on <0.1% of household income and 0.6% of parental educational level. Missing data on parental education were more common among individuals with origins other than Denmark, likely due to incomplete registration of foreign educational histories (Supplementary Table 2). The prevalence of adolescents living with both parents have remained stable at around 57% throughout the period. The general multimorbidity of the adolescents increased from a mean on 0.19 (0.19–0.19) in 2002–2004 to 0.22 (0.22–0.23) in 2020–2022. As the adolescents were grouped in income-groups with adolescents born the same year according to the OECD definition, and afterwards the populations were grouped in 3-year-cohorts, the size of the income groups differs slightly from the 20/60/20 distribution.

Sex specific analyses showed that males had a higher prevalence of any mental disorder and medication use than females in all seven periods. Generally, males had a higher prevalence of developmental disorders and behavioral disorder, while females had a slightly higher prevalence of mood disorders, eating disorders, and anxiety-related disorders (Supplementary Table 3).

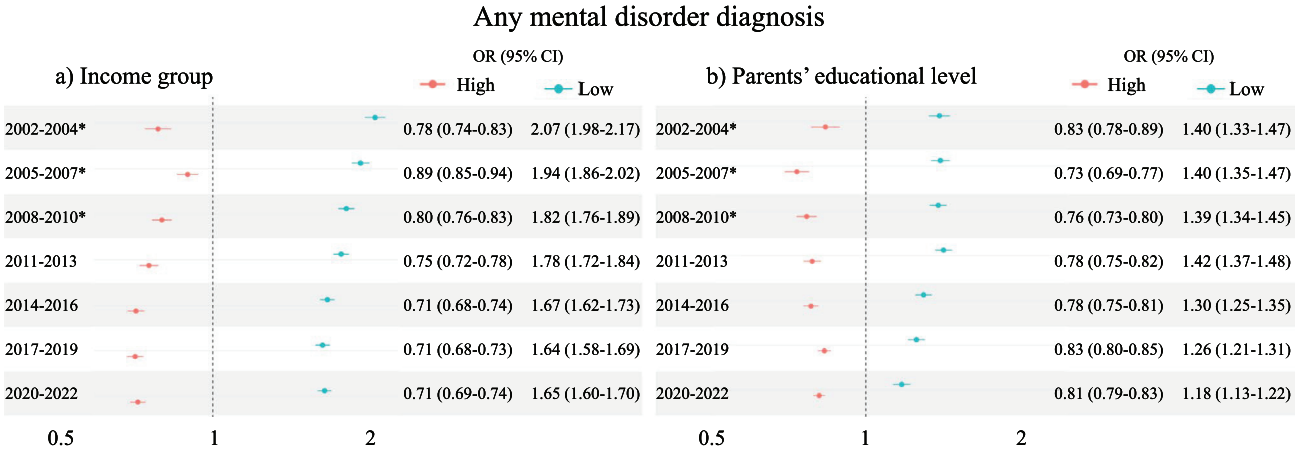


Fig. 1 Odds ratios (OR) of any mental disorder diagnoses by (**a**) income group and (**b**) parents' educational level

Table 1 Characteristics of 15-year-olds grouped in 3-year periods

Cohort		2002-2004* N=189117	2005-2007* N=208948	2008-2010* N=221302	2011-2013 N=215761	2014-2016 N=216274	2017-2019 N=215053	2020-2022 N=221882
Sex	Males	97396 (51.5%)	107475 (51.4%)	113762 (51.4%)	111064 (51.5%)	110748 (51.2%)	110703 (51.5%)	113559 (51.2%)
	Females	91721 (48.5%)	101473 (48.6%)	107540 (48.6%)	104697 (48.5%)	105526 (48.8%)	104350 (48.5%)	108323 (48.8%)
Mental disorder diagnosis	Any mental disorder	11890 (6.3%)	17097 (8.2%)	23168 (10.5%)	26758 (12.4%)	33466 (15.5%)	36967 (17.2%)	43080 (19.4%)
	Mean age of onset (95% CI)	11.74 (11.68-11.80)	11.04 (10.98-11.10)	10.47 (10.41-10.53)	10.27 (10.21-10.33)	10.25 (10.20-10.30)	10.09 (10.04-10.14)	10.11 (10.06-10.16)
	Substance use disorders	1390 (0.7%)	1548 (0.7%)	1581 (0.7%)	905 (0.4%)	740 (0.3%)	556 (0.3%)	571 (0.3%)
	Mean age of onset (95% CI)	14.36 (14.31-14.41)	14.35 (14.28-14.42)	13.94 (13.82-14.05)	13.59 (13.38-13.80)	13.55 (13.30-13.80)	13.22 (12.88-13.55)	12.92 (12.57-13.27)
	Schizofrenia	254 (0.1%)	334 (0.2%)	414 (0.2%)	531 (0.2%)	663 (0.3%)	731 (0.3%)	805 (0.4%)
	Mean age of onset (95% CI)	13.78 (13.57-14.00)	13.54 (13.32-13.75)	13.45 (13.26-13.64)	13.72 (13.55-13.89)	13.72 (13.58-13.86)	13.54 (13.40-13.68)	13.49 (13.35-13.63)
	Mood disorders	552 (0.3%)	785 (0.4%)	1101 (0.5%)	1348 (0.6%)	1749 (0.8%)	1626 (0.8%)	1581 (0.7%)
	Mean age of onset (95% CI)	14.04 (13.92-14.16)	13.93 (13.83-14.04)	13.99 (13.90-14.08)	13.81 (13.73-13.90)	13.71 (13.63-13.79)	13.51 (13.42-13.60)	13.70 (13.62-13.79)
	Neurotic disorders	2252 (1.2%)	3643 (1.7%)	4617 (2.1%)	5722 (2.7%)	7491 (3.5%)	8750 (4.1%)	9892 (4.5%)
	Mean age of onset (95% CI)	12.83 (12.74-12.93)	12.69 (12.60-12.77)	12.24 (12.14-12.34)	12.18 (12.09-12.28)	12.43 (12.36-12.51)	12.22 (12.16-12.29)	11.87 (11.81-11.94)
	Eating disorders	587 (0.3%)	771 (0.4%)	1086 (0.5%)	1377 (0.6%)	1688 (0.8%)	1947 (0.9%)	2454 (1.1%)
	Mean age of onset (95% CI)	13.21 (13.03-13.38)	12.55 (12.35-12.75)	11.16 (10.88-11.44)	11.18 (10.92-11.44)	11.25 (11.02-11.48)	11.34 (11.13-11.54)	11.26 (11.09-11.44)
	Personality disorders	376 (0.2%)	369 (0.2%)	399 (0.2%)	367 (0.2%)	442 (0.2%)	346 (0.2%)	325 (0.1%)
	Mean age of onset (95% CI)	10.65 (10.57-10.73)	9.96 (9.88-10.04)	9.89 (9.81-9.97)	9.80 (9.73-9.87)	9.75 (9.69-9.81)	9.60 (9.54-9.66)	9.95 (9.89-10.00)
	Developmental disorders	2099 (1.1%)	3307 (1.6%)	5023 (2.3%)	6167 (2.9%)	8177 (3.8%)	9559 (4.4%)	11179 (5.0%)
	Mean age of onset (95% CI)	10.52 (10.40-10.63)	9.49 (9.38-9.61)	9.55 (9.44-9.66)	9.82 (9.73-9.92)	9.94 (9.85-10.02)	9.96 (9.88-10.03)	10.05 (9.97-10.12)
	Behavioral disorders	4380 (2.3%)	6340 (3.0%)	8947 (4.0%)	10341 (4.8%)	12516 (5.8%)	13452 (6.3%)	16273 (7.3%)
	Mean age of onset (95% CI)	10.65 (10.57-10.73)	9.96 (9.88-10.04)	9.89 (9.81-9.97)	9.80 (9.73-9.87)	9.75 (9.69-9.81)	9.60 (9.54-9.66)	9.95 (9.89-10.00)
Medication use	Age 14.5-15.5	2951 (1.6%)	5246 (2.5%)	9483 (4.3%)	11559 (5.4%)	13691 (6.3%)	15133 (7.0%)	19766 (8.9%)
Household income	High	37540 (19.9%)	41459 (19.8%)	43686 (19.7%)	42456 (19.7%)	42252 (19.5%)	41927 (19.5%)	43148 (19.4%)
	Middle	112828 (59.7%)	124657 (59.7%)	131829 (59.6%)	128580 (59.6%)	129047 (59.7%)	128274 (59.6%)	132161 (59.6%)
	Low	38750 (20.5%)	42832 (20.5%)	45787 (20.7%)	44725 (20.7%)	44975 (20.8%)	44852 (20.9%)	46573 (21.0%)
Educational level	Long	21266 (11.2%)	25454 (12.2%)	29497 (13.3%)	33376 (15.5%)	39349 (18.2%)	46216 (21.5%)	54153 (24.4%)
	Middle	136610 (72.2%)	152973 (73.2%)	163028 (73.7%)	156705 (72.6%)	153254 (70.9%)	147020 (68.4%)	147439 (66.4%)
	Short	31241 (16.5%)	30521 (14.6%)	28778 (13.0%)	25679 (11.9%)	23671 (10.9%)	21817 (10.1%)	20290 (9.1%)
Origin	Denmark	171261 (90.6%)	189074 (90.5%)	199830 (90.3%)	193132 (89.5%)	191736 (88.7%)	189483 (88.1%)	195370 (88.1%)
	Other	17856 (9.4%)	19874 (9.5%)	21472 (9.7%)	22629 (10.5%)	24538 (11.3%)	25570 (11.9%)	26512 (11.9%)
Cohabitation	No	79444 (42.0%)	90156 (43.1%)	97881 (44.2%)	96465 (44.7%)	95641 (44.2%)	93242 (43.4%)	94775 (42.7%)
	Yes	109673 (58.0%)	118792 (56.9%)	123421 (55.8%)	119296 (55.3%)	120633 (55.8%)	121811 (56.6%)	127107 (57.3%)
NMI**	Mean (95%CI)	0.19 (0.19-0.19)	-0.20)	-0.20)	-0.20)	-0.22)	-0.22)	-0.23)
	N (missing)	189117 (0)						

*Mental disorder diagnosis not available since birth, but only available from year 1995
**NMI = Nordic morbidity index
Note: data on 0.6% of educational level and <0.1% of household income are imputed.

SES-specific prevalences

Income group specific analyses showed the highest prevalences of any mental disorder in the low-income group and the lowest prevalences in the high-income group across all time periods (Supplementary Table 4). Diagnosis-specific analyses showed the highest prevalences of substance use disorders, psychotic disorders, anxiety-related disorders, developmental disorders, and behavioral disorders in the low-income group and the lowest prevalences in the high-income group across all time periods. Likewise, the prevalences of medication use was highest in the low-income group and lowest in the high-income group across time periods. Educational level specific analyses showed that for most time periods, the short-education group had the highest prevalence of any mental disorder while the long-education group had the lowest prevalences (Supplementary Table 5). However, in the latest period, the short- and middle-education group had the same prevalences of any mental disorder diagnosis. The same tendency was present regarding medication use. The diagnosis specific analyses showed higher prevalences of behavioral disorders in the short-education group and lowest prevalences in the long-education group.

Associations between SES measures and mental disorder diagnoses

Analyses of odds for having any mental disorder diagnosis by income group showed that the high-income group consistently had lower odds compared to the middle-income group, while the low-income group consistently had higher odds compared to the middle-income group (Fig. 1a). A similar tendency was found when analyzing the odds for mental disorder diagnosis by educational level, where the odds were consistently lower for the long-education group compared to the middle-education group and consistently higher for the short-education group (Fig. 1b). The strengths of the associations between short-educational level and mental disorder diagnoses appeared to decrease over time, and a similar pattern was observed for low-income compared to the middle-income group. In contrast, the associations between long educational level and high income relative to the middle group remained stable over time.

Diagnosis specific analyses of income showed that the low-income group generally had higher odds compared to the middle-income group across diagnoses and across time periods, while the opposite was present for the high-income

group compared with the middle-income group (Fig. 2A-H). The tendency was most pronounced for substance use disorder and personality disorder. For eating disorder, no association was found between income groups and odds of diagnoses, only for the low-income group compared with the middle-income group in the two earliest periods. A general pattern of decreasing associations between the low-income group and the specific mental disorder diagnosis was present in all diagnosis but substance use disorder, where the association seemed to strengthen over time, and anxiety-related disorder, where the association was stable over time.

Diagnosis-specific analyses of educational level showed that for most disorders, the odds were higher for the short-education group compared to the middle-education group, and lower for the long-education group compared to the middle-education group (Fig. 3A-H). For mood disorders and eating disorders the tendency was reversed with higher odds for the long-education group compared to the middle-education group and lower odds for the short-education group compared to the middle-education group. For developmental disorders, the associations were smaller in the recent years. Over time, the associations between educational level and anxiety-related-, developmental-, and behavioral disorder decreased, the associations between educational level and substance use-, mood-, and eating strengthened, and the associations between educational level and psychotic disorders and personality disorder were stable. The association between educational level and mood disorders reversed over time, so the long-education group had a higher odds than the middle-education group, while the low-education group had lower odds than the middle-education group.

Associations between SES measures and medication use

Analyses of medication use by income level showed higher odds of medication use for the high-income group compared to the middle-income group in the three periods from 2002–2010 and comparable odds in the remaining four periods from 2011–2022 (Fig. 4A). The low-income group had consistently higher odds for medication use compared with the middle-income group.

Analyses of medication use by educational level showed lower odds of medication use for the high-education group compared to the middle-education group and higher odds of medication use for the low-education group compared to the middle-education group in the periods from 2005–2022 (Fig. 4B). In the period 2002–2004, the odds were comparable between groups.

Fig. 2 Odds Ratios (OR) of specific mental disorder diagnoses by income group for (**a**) Substance use disorders, (**b**) Psychotic disorders, (**c**) Mood disorders, (**d**) Anxiety-related disorders, (**e**) Eating disorders, (**f**) Personality disorders, (**g**) Developmental disorders, and (**h**) Behavioral disorders

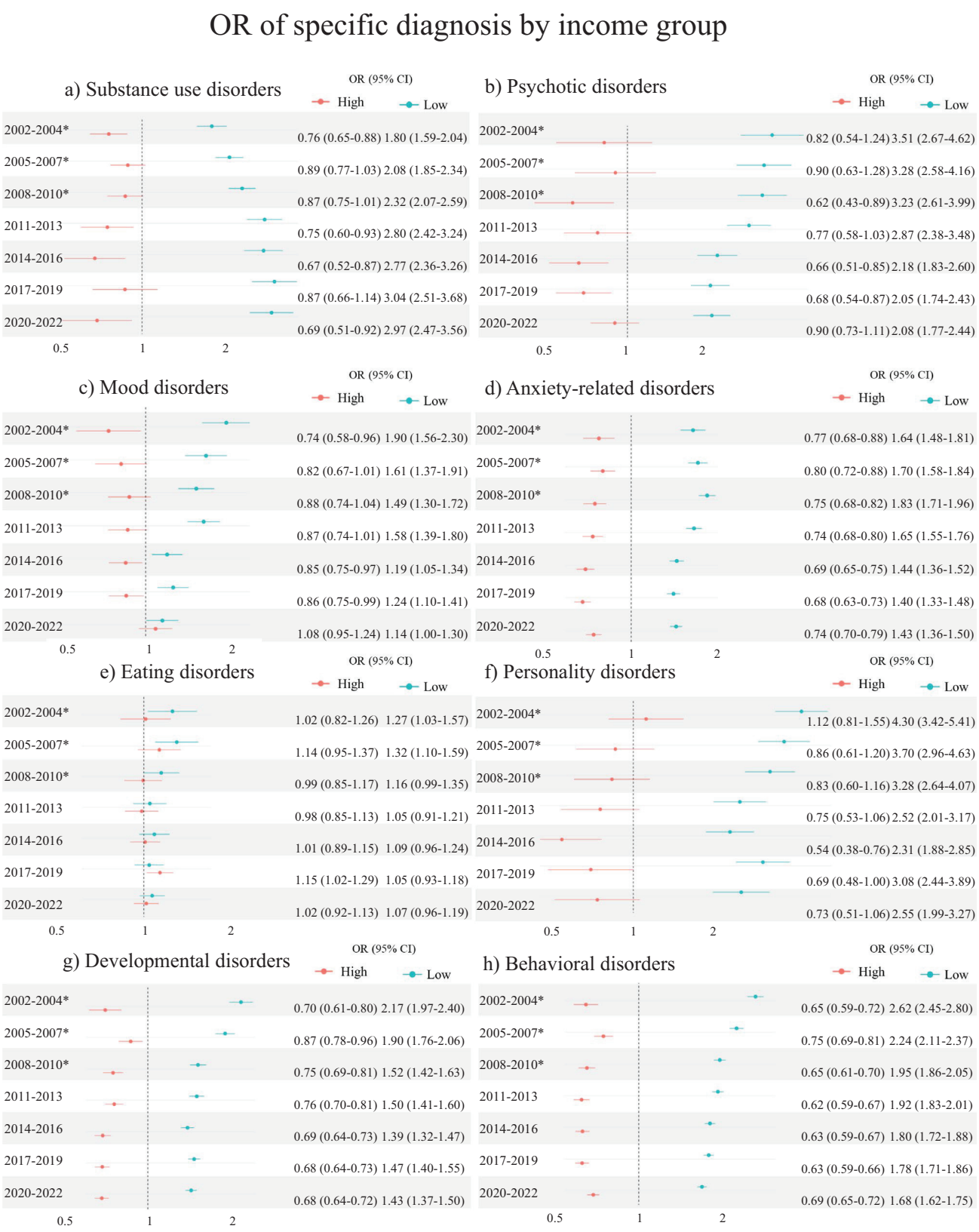
Sensitivity analyses

Sensitivity analyses of alternative measures of income (5-year-mean instead of 3 and grouped as tertiles instead of the OECD classification) did not show notably different results than the main analyses. Neither did the sensitivity analyses of mental disorder diagnosis measured from age 7 change the associations, even though the absolute estimates showed higher prevalence and earlier age-of-onset of mental disorder in the more recent cohorts (Supplementary Fig. 3 & Table 4).

Discussion

Key results

This study found that the prevalence of mental disorder diagnoses and medication use among 15-year-old adolescents increased during the past decades, with developmental disorder and behavioural disorder being most frequent and showing the largest increases. Higher prevalences of mental disorder diagnoses and medication use were consistently observed in the low-income and short-education groups. However, over time, the prevalences of mental disorder diagnoses and medication use between educational groups and income-groups became more similar. The associations between short-educational level and mental disorder diagnoses decreased over the study period, while the associations between short-educational level and medication use increased until 2011–2013 and then decreased. In contrast, associations between long-educational level and mental disorder diagnoses remained stable over time, while associations with medication use first increased until 2011–2013 and then decreased. Time trends varied across specific mental disorder diagnosis: for income, a general decrease in associations with most mental disorder diagnosis and low-income was observed, except for substance use disorder, where the associations seemed to increase, and anxiety-related disorder, where the association remained stable. For shot-educational level, associations with anxiety-related-, developmental-, and behavioral disorder decreased over time, while associations with substance use-, mood-, and eating disorders increased over time. Associations with psychotic- and personality disorder remained stable. Notably, associations between educational level and mood disorder were reversed compared to other disorders: the



*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.

Note: Models are adjusted for country of origin, adolescent's chronic illness, siblings' chronic illness, parents' chronic illness, siblings' mental disorder, parents' mental disorder, and cohabitation

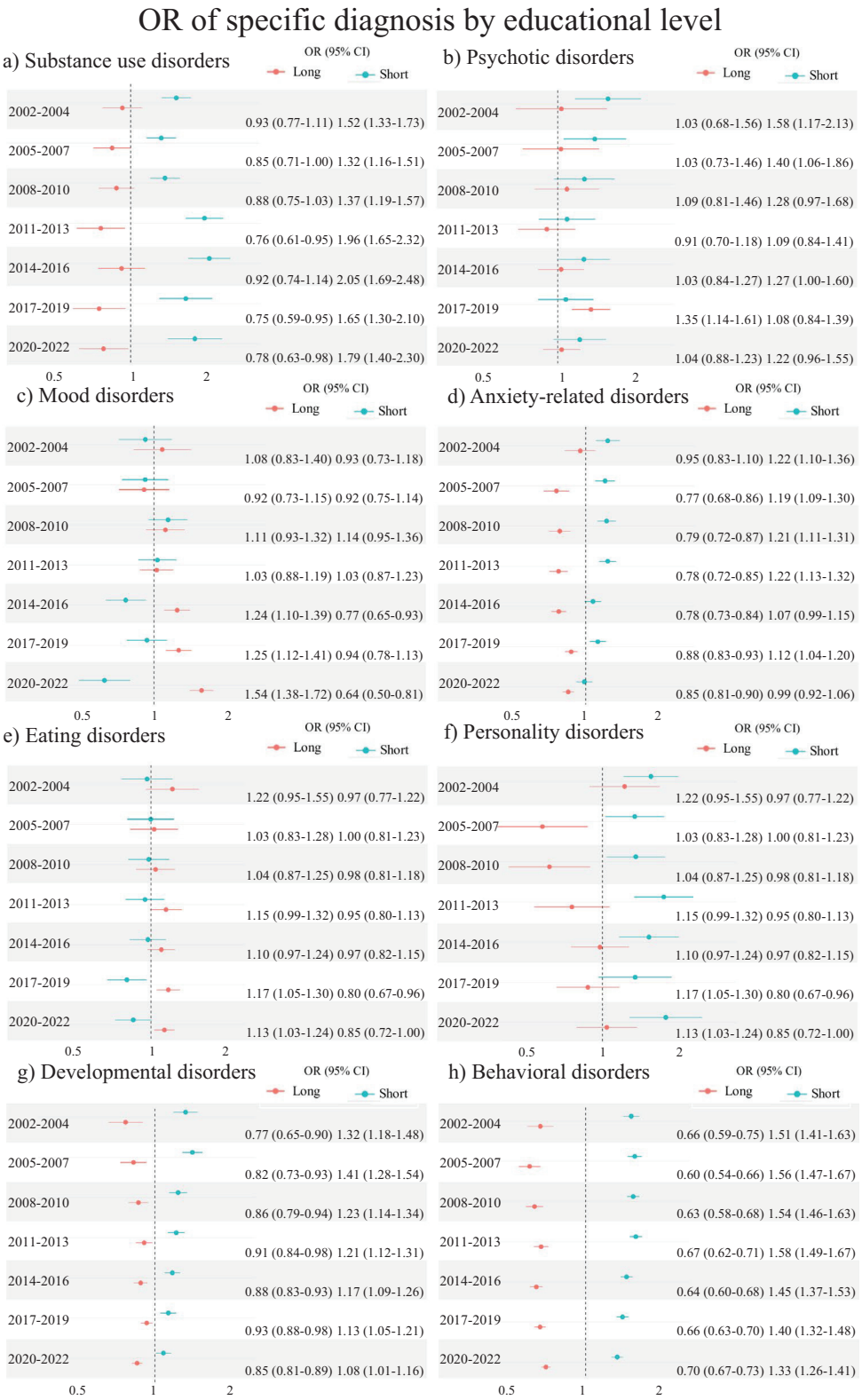


Fig. 3 Odds ratios (OR) of specific mental disorder diagnoses by educational level for (**a**) Substance use disorders, (**b**) Psychotic disorders, (**c**) Mood disorders, (**d**) Anxiety-related disorders, (**e**) Eating disorders, (**f**) Personality disorders, (**g**) Developmental disorders, and (**h**) Behavioral disorders

*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.
Note: Models are adjusted for country of origin, parents' chronic illness and parents' mental disorder

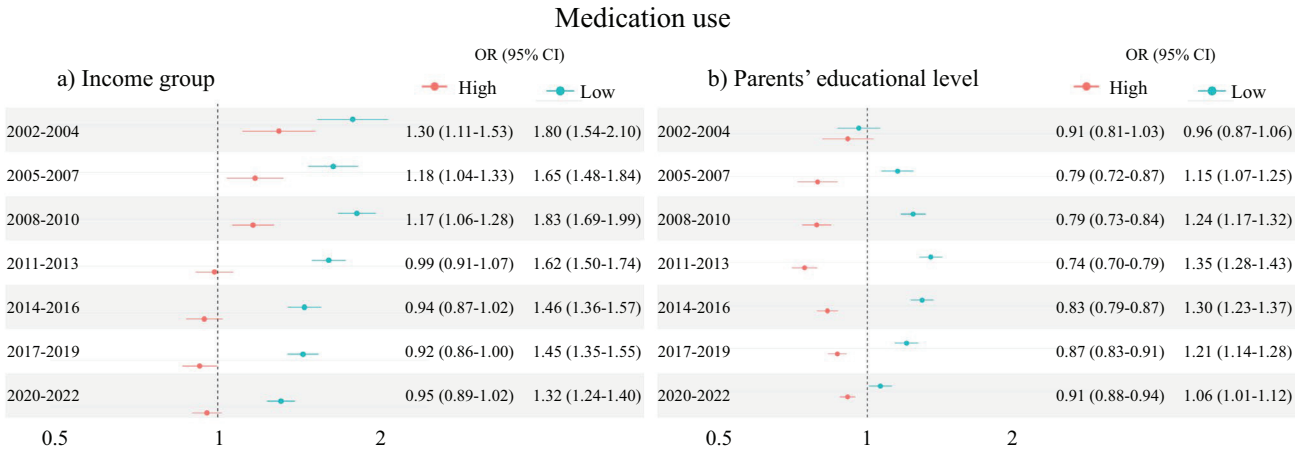


Fig. 4 Odds Ratios (OR) of any medication use by (**a**) income group and (**b**) parents' educational level

long-education group had higher odds than the middle-education group, and the low-education group having lower odds than the middle-education group. Regarding general time trends in income, low-income had decreasing associations with both mental disorder diagnosis and medication use over time, while associations between high-income and mental disorder diagnoses remained stable.

Discussion of results

We observed an increasing prevalence of mental disorder diagnoses and medication use among adolescents over the study period, aligning with previous research [3, 7, 8, 32, 33]. Importantly, a clear tendency of social inequality was present with adolescents from the low-income and short-education groups exhibiting higher odds of being diagnosed with mental disorders and of medication use compared to their peers from middle-income and middle-education groups, underscoring their heightened vulnerability. These findings align with previous research on the association between SES and mental health [11–17]. To our knowledge, this study is the first to show a trend of less social inequality over time with decreasing associations between low-SES and mental health.

Interestingly, a tendency of decreasing associations between the low-income group compared to the middle-income group and mental health was found, even though the income inequality has increased the past decades, reflected in the GINI coefficient [9]. In our data, we saw a tendency of rising inequality between income groups in the later cohorts reflected in a higher relative mean income in the high-income group compared to the mean income in middle-income group, and a lower relative mean income in the low-income group compared to the mean income in the middle-income group. Therefore, the decreasing associations cannot be explained by the definition of income-groups over time. However, the decreasing associations of short-educational level compared to middle and mental health over time may be explained by changes in educational level. A shift has been recognized in the composition of educational groups, as more individuals pursue higher education, thereby making the long-education group more heterogeneous while shrinking the short-education group, resulting in people from the middle and short group becoming more alike.

The observed differences in associations between income and education with mental health over time may reflect the distinct dimensions of social status they capture—income reflects economic resources, while parental education reflects cognitive skills and cultural capital—each potentially influencing mental health in different ways.

The increasing prevalence of poor mental health has fuelled the ongoing debate about its underlying causes which may also explain the lower inequality. Key hypotheses include improved diagnostic practices, a lowered threshold for diagnosis, increased psychologization, or a genuine increase in mental health problems [34–36]. A prominent area of discussion focuses on potential over-diagnosis, particularly among young people with ADHD. For instance, Australian research suggests that the substantial increase in ADHD diagnoses was not accompanied by a corresponding increase in symptoms such as hyperactivity and inattention [36]. Psychologization refers to the growing tendency to interpret challenges through a psychological lens, often framing difficulties in terms of mental health diagnoses. This phenomenon may reflect broader societal shifts, where young people increasingly rely on psychological explanations for their struggles [34, 35]. Over-diagnosis and psychologization may particularly affect individuals from high SES, who are more likely to engage in public debates and be influenced by discussions around mental health. They are

also better equipped to navigate the healthcare system and consistently seek treatment for their children. As a result, they may be more susceptible to over-diagnosis and the psychotropic medications that often follow [37, 38]. This may help explain the decreasing associations between both income and educational level and poor mental health.

The latter hypothesis, of a genuine increase in adolescents' mental health problems, suggests that adolescents may be experiencing increasing performance pressure from academic, social, and cultural expectations, which may act as a mechanism driving the observed increase in mental health problems [34, 39]. Qualitative studies offer insights into social inequality in mental health, suggesting that adolescents from low-SES backgrounds face compounded challenges. The dual burden of performance pressure and financial strain makes adolescents more susceptible to adverse outcomes when encountering difficulties. Conversely, a new trend has emerged: adolescents from middle- and high-SES backgrounds are increasingly susceptible to mental health problems due to rising academic, social, and cultural expectations [34]. Our results of decreased association between SES and poor mental health may reflect a societal shift, indicating that increased pressure on adolescents is now affecting both high- and middle-SES groups as well.

Diagnosis-specific analyses showed associations between the low-SES groups and several diagnoses compared to the middle-SES groups. Moreover, the associations changed over time, especially the associations between educational level and specific mental diagnoses showed diverse patterns over time. The associations between substance use disorders and both educational level and income strengthened over time. Substance use disorders are known to have heritable components [40]. Although our analyses adjusted for parental mental health diagnoses and psychotropic medication use, residual confounding may persist due to undiagnosed conditions. Undiagnosed conditions might especially be prevalent in parents because of a birth cohort effect of mental disorder diagnoses. Momen et al. have demonstrated that the age of onset for several mental disorder diagnoses has shifted downward in the past years [7]. Therefore, parents may be more prone to be undiagnosed. Undiagnosed mental health conditions in parents could affect labor market attachment and subsequently household income and the parents' educational level, and thereby explain the results. In contrast, for mood disorders and eating disorders, the associations changed over time to higher odds for long-education compared to the middle-education group while the odds were lower for the short-education compared to the middle-education group in the later cohorts. Likewise, the associations of income and mood- and eating disorders decreased over time and were comparable across groups in the later cohorts. This pattern suggests a different dynamic than for other diagnoses, that might reflect a higher likelihood among high SES parents to navigate the healthcare system and consistently seek treatment for their children within these specific diagnoses [37, 38]. Moreover, our diagnosis-specific analyses showed that the prevalence of developmental disorders was more equally distributed across educational levels in the latest cohort, especially in 2020–2022, where the middle-education group had the highest prevalence. Diagnoses of developmental disorders might drive some of the general decreased associations between educational level and mental disorder diagnoses over time.

Finally, the associations between SES and medication use decreased over the years, which partly could be explained by a change in prescription practices since 2014. Since the change in prescription practices, general practitioners (GP) were no longer allowed to prescribe antidepressants drugs for people under 25 years, only psychiatrist were allowed to prescribe this kind of medication [6]. Nevertheless, the overall prevalence of medication use continued to increase, which means that psychiatrists are prescribing more. This may be partly explained by the fact that approximately half of all prescriptions were for ADHD medication, as shown in the supplementary analyses. The decreased social inequality in medication use could be explained by the low-income group and short-education group being more affected by the change in prescription practices resulting in not getting as many prescriptions at the psychiatrist as they got at the GPs. It is also relevant to consider if other mental health treatments have shifted from GPs to hospital-based settings, which could affect the interpretation of changes observed over time.

Strengths

Our study has several strengths. First, the use of national register data ensured comprehensive coverage of all Danish adolescents, minimizing the risk of selection bias. Second, missing data were minimal, and the application of multiple imputation methods combined with strong auxiliary variables ensured robust handling of any missingness. These features enhance the reliability and generalizability of our findings. Third, the rich information from registers and the possibility to connect with information from families makes it possible to adjust for several relevant confounders of the associations between SES and mental health measures.

Limitations

Despite its strengths, the study has several limitations. First, the data break with no information on outpatients' mental disorder diagnoses before 1995 makes the comparison of cohorts over time difficult for the periods 2002–2009 since

no information is present in the first years of the adolescents' life in these cohorts. The results on prevalences of mental disorder diagnoses from the first three cohorts should be interpreted with caution as mental disorder diagnoses might be underreported. However, the sensitivity analyses using diagnosis from age 7 for all cohorts did not alter the conclusions of the relative measures and therefore, the results on the associations are considered valid. Second, our analyses were constrained by the variables available in the registers, leaving the possibility of residual confounding due to unmeasured factors such as parenting style, community characteristics, or individual coping mechanisms [41–43]. Third, the reliance on register data means that only severe mental disorders requiring hospital-based care (including outpatient visits) were captured. This limitation may lead to an underrepresentation of cases among adolescents from low-income and short education groups, as more resourceful families may be more proactive in navigating the healthcare system [37, 38]. However, adolescents from high-income and long-education groups might have more resources to go to private psychiatrists which could lead to underrepresentation of cases among adolescents from high-income and long-education groups. Moreover, this study is likely only to capture the most severe cases of poor mental health, as it relies on mental disorder diagnoses and psychotropic medication use from national registers. Weye et al. found that only 15% of individuals with current depression were captured in the hospital registers, while 51% were identified through prescription [44]. Therefore, a substantial underrepresentation of less severe cases is likely. Finally, because SES and mental health were measured simultaneously, our findings cannot establish causal relationships. Thus, our results could indicate that mental health of the adolescents during their upbringing could affect the parents' ability to obtain a higher education and/or their ability to obtain a high-income. Conversely, low-SES of the parents could reflect low resources in the family which can lead to poor mental health of the adolescents.

Conclusion

This study highlights persistent but evolving social inequalities in adolescent mental health in Denmark from 2002 to 2022. While the prevalence of adolescents' mental health diagnoses and medication use increased over the period, a general trend towards decreasing OR between low- and middle-SES groups were observed, while the association between high- and middle-SES groups remained relatively stable. However, changes in inequality patterns varied by diagnosis, with some conditions showing decreasing associations with SES and others showing increasing trends. These diagnosis-specific shifts suggest that broader societal changes may influence different mental disorder diagnoses in diverse ways. Future research should explore the mechanisms driving these diagnosis-specific trends and examine strategies to address social inequalities in adolescent mental health.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00127-025-02943-y.

Acknowledgements This work was supported by KV fonden and Sygeforsikring Danmark (Grant number 2021-0105).

Author contribution CLBS: Conceptualization; Methodology; Formal analysis; Investigation; Project administration; Writing-Original draft preparation; Writing-Reviewing and Editing. KB: Conceptualization; Methodology; Supervision, Writing-Reviewing and Editing. TNW, OPR, UB, PBS: Conceptualization; Methodology; Writing-review & editing.

Funding Open access funding provided by Aarhus Universitet. Open access funding provided by Aarhus Universitet. Sygeforsikring Danmark, 2021-0105, 2021-0105, 2021-0105, KV fonden.

Availability of Data and Materials Data have been made available for the first author specifically via Statistics Denmark and can therefore not be shared. The codes are available from the corresponding author on reasonable request.

Declaration

Conflict of interest None reported.

Ethical standards The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975.

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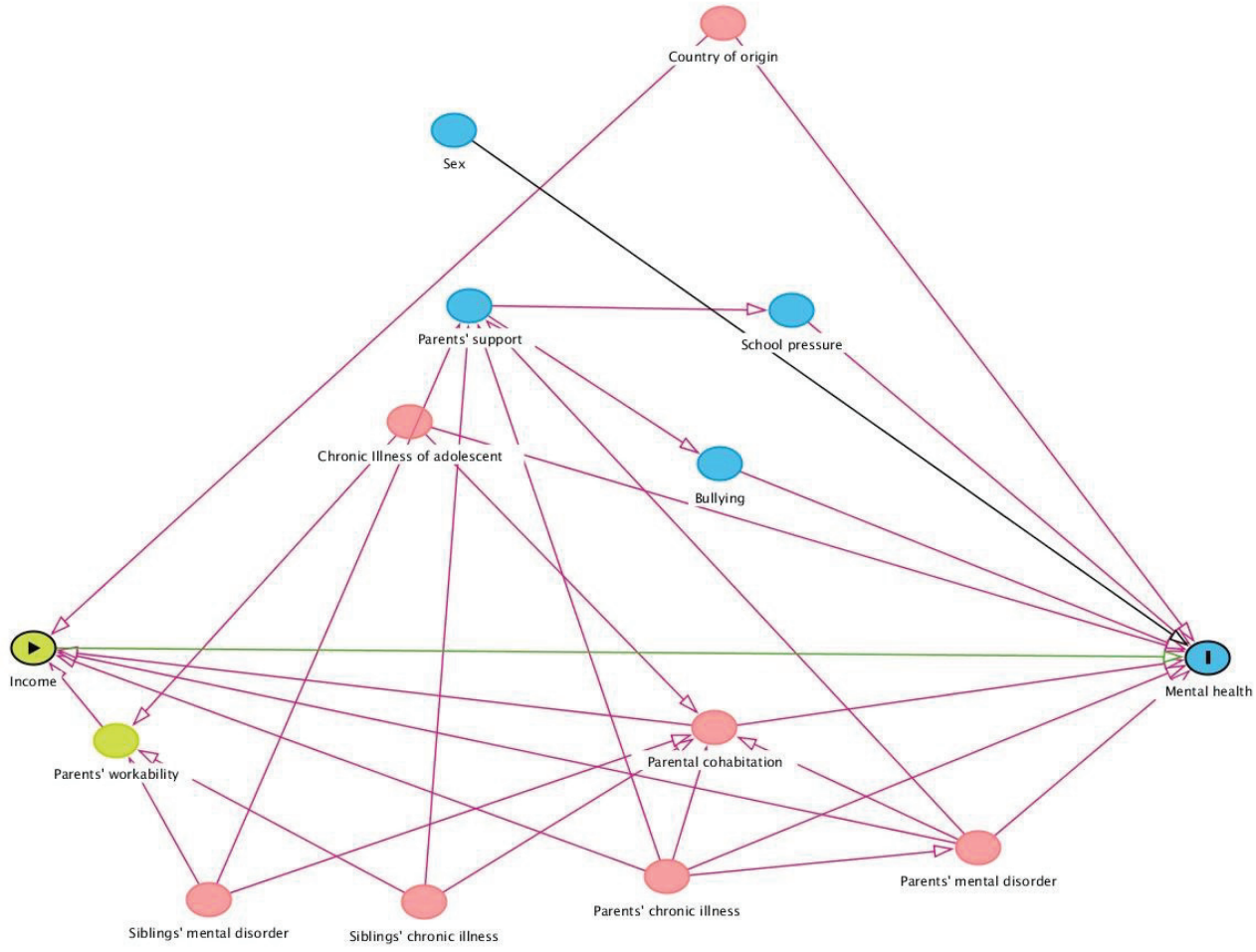
Supplementary

Reading instruction Supplementary Figure 1 & 2

A DAG is a Directed (implies direction) Acyclic (no cycles: a variable can't cause itself) Graph. DAGs are used to visualize the association between variables and help identify how to analyse an unbiased association between an exposure and an outcome. Ancestors of both exposures and outcome must be adjusted for in an analysis to ensure no biased paths. In this study, the exposure and outcome happen at the same time. Therefore, the associations between outcome and exposure in the DAG's should be interpreted as potentially bidirectional.

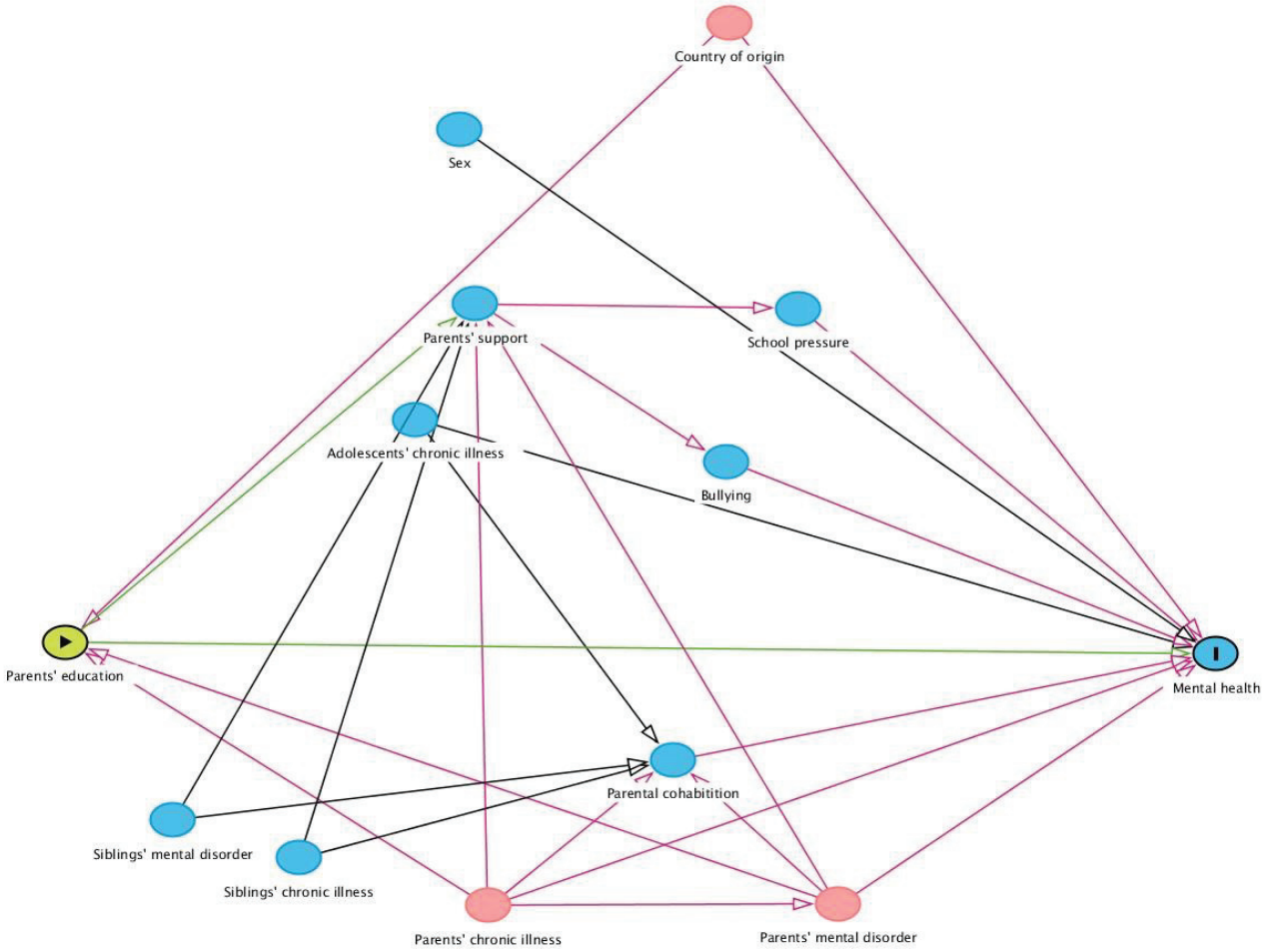
Main variables	Ancestors	Paths
Outcome	Ancestor of exposure	Causal path
Exposure	Ancestor of outcome	Biased path
	Ancestor of both exposure and outcome	

Supplementary Figure 1: Equivalized family income & adolescent mental health



The model will be adjusted for; country of origin, adolescent's chronic illness, siblings' chronic illness, parents' chronic illness, siblings' mental disorder, parents' mental disorder and parental cohabitation.

Supplementary Figure 2: Parents' education & adolescent mental health



The model will be adjusted for; country of origin, parents' chronic illness and parents' mental disorder.

Supplementary Table 1: Prevalence of ADHD medication use among all prescriptions for 15-year-olds, grouped in 3-year periods

N(%)	2002-2004	2005-2007	2008-2010	2011-2013	2014-2016	2017-2019	2020-2022
Other psychotropic medication use	1,662 (76%)	2,449 (64%)	3,272 (48%)	3,858 (45%)	4,423 (47%)	4,888 (48%)	7,042 (51%)
ADHD related medication use	515 (24%)	1,390 (36%)	3,636 (53%)	4,670 (55%)	5,040 (53%)	5,319 (52%)	6,744 (49%)
Total prescriptions	2,177	3,839	6,908	8,528	9,463	10,207	13,786

*Note: Individuals may appear more than once if they received both ADHD and other psychotropic medications.

Supplementary Table 2: Parental educational level and missingness by country of origin

N(%)	Parental educational level				
Country of origin	**Long**	**Middle**	**Short**	**Missing**	**Total**
Denmark	232,196 (17.5%)	974,346 (73.3%)	122,198 (9.2%)	1,146 (0.1%)	1,329,886 (100%)
Other	16,199 (10.2%)	77,233 (48.7%)	56,690 (35.8%)	8,329 (5.3%)	158,451 (100%)

Supplementary Table 3: Mental health measures of 15-year-olds grouped in 3-year periods stratified by sex

Cohort	Sex	Mental disorder diagnosis									Medication use
		Any mental disorder	Substance use disorders	Psychotic disorders	Mood disorders	Anxiety-related disorders	Eating disorders	Personality disorders	Developmental disorders	Behavioral disorders	Age 14.5-15.5
2002-2004*	Males (N=97,396)	6792 (7.0%)	703 (0.7%)	116 (0.1%)	193 (0.2%)	863 (0.9%)	119 (0.1%)	107 (0.1%)	1629 (1.7%)	3062 (3.1%)	1547 (1.6%)
	Females (N=107,475)	5098 (5.6%)	687 (0.7%)	138 (0.2%)	359 (0.4%)	1389 (1.5%)	468 (0.5%)	269 (0.3%)	470 (0.5%)	1318 (1.4%)	1404 (1.5%)
2005-2007*	Males (N=107,475)	9680 (9.0%)	760 (0.7%)	137 (0.1%)	260 (0.2%)	1358 (1.3%)	177 (0.2%)	95 (0.1%)	2551 (2.4%)	4342 (4.0%)	2797 (2.6%)
	Females (N=101,473)	7417 (7.3%)	788 (0.8%)	197 (0.2%)	525 (0.5%)	2285 (2.3%)	594 (0.6%)	274 (0.3%)	756 (0.7%)	1998 (2.0%)	2449 (2.4%)
2008-2010*	Males (N=113,762)	13520 (11.9%)	781 (0.7%)	182 (0.2%)	372 (0.3%)	1811 (1.6%)	294 (0.3%)	107 (0.1%)	3846 (3.4%)	6127 (5.4%)	5561 (4.9%)
	Females (N=107,540)	9648 (9.0%)	800 (0.7%)	232 (0.2%)	729 (0.7%)	2806 (2.6%)	792 (0.7%)	292 (0.3%)	1177 (1.1%)	2820 (2.6%)	3922 (3.6%)
2011-2013	Males (N=111,064)	15561 (14.0%)	781 (0.7%)	218 (0.2%)	457 (0.4%)	2255 (2.0%)	310 (0.3%)	83 (0.1%)	4655 (4.2%)	7129 (6.4%)	6965 (6.3%)
	Females (N=104,697)	11197 (10.7%)	800 (0.7%)	313 (0.3%)	891 (0.9%)	3467 (3.3%)	1067 (1.0%)	284 (0.3%)	1512 (1.4%)	3212 (3.1%)	4594 (4.4%)
2014-2016	Males (N=110,748)	18825 (17.0%)	454 (0.4%)	255 (0.2%)	564 (0.5%)	2944 (2.7%)	438 (0.4%)	116 (0.1%)	5816 (5.3%)	8330 (7.5%)	7995 (7.2%)
	Females (N=105,526)	14641 (13.9%)	451 (0.4%)	408 (0.4%)	1185 (1.1%)	4547 (4.3%)	1250 (1.2%)	326 (0.3%)	2361 (2.2%)	4186 (4.0%)	5696 (5.4%)
2017-2019	Males (N=110,703)	20979 (19.0%)	362 (0.3%)	269 (0.2%)	556 (0.5%)	3638 (3.3%)	576 (0.5%)	73 (0.1%)	6625 (6.0%)	8943 (8.1%)	8786 (7.9%)
	Females (N=104,350)	15988 (15.3%)	378 (0.4%)	462 (0.4%)	1070 (1.0%)	5112 (4.9%)	1371 (1.3%)	273 (0.3%)	2934 (2.8%)	4509 (4.3%)	6347 (6.1%)
2020-2022	Males (N=113,559)	23367 (20.6%)	299 (0.3%)	268 (0.2%)	467 (0.4%)	4013 (3.5%)	795 (0.7%)	47 (0.0%)	7310 (6.4%)	10194 (9.0%)	10596 (9.3%)
	Females (N=108,323)	19713 (18.2%)	257 (0.2%)	537 (0.5%)	1114 (1.0%)	5879 (5.4%)	1659 (1.5%)	278 (0.3%)	3869 (3.6%)	6079 (5.6%)	9170 (8.5%)

*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.

Supplementary Table 4: Mental health measures of 15-year-olds grouped in 3-year periods stratified by income group

Cohort	Income group	Mental disorder diagnosis									Medication use
		Any mental disorder	Substance use disorders	Psychotic disorders	Mood disorders	Anxiety-related disorders	Eating disorders	Personality disorders	Developmental disorders	Behavioral disorders	Age 14.5-15.5
2002-2004*	High (N=37,540)	7577 (4.0%)	987 (0.5%)	141 (0.1%)	368 (0.2%)	1562 (0.8%)	569 (0.3%)	252 (0.1%)	1335 (0.7%)	2363 (1.2%)	2504 (1.3%)
	Middle (N=112,828)	10407 (5.5%)	1296 (0.7%)	176 (0.1%)	503 (0.3%)	2083 (1.1%)	565 (0.3%)	230 (0.1%)	1887 (1.0%)	3667 (1.9%)	2561 (1.4%)
	Low (N=38,749)	20386 (10.8%)	2055 (1.1%)	591 (0.3%)	874 (0.5%)	3411 (1.8%)	669 (0.4%)	922 (0.5%)	3455 (1.8%)	8409 (4.4%)	4519 (2.4%)
2005-2007*	High (N=41,459)	12116 (5.8%)	1169 (0.6%)	202 (0.1%)	580 (0.3%)	2550 (1.2%)	811 (0.4%)	217 (0.1%)	2550 (1.2%)	4037 (1.9%)	3845 (1.8%)
	Middle (N=124,657)	15094 (7.2%)	1333 (0.6%)	235 (0.1%)	734 (0.4%)	3341 (1.6%)	719 (0.3%)	258 (0.1%)	2975 (1.4%)	5500 (2.6%)	4620 (2.2%)
	Low (N=42,832)	27748 (13.3%)	2542 (1.2%)	751 (0.4%)	1132 (0.5%)	5581 (2.7%)	883 (0.4%)	839 (0.4%)	5005 (2.4%)	11015 (5.3%)	8425 (4.0%)
2008-2010*	High (N=43,686)	15066 (6.8%)	1089 (0.5%)	182 (0.1%)	876 (0.4%)	2933 (1.3%)	1018 (0.5%)	228 (0.1%)	3571 (1.6%)	5167 (2.3%)	6818 (3.1%)
	Middle (N=131,829)	21160 (9.6%)	1298 (0.6%)	304 (0.1%)	1042 (0.5%)	4150 (1.9%)	1059 (0.5%)	285 (0.1%)	4867 (2.2%)	8155 (3.7%)	8471 (3.8%)
	Low (N=45,787)	36680 (16.6%)	2866 (1.3%)	952 (0.4%)	1484 (0.7%)	7569 (3.4%)	1228 (0.6%)	889 (0.4%)	6858 (3.1%)	14833 (6.7%)	14940 (6.8%)
2011-2013	High (N=42,456)	17167 (8.0%)	503 (0.2%)	285 (0.1%)	1047 (0.5%)	3695 (1.7%)	1296 (0.6%)	208 (0.1%)	4401 (2.0%)	5732 (2.7%)	7923 (3.7%)
	Middle (N=128,580)	24998 (11.6%)	703 (0.3%)	398 (0.2%)	1269 (0.6%)	5368 (2.5%)	1379 (0.6%)	297 (0.1%)	6002 (2.8%)	9582 (4.4%)	10723 (5.0%)
	Low (N=44,725)	40923 (19.0%)	1867 (0.9%)	1148 (0.5%)	1862 (0.9%)	8664 (4.0%)	1447 (0.7%)	719 (0.3%)	8317 (3.9%)	16899 (7.8%)	17415 (8.1%)
2014-2016	High (N=42,252)	21457 (9.9%)	369 (0.2%)	358 (0.2%)	1428 (0.7%)	4847 (2.2%)	1623 (0.8%)	195 (0.1%)	5467 (2.5%)	7171 (3.3%)	9014 (4.2%)
	Middle (N=129,047)	32645 (15.1%)	583 (0.3%)	577 (0.3%)	1785 (0.8%)	7450 (3.4%)	1674 (0.8%)	387 (0.2%)	8251 (3.8%)	11939 (5.5%)	13310 (6.2%)
	Low (N=44,975)	47102 (21.8%)	1539 (0.7%)	1197 (0.6%)	1948 (0.9%)	10094 (4.7%)	1789 (0.8%)	832 (0.4%)	10512 (4.9%)	19192 (8.9%)	19177 (8.9%)
2017-2019	High (N=41,927)	24046 (11.2%)	339 (0.2%)	415 (0.2%)	1303 (0.6%)	5642 (2.6%)	2113 (1.0%)	174 (0.1%)	6360 (3.0%)	7699 (3.6%)	9776 (4.5%)
	Middle (N=128,274)	36167 (16.8%)	411 (0.2%)	645 (0.3%)	1633 (0.8%)	8823 (4.1%)	1913 (0.9%)	268 (0.1%)	9575 (4.5%)	12899 (6.0%)	14462 (6.7%)
	Low (N=44,852)	51332 (23.9%)	1175 (0.5%)	1271 (0.6%)	1908 (0.9%)	11445 (5.3%)	1889 (0.9%)	729 (0.3%)	12505 (5.8%)	20411 (9.5%)	22061 (10.3%)
2020-2022	High (N=43,148)	29183 (13.2%)	283 (0.1%)	576 (0.3%)	1522 (0.7%)	6690 (3.0%)	2412 (1.1%)	180 (0.1%)	7333 (3.3%)	10187 (4.6%)	14157 (6.4%)
	Middle (N=132,161)	42079 (19.0%)	440 (0.2%)	685 (0.3%)	1551 (0.7%)	9739 (4.4%)	2468 (1.1%)	260 (0.1%)	11257 (5.1%)	15679 (7.1%)	19136 (8.6%)
	Low (N=46,573)	58795 (26.5%)	1210 (0.5%)	1358 (0.6%)	1720 (0.8%)	13292 (6.0%)	2454 (1.1%)	643 (0.3%)	14521 (6.5%)	23597 (10.6%)	26751 (12.1%)

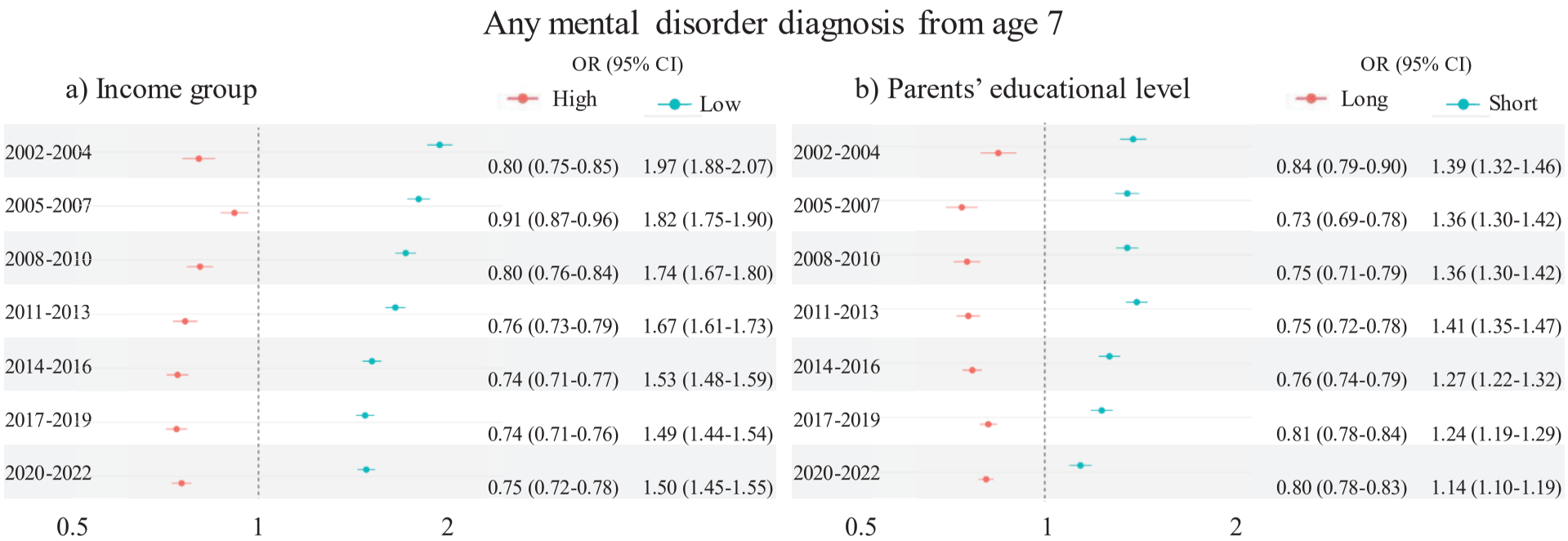
* Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.

Supplementary Table 5: Mental health measures of 15-year-olds grouped in 3-year periods stratified by educational level

Cohort	Educational level	Mental disorder diagnosis									Medication use
		Any mental disorder	Substance use disorders	Schizophreni Psychotic disorders	Mood disorders	Anxiety-related disorders	Eating disorders	Personality disorders	Developmental disorders	Behavioral disorders	Age 14.5-15.5
2002-2004*	Long (N=21,253)	9464 (5.0%)	1202 (0.6%)	232 (0.1%)	589 (0.3%)	2028 (1.1%)	695 (0.4%)	400 (0.2%)	1568 (0.8%)	2751 (1.5%)	2685 (1.4%)
	Middle (N=136,626)	11450 (6.1%)	1307 (0.7%)	228 (0.1%)	556 (0.3%)	2168 (1.1%)	579 (0.3%)	334 (0.2%)	2074 (1.1%)	4204 (2.2%)	3009 (1.6%)
	Short (N=31,238)	15465 (8.2%)	1883 (1.0%)	382 (0.2%)	510 (0.3%)	2772 (1.5%)	547 (0.3%)	543 (0.3%)	2570 (1.4%)	6259 (3.3%)	2878 (1.5%)
2005-2007*	Long (N=25,441)	12087 (5.8%)	1244 (0.6%)	304 (0.1%)	699 (0.3%)	2665 (1.3%)	781 (0.4%)	206 (0.1%)	2575 (1.2%)	3613 (1.7%)	3994 (1.9%)
	Middle (N=152,954)	16881 (8.1%)	1517 (0.7%)	314 (0.2%)	808 (0.4%)	3648 (1.7%)	776 (0.4%)	374 (0.2%)	3239 (1.6%)	6205 (3.0%)	5309 (2.5%)
	Short (N=30,553)	22360 (10.7%)	1957 (0.9%)	461 (0.2%)	743 (0.4%)	4431 (2.1%)	739 (0.4%)	478 (0.2%)	4258 (2.0%)	9292 (4.4%)	5976 (2.9%)
2008-2010*	Long (N=29,514)	17128 (7.7%)	1285 (0.6%)	404 (0.2%)	1139 (0.5%)	3443 (1.6%)	1097 (0.5%)	233 (0.1%)	4171 (1.9%)	5356 (2.4%)	7157 (3.2%)
	Middle (N=163,026)	22931 (10.4%)	1535 (0.7%)	392 (0.2%)	1077 (0.5%)	4613 (2.1%)	1086 (0.5%)	400 (0.2%)	5011 (2.3%)	8816 (4.0%)	9538 (4.3%)
	Short (N=28,762)	30701 (13.9%)	2144 (1.0%)	548 (0.2%)	1197 (0.5%)	5842 (2.6%)	1075 (0.5%)	561 (0.3%)	5965 (2.7%)	13369 (6.0%)	11555 (5.2%)
2011-2013	Long (N=33,377)	20225 (9.4%)	606 (0.3%)	439 (0.2%)	1312 (0.6%)	4235 (2.0%)	1500 (0.7%)	246 (0.1%)	5356 (2.5%)	6531 (3.0%)	8235 (3.8%)
	Middle (N=156,731)	26689 (12.4%)	842 (0.4%)	531 (0.2%)	1356 (0.6%)	5794 (2.7%)	1364 (0.6%)	351 (0.2%)	6171 (2.9%)	10280 (4.8%)	11718 (5.4%)
	Short (N=25,653)	35669 (16.5%)	1675 (0.8%)	649 (0.3%)	1349 (0.6%)	7217 (3.3%)	1296 (0.6%)	619 (0.3%)	7199 (3.3%)	15666 (7.3%)	14911 (6.9%)
2014-2016	Long (N=39,329)	25844 (11.9%)	573 (0.3%)	617 (0.3%)	2015 (0.9%)	5707 (2.6%)	1772 (0.8%)	380 (0.2%)	6942 (3.2%)	7837 (3.6%)	10707 (5.0%)
	Middle (N=153,268)	34341 (15.9%)	679 (0.3%)	646 (0.3%)	1756 (0.8%)	7852 (3.6%)	1681 (0.8%)	427 (0.2%)	8339 (3.9%)	12960 (6.0%)	14014 (6.5%)
	Short (N=23,677)	40473 (18.7%)	1409 (0.7%)	847 (0.4%)	1265 (0.6%)	8117 (3.8%)	1594 (0.7%)	639 (0.3%)	9184 (4.2%)	17419 (8.1%)	16559 (7.7%)
2017-2019	Long (N=46,207)	30344 (14.1%)	387 (0.2%)	852 (0.4%)	1847 (0.9%)	7370 (3.4%)	2194 (1.0%)	279 (0.1%)	8573 (4.0%)	8842 (4.1%)	12450 (5.8%)
	Middle (N=147,042)	38310 (17.8%)	555 (0.3%)	687 (0.3%)	1594 (0.7%)	9104 (4.2%)	1944 (0.9%)	354 (0.2%)	9809 (4.6%)	14262 (6.6%)	15740 (7.3%)
	Short (N=21,804)	41949 (19.5%)	921 (0.4%)	769 (0.4%)	1370 (0.6%)	9290 (4.3%)	1444 (0.7%)	434 (0.2%)	9961 (4.6%)	17761 (8.3%)	16726 (7.8%)
2020-2022	Long (N=54,150)	35284 (15.9%)	408 (0.2%)	764 (0.3%)	2081 (0.9%)	8224 (3.7%)	2645 (1.2%)	292 (0.1%)	9423 (4.2%)	11448 (5.2%)	17134 (7.7%)
	Middle (N=147,443)	45502 (20.5%)	576 (0.3%)	800 (0.4%)	1493 (0.7%)	10524 (4.7%)	2466 (1.1%)	306 (0.1%)	11828 (5.3%)	17506 (7.9%)	20783 (9.4%)
	Short (N=20,289)	46288 (20.9%)	968 (0.4%)	948 (0.4%)	881 (0.4%)	9749 (4.4%)	1855 (0.8%)	550 (0.2%)	11149 (5.0%)	20187 (9.1%)	19401 (8.7%)

*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.

Supplementary Figure 3: Odds ratios (OR) of any mental disorder diagnoses from age 7-15.5 by a) income group and b) parents' educational level.



Note: Models a) are adjusted for country of origin, adolescent's chronic illness, siblings' chronic illness, parents' chronic ill ness, siblings' mental disorder, parents' mental disorder, and cohabitation and b) are adjusted for country of origin, parents' chronic illness and parents' mental disorder

Supplementary Table 6: Mental disorder diagnoses from age 7 in 15-year-olds grouped in 3-year periods

Cohort		2002-2004 N=189117	2015-2007 N=208948	2008-2010 N=221302	2011-2013 N=215761	2014-2016 N=216274	2017-2019 N=215053	2020-2022 N=221882
Mental disorder diagnosis*	Any mental disorder	11468 (6.1%)	15261 (7.3%)	20154 (9.1%)	23481 (10.9%)	30224 (14.0%)	33164 (15.5%)	38652 (17.5%)
	Mean age of onset (95% CI)	12.03 (11.98-12.09)	12.05 (12.01-12.10)	11.99 (11.95-12.03)	11.86 (11.82-11.90)	11.62 (11.59-11.66)	11.52 (11.49-11.56)	11.54 (11.51-11.58)
	Substance use disorders	1387 (0.7%)	1532 (0.7%)	1529 (0.7%)	847 (0.4%)	685 (0.3%)	501 (0.2%)	501 (0.2%)
	Mean age of onset (95% CI)	14.38 (14.33-14.43)	14.45 (14.41-14.50)	14.33 (14.29-14.38)	14.39 (14.32-14.46)	14.49 (14.42-14.56)	14.48 (14.39-14.57)	14.48 (14.40-14.56)
	Psychotic disorders	254 (0.1%)	332 (0.2%)	411 (0.2%)	529 (0.2%)	660 (0.3%)	722 (0.3%)	795 (0.4%)
	Mean age of onset (95% CI)	13.79 (13.57-14.00)	13.59 (13.38-13.79)	13.50 (13.31-13.68)	13.79 (13.63-13.94)	13.78 (13.66-13.91)	13.67 (13.54-13.79)	13.60 (13.47-13.73)
	Mood disorders	552 (0.3%)	784 (0.4%)	1096 (0.5%)	1344 (0.6%)	1743 (0.8%)	1616 (0.8%)	1569 (0.7%)
	Mean age of onset (95% CI)	14.04 (13.92-14.16)	13.94 (13.84-14.05)	14.03 (13.95-14.12)	13.84 (13.76-13.92)	13.74 (13.67-13.82)	13.56 (13.48-13.65)	13.77 (13.69-13.85)
	Anxiety-related disorders	2210 (1.2%)	3448 (1.7%)	4256 (1.9%)	5255 (2.4%)	7100 (3.3%)	8265 (3.9%)	9194 (4.2%)
	Mean age of onset (95% CI)	12.97 (12.88-13.06)	13.13 (13.06-13.20)	13.10 (13.04-13.16)	13.09 (13.03-13.14)	13.03 (12.98-13.08)	12.80 (12.76-12.85)	12.60 (12.55-12.64)
	Eating disorders	577 (0.3%)	722 (0.3%)	870 (0.4%)	1103 (0.5%)	1383 (0.6%)	1628 (0.8%)	2066 (0.9%)
	Mean age of onset (95% CI)	13.34 (13.19-13.50)	13.06 (12.90-13.21)	13.30 (13.17-13.43)	13.50 (13.40-13.61)	13.36 (13.27-13.46)	13.17 (13.07-13.26)	12.98 (12.89-13.07)
	Personality disorders	375 (0.2%)	360 (0.2%)	381 (0.2%)	346 (0.2%)	417 (0.2%)	325 (0.2%)	311 (0.1%)
	Mean age of onset (95% CI)	13.92 (13.74-14.11)	13.65 (13.45-13.84)	13.93 (13.75-14.12)	14.01 (13.84-14.18)	13.97 (13.81-14.14)	13.88 (13.67-14.08)	14.16 (13.98-14.34)
	Developmental disorders	1974 (1.0%)	2668 (1.3%)	4022 (1.8%)	5137 (2.4%)	7075 (3.3%)	8196 (3.8%)	9627 (4.4%)
	Mean age of onset (95% CI)	10.92 (10.82-11.03)	10.97 (10.87-11.06)	11.41 (11.33-11.49)	11.60 (11.53-11.66)	11.42 (11.36-11.48)	11.47 (11.42-11.53)	11.54 (11.49-11.59)
	Behavioral disorders	4139 (2.2%)	5415 (2.6%)	7589 (3.4%)	8920 (4.1%)	11161 (5.2%)	11911 (5.6%)	14589 (6.6%)
	Mean age of onset (95% CI)	11.01 (10.93-11.08)	11.05 (10.98-11.12)	11.29 (11.24-11.35)	11.20 (11.15-11.25)	10.92 (10.87-10.97)	10.81 (10.77-10.86)	11.07 (11.02-11.11)

*Mental disorder diagnoses reflect lifetime prevalence up to age 15.5, based on any recorded primary or secondary diagnosis. Diagnostic data are available from 1995 onward.

Study II

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Developmental trajectories in mental health through adolescence and adulthood: does socio-economic status matter?

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Original Article

Cite this article: Sørensen CLB, Plana-Ripoll O, Bültmann U, Winding TN, Steen PB, Biering K (2025) Developmental trajectories in mental health through adolescence and adulthood: does socio-economic status matter?. *Epidemiology and Psychiatric Sciences* **34**, e33, 1–12. https://doi.org/10.1017/S2045796025100073

Received: 19 December 2024
Revised: 29 April 2025
Accepted: 15 May 2025

Keywords:
adolescence; depression; epidemiology; mental health

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Abstract

Aims. This study aims to examine the different aspects of socio-economic status (SES) patterns in mental health from adolescence into adulthood by investigating the mean, prevalence, cumulative incidence and trajectories of several mental health measures, including depressive symptoms, mental disorder diagnosis and medication use. The different aspects of SES are investigated through the measures of subjective social status (SSS) in school, SSS in society, income and parental educational level.

Methods. Individuals born in 1989 were followed from 2004 to 2021 with surveys at ages 15, 18, 21, 28 and 32 years, supplied with yearly register data. The mean level of depressive symptoms, yearly prevalence of medication use and cumulative incidence of mental disorder diagnosis were calculated for each SES group (low, middle and high) across each measure. Group-Based Trajectory Modelling (GBTM) was used to identify depressive symptom trajectories and logistic regressions were used to analyse the relative odds ratios (ROR) of membership to the different trajectory groups by characteristics.

Results. Individuals with low SES at age 15 years across all SES measures showed higher mean depressive symptoms, prevalence of medication use and cumulative incidence of mental disorder diagnosis through adolescence and adulthood (age 15–32 years). Four depressive symptom trajectories were identified: low stable, moderate stable, decreasing and increasing trajectories. Being female, receiving medication or a mental disorder diagnosis in early adulthood and during the study period, having low SSS in school, parents not living together, being bullied, lacking support from teachers or classmates, lower levels of parents' support or higher school pressure resulted in higher RORs of membership to the other trajectory groups compared to the low stable trajectory, while having high SSS in society resulted in a lower ROR.

Conclusions. This is the first study to detect the role of social support in relation to depressive symptom trajectories. While individuals with low social status consistently experienced more negative mental health outcomes than those with middle and high social status in the study period (age 15–32 years), low SSS showed the strongest associations. This indicates that SSS may capture vulnerable individuals not identified by traditional SES. Being female, having low SES, low social support, and other mental health outcomes were associated with higher odds of being in trajectories with more depressive symptoms. Preventive initiatives should therefore target individuals with such characteristics. It is worth exploring whether adolescents with increasing depressive symptoms could benefit from increased social support.

Background

Mental health problems during the transition from adolescence into adulthood are a matter of great concern (Leebens and Williamson, 2017; Shorey *et al.*, 2022). This transitional period is characterized by diverse life paths, developmental milestones, and the creation of new pathways, which can be linked to future psychopathology (Schulenberg *et al.*, 2004). Mental health problems during this period can lead to long-term consequences such as educational dropout, poor labour market attachment and mental health problems in adulthood (Schulenberg *et al.*, 2004; Veldman *et al.*, 2022). As the prevalence of mental health problems among adolescents has increased in recent decades, concerns today are more and more pressing (Larsen *et al.*, 2018; Plana-Ripoll *et al.*, 2022; Shorey *et al.*, 2022; The Danish Health Data Authority, 2024). A recent systematic review showed an increase of the global point prevalence of elevated self-reported depressive symptoms from 24% in 2001–2010 to 37% in 2011–2020 (Shorey *et al.*, 2022). This trend has also been observed in Denmark, with increases in self-reported mental

health problems, mental health-related medication use and mental disorder diagnoses (Larsen *et al.*, 2018; Plana-Ripoll *et al.*, 2022; The Danish Health Data Authority, 2024). Many mental disorders have their onset during adolescence and early adulthood. The age of onset of mental disorder diagnoses has decreased since the 1970s. During the 1970s and 1980s, most individuals diagnosed with any mental disorder were aged between 25 and 50 years, while from 2004 the most common age was between 15 and 25 years (Plana-Ripoll *et al.*, 2022). The drivers behind this decrease in age of onset have been widely discussed. Some argue that the thresholds for mental disorder diagnoses have been lowered, that the practice has been improved, while others argue that a psychologization of the society is the reason for more frequent and earlier diagnoses (Katznelson *et al.*, 2022; Madsen, 2018; Kazda *et al.*, 2023). Nevertheless, knowledge about the mental health development during this transitional period is of great importance.

From a life course perspective, low socio-economic status (SES) in childhood has been linked to poor mental health later in life (Agerbo *et al.*, 2021; Lange *et al.*, 2023; Poulsen *et al.*, 2020; Reiss, 2013). Research has examined not only various SES measures, most commonly income and educational level, but also subjective measures of social status, and the strength of associations with mental health appear to vary across SES measures (Agerbo *et al.*, 2021; Lange *et al.*, 2023; Poulsen *et al.*, 2020; Reiss, 2013). This suggests that exploring multiple facets of SES could provide valuable insights into the relationship with mental health. Despite this growing body of evidence, gaps remain in understanding how SES influences mental health during critical developmental periods. While the course of mental health in Denmark has been studied by estimating the age- and sex-specific incidence of mental disorders during childhood and adolescence, SES-specific patterns in the incidence of mental disorders during these life stages remain unknown (Dalsgaard *et al.*, 2020). Additionally, most studies have investigated mental health defined as mental disorder diagnosis; the most severe cases of mental health problems (Dalsgaard *et al.*, 2020; Kessing *et al.*, 2023). More information is needed on broader aspects of mental health, as self-reported mental health, and medication use, during the transition from adolescence to early adulthood, particularly regarding SES-specific patterns.

To understand the development of mental health during the early life course and to identify adolescents at risk of poor mental health trajectories, studies on depressive symptom trajectories are valuable. A systematic review of depressive symptom trajectories in 15- to 25-year-olds found that most adolescents had consistently low depressive symptoms (60–80%), while 5–12% had consistently elevated symptoms, and 1–5% experienced increasing or decreasing symptoms (Schubert *et al.*, 2017). Risk factors for consistently elevated depressive symptoms included being female, having a dopamine receptor phenotype, and being a sexual or ethnic minority, whereas good parental support was associated with consistently low symptoms (Schubert *et al.*, 2017). Minh *et al.* (2021) found similar trajectories in Canada and the USA but observed different distributions of childhood SES measures between the two countries. In Canada, depressive symptom trajectories depended less on childhood SES compared to the USA, suggesting that country-level differences may influence how childhood SES affects depressive symptom risk (Minh *et al.*, 2021). Therefore, examining depressive trajectories and their associations with SES and other risk factors in a Danish setting is relevant.

This study aims to investigate the SES patterns in mental health from adolescence to adulthood by examining the mean, prevalence, cumulative incidence and trajectories of several mental health measures, including depressive symptoms, mental disorder diagnosis and medication use. Several SES measures, including subjective social status (SSS) in school and society, income and parental educational level, were used to cover different SES aspects.

Materials and methods

Study design, participants and setting

This present study was conducted within the VestLiv Cohort study, a longitudinal cohort study following a population of adolescents, born in 1989 and living in the western part of Denmark in 2004. A total of 3681 adolescents were invited to participate and 3054 (83%) participated at age 15 years, 2400 (65%) at age 18 years, 2145 (58%) at age 21 years, 2102 (57%) at age 28 years and 1206 (33%) at age 32 years. The geographical area covered by the cohort was rural, consisting of municipalities with towns of less than 30 000 inhabitants. The initial data collection in 2004 used paper questionnaires distributed to all primary schools in the region (Winding *et al.*, 2014). Despite the rural context, the social structure of the sample has been shown to be broadly comparable to the general Danish population (Glasscock *et al.*, 2013). The surveys consisted of questions about health, family, social life, school, work, and wellbeing. The survey data were linked with register data using unique identification numbers from the Danish Civil Registration System (Schmidt *et al.*, 2014).

Data

Mental health measures

Three mental health measures were included: depressive symptoms, medication use and mental disorder diagnosis. Depressive symptoms were assessed using the 4-item version of the Center for Epidemiological Studies Depression Scale for Children (CES-DC4) at age 15, 18 and 21 years, and the adult version (CES-D4) at age 28 and 32 years. The four items are each scored from 0 to 3, resulting in a sum score from 0 to 12, with higher scores indicating more depressive symptoms (Fendrich *et al.*, 1990).

Medication use was defined as prescriptions for psychotropic medication using Anatomical Therapeutic Chemical codes N05A (minus N05AN), N05AN, N05B, N05C, N06A, N06B, N06C (minus N06AX01 and N06AX02), N07BB and N07BC), obtained from the Danish National Prescription Register (Pottegård *et al.*, 2017). The adolescents' medication use was described as present or not present for each age of interest (age 15–32 years) and within the following categories: young child (age 0–4 years), older child (age 5–12 years), adolescent (age 13–17 years), adult (age 18–32 years) and throughout the study period.

Mental disorder diagnoses were obtained from the Danish National Patient Register from 1995 onwards, i.e. from the age of 6 year in the present population born in 1989 (Mors *et al.*, 2011; Plana-Ripoll *et al.*, 2025; Schmidt *et al.*, 2015). The register includes diagnoses recorded during all hospital contacts but does not cover consultations in the primary care sector, such as with general practitioners, psychologists, or independent specialist doctors. We included both psychiatric and somatic units as well as both primary and secondary diagnoses. Diagnoses were defined by the ICD-10 codes F10-F69 and F80-F99, excluding organic disorders (F00-F09) and intellectual disabilities (F70-79) given that these disorders either have onset at old ages or are congenital. The mental disorder diagnoses were described as 'any mental disorder diagnosis', a dichotomized measure of present/not present for each age

https://doi.org/10.1017/S2045796025100073 Published online by Cambridge University Press

of interest (15–32 years) and within the following categories: child (age 6–12 years), adolescent (age 13–17 years), adult (age 18–32 years) and throughout the study period.

Socio-economic status

Four SES measures were included: SSS in School, SSS in society, equalized household income, and parental educational level. SSS in school and SSS in society were measured at age 15 years with the MacArthur Scale of Subjective Social Status—youth version (MacArthur scale). The adolescents were asked to place themselves on a 10-step ladder representing the social hierarchy in their class (SSS in school) and to place their family on a 10-step social ladder representing the society (SSS in society) (Goodman *et al.*, 2001). Three groups of SSS were defined: low (steps 1-4), middle (steps 5-8) and high (steps 9-10). Equalized family income during the 3 years preceding the initial survey in 2004, obtained from the Register of Family Income, was used to measure annual income. The equalized income accounts for household size and age composition by applying equivalence scales. This allows for more accurate comparisons of economic resources across households with differing compositions (Eurostat, 2025). Three income groups were defined by the OECD definition of income quintile share ratio or the S60/S20 ratio: the low-income group was the families with the 20% lowest income, the high-income group was the families with the 20% highest income and the middle-income group was the families with incomes in between (OECD, 2023). The legal parents' highest educational level in 2004 was used as measure of parental educational level. Data on both legal parents' educational level was obtained from Register of the Highest Completed Education (Statistics Denmark, 2024). The highest educational levels of the parents' were categorized into three groups: the low educational level group contained individuals with completion of up to secondary school (International Standard Classification of Education (ISCED): 0–2), the middle educational level group contained individuals with upper secondary school, vocational education, or short-cycle tertiary education (ISCED: 3–5) and the high educational level group contain individuals with a bachelor's degree or higher (ISCED: 6–8).

Covariates

Based on the existing literature and discussions with experts working with adolescents with mental health problems, the following covariates were included: school pressure, social support from teachers, social support from classmates, bullying and parents' support, sex, country of origin, family history of poor mental health, multimorbidity in family, multimorbidity in the adolescent and parental cohabitation (Details in Supplementary 1) (Balvig, (2000), Currie and Alemán-Díaz, 2015, Oecd, 2016, Kristensen *et al.*, 2022).

Statistical methods

Missing data and participation into the survey

To address potential selection bias, multiple imputations (MI) with chained equations and inverse probability weights (IPW) were used (Details in Supplementary 2).

Descriptive statistics

For each SES measure, the mean values of the sum score of depressive symptoms across all survey waves, medication use prevalence across age 15–32 years, and the cumulative incidence of any mental disorder diagnosis across age 15–32 years were calculated with 95% confidence intervals (CI). The prevalence of medication use for ages 15–17 years were presented together because of the small numbers of observations. Individuals with any medication use before age 15 years were excluded from the analyses of medication use prevalence and individuals with mental disorder diagnosis before age 15 years were excluded from the analyses of cumulative incidence of mental disorder diagnosis to avoid reverse causality.

Mental health trajectories

Mental health trajectories from ages 15–32 years were determined using Group-Based Trajectory Modelling (GBTM) (Dalsgaard *et al.*, 2020; Sánchez-Gelabert, 2023). The analyses were conducted on depressive symptoms scores (CES-D(C)4). First, the optimal number of groups was taken based on the Bayesian information criteria (BIC) and the minimum group sizes of all groups above 5%. Second, the optimal shape of the trajectories was determined by combining all different opportunities of linear, quadratic and cubic trajectories. The optimal combination was the model with the lowest BIC, no groups smaller than 5%, average posterior probability of assignments (APPA) values $>$ 70% for each group, and odds of correct classification (OCC) $>$ 5.0 for each group (Sánchez-Gelabert, 2023). Third, the population was assigned membership of the trajectory group that they have the highest probability of belonging to and descriptive statistics of the members of each trajectory group was presented. Logistic regression was used to calculate the relative odds ratio (ROR) of membership to each of the trajectory groups compared with the low stable group for each of the characteristics.

Sensitivity analysis

A sensitivity analysis was conducted to investigate how a change in the definition of income groups, using tertiles of income, affects the results (Kempel *et al.*, 2022; Poulsen *et al.*, 2020).

All statistical analyses are performed in Stata Version 18.0. Plots and graphs are performed in R Studio (Version 4.4.1).

Results

Participants

The VestLiv sample consisted of 3681 individuals, of which 81.5% (2004) to 31.9% (2021) were included in the descriptive analyses of depressive symptoms. In the descriptive analyses, 97.9% were included in the medication use sample, 96.7% in the mental disorder diagnosis sample and 92.8% in the trajectory sample (Supplementary F1). Attrition analyses showed that non-responders were more often males, with low SES across all SES measures, used psychotropic medication, and more often were having a mental disorder diagnosis in the study period, which resulted in largest IPW's in persons with these characteristics. After imputations and weighting, only minor differences were found in the distributions of the characteristics between the samples (Table 1). For example, the proportion of males ranged between 51% and 52% in the diagnosis sample, the medication sample, and the survey samples from 2004, 2007, 2010, 2017 and 2021, while the proportion of males differed slightly in the trajectory sample with 59% (Details of characteristics without imputations and IPW in Supplementary T1).

SES-specific patterns

The low SES group, particularly individuals reporting low SSS in school, tended to have the highest mean depressive symptoms

https://doi.org/10.1017/S2045796025100073 Published online by Cambridge University Press

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Table 1. Characteristics of samples (imputed and weighted data)

Variables		Mental disorder diagnosis sample N = 3520	Medication use sample N = 3605	Trajectory sample N = 3416	2004 N = 3000	2007 N = 2367	2010 N = 1951	2017 N = 1927	2021 N = 1175
Sex (N (%))	Males	1799 (51)	1856 (51)	2004 (59)	1554 (52)	1220 (52)	1020 (52)	1010 (52)	598 (51)
	Females	1721 (49)	1749 (49)	1412 (41)	1446 (48)	1147 (48)	931 (48)	917 (48)	577 (49)
Depressive symptoms (Mean (95% CI))	15 years	2.20 (2.12–2.28)	2.21 (2.13–2.29)	2.20 (2.12–2.28)	2.22 (2.14–2.30)	2.23 (2.13–2.32)	2.22 (2.10–2.34)	2.20 (2.09–2.32)	2.24 (2.04–2.44)
	N (missing) 18 years	2902 (618) 2.86 (2.76–2.95)	2954 (651) 2.85 (2.76–2.94)	3000 (416) 2.82 (2.72–2.92)	3000 (0) 2.85 (2.75–2.95)	2127 (240) 2.86 (2.75–2.96)	1772 (179) 2.85 (2.74–2.97)	1698 (229) 2.86 (2.74–2.99)	1073 (102) 2.83 (2.65–3.01)
	N (missing) 21 years	2294 (1226) 2.45 (2.34–2.55)	2336 (1269) 2.45 (2.35–2.56)	2367 (1049) 2.54 (2.42–2.65)	2127 (873) 2.44 (2.33–2.55)	2367 (0) 2.42 (2.30–2.54)	1648 (303) 2.64 (2.49–2.79)	1461 (466) 2.48 (2.35–2.61)	955 (220) 2.41 (2.25–2.57)
	N (missing) 28 years	1885 (1635) 2.54 (2.44 – 2.63)	1924 (1681) 2.55 (2.45 – 2.64)	1951 (1465) 2.65 (2.54 – 2.75)	1772 (1228) 2.48 (2.38 – 2.57)	1648 (719) 2.56 (2.44 – 2.68)	1951 (0) 2.56 (2.43 – 2.69)	1302 (625) 2.68 (2.57 – 2.80)	882 (293) 2.57 (2.43 – 2.71)
	N (missing) 32 years	1866 (1654) 2.52 (2.40–2.64)	1895 (1710) 2.53 (2.41–2.64)	1927 (1489) 2.59 (2.46–2.73)	1698 (1302) 2.54 (2.42–2.66)	1461 (906) 2.53 (2.39–2.67)	1302 (649) 2.54 (2.38–2.70)	1927 (0) 2.49 (2.36–2.62)	946 (229) 2.72 (2.50–2.94)
	N (missing)	2294 (1226)	2336 (1269)	2367 (1049)	1073 (1927)	955 (1412)	882 (1069)	946 (981)	1175 (0)
Medication use (N (%))	Child (age 4–12 years)	23 (1)	0 (0)	41 (1)	27 (1)	20 (1)	18 (1)	24 (1)	6 (1)
	Adolescence (age 12–17 years)	79 (2)	74 (2)	113 (3)	84 (3)	66 (3)	55 (3)	61 (3)	42 (4)
	Adult (age 17 – 32)	942 (27)	983 (27)	985 (29)	773 (26)	611 (26)	520 (27)	533 (28)	343 (29)
	Study period (age 0–32 years)	1038 (29)	1058 (29)	1084 (32)	859 (29)	676 (29)	572 (29)	590 (31)	387 (33)
Mental disorder diagnosis (N (%))	Child (age 4–12 years)	0 (0)	80 (2)	126 (4)	85 (3)	76 (3)	58 (3)	59 (3)	34 (3)
	Adolescence (age 12–17)	117 (3)	155 (4)	172 (5)	138 (5)	106 (4)	96 (5)	73 (4)	67 (6)
	Adult (age 17–32 years)	576 (16)	605 (17)	611 (18)	466 (16)	380 (16)	338 (17)	366 (19)	206 (18)
	Study period (age 0 – 32)	602 (17)	707 (20)	743 (22)	573 (19)	469 (20)	408 (21)	410 (21)	254 (22)
SSS* **in school** (N (%))	High	1446 (41)	1476 (41)	1387 (41)	1307 (44)	959 (41)	787 (40)	763 (40)	503 (43)
	Middle	1923 (55)	1971 (55)	1868 (55)	1559 (52)	1312 (55)	1072 (55)	1077 (56)	605 (51)
	Low	151 (4)	158 (4)	161 (5)	134 (4)	96 (4)	92 (5)	87 (5)	67 (6)

(*Continued*)

https://doi.org/10.1017/S2045796025100073 Published online by Cambridge University Press

Table 1. (*Continued.*)

Variables		Mental disorder diagnosis sample N = 3520	Medication use sample N = 3605	Trajectory sample N = 3416	2004 N = 3000	2007 N = 2367	2010 N = 1951	2017 N = 1927	2021 N = 1175
SSS* in society (N (%))	High	1070 (30)	1087 (30)	1024 (30)	963 (32)	689 (29)	577 (30)	529 (27)	359 (31)
	Middle	2391 (68)	2455 (68)	2328 (68)	1985 (66)	1634 (69)	1342 (69)	1363 (71)	790 (67)
	Low	59 (2)	63 (2)	64 (2)	53 (2)	44 (2)	32 (2)	35 (2)	26 (2)
Household income (N (%))	High	714 (20)	721 (20)	628 (18)	599 (20)	468 (20)	379 (19)	371 (19)	239 (20)
	Middle	2124 (60)	2172 (60)	2022 (59)	1797 (60)	1438 (61)	1224 (63)	1174 (61)	709 (60)
	Low	682 (19)	712 (20)	767 (22)	604 (20)	461 (19)	348 (18)	382 (20)	227 (19%)
Educational level (N (%))	High	208 (6)	214 (6)	171 (5%)	177 (6%)	140 (6%)	119 (6%)	117 (6%)	71 (6%)
	Middle	2758 (78)	2815 (78)	2599 (76%)	2341 (78%)	1843 (78%)	1517 (78%)	1489 (77%)	941 (80%)
	Low	554 (16)	576 (16)	646 (19%)	482 (16%)	383 (16%)	315 (16%)	320 (17%)	163 (14%)
Origin (N (%))	Denmark	3304 (94)	3385 (94)	3201 (94%)	2851 (95%)	2243 (95%)	1879 (96%)	1846 (96%)	1127 (96%)
	Other	216 (6)	220 (6)	215 (6	149 (5)	124 (5)	72 (4)	81 (4)	48 (4)
Cohabitation	No	1113 (32)	1162 (32)	1175 (34)	893 (30%)	656 (28%)	593 (30%)	625 (32%)	386 (33%)
(N (%))	Yes	2407 (68)	2443 (68)	2241 (66)	2107 (70)	1711 (72)	1358 (70)	1302 (68)	789 (67)
Bullied (N (%))	No	2633 (75)	2695 (75)	2547 (75)	2227 (74)	1745 (74)	1438 (74)	1420 (74)	873 (74)
	Yes	887 (25)	910 (25)	869 (25)	773 (26)	622 (26)	513 (26)	507 (26)	302 (26)
Support classmates (N (%))	No	214 (6)	223 (6)	212 (6)	190 (6)	141 (6)	142 (7)	121 (6)	82 (7)
	Yes	3306 (94)	3382 (94)	3204 (94)	2810 (94)	2226 (94)	1809 (93)	1806 (94)	1093 (93)
Support teacher (N (%))	No	564 (16)	576 (16)	566 (17)	472 (16)	347 (15)	300 (15)	299 (15)	211 (18)
	Yes	2956 (84)	3029 (84)	2850 (83)	2528 (84)	2020 (85)	1651 (85)	1628 (85)	964 (82)
NMI**	Sum score	0.14 (0.13–0.16)	0.14 (0.13–0.16)	0.14 (0.12–0.16)	0.17 (0.15–0.19)	0.14 (0.12–0.16)	0.13 (0.11–0.15)	0.14 (0.12–0.16)	0.13 (0.10–0.16)
Mean (95% CI)	*N* (missing)	3520 (0)	3605 (0)	3416 (0)	3000 (0)	2367 (0)	1951 (0)	1927 (0)	1175 (0)
Parents' support	Sum score	9.29 (9.21–9.37)	9.28 (9.20–9.35)	9.26 (9.17–9.35)	9.29 (9.21–9.36)	9.33 (9.23–9.44)	9.23 (9.09–9.37)	9.24 (9.11–9.36)	9.20 (8.98–9.41)
(Mean (95% CI))	*N* (missing)	3520 (0)	3605 (0)	3416 (0)	3000 (0)	2367 (0)	1951 (0)	1927 (0)	1175 (0)
School pressure	Sum score	3.05 (3.00–3.09)	3.05 (3.01–3.10)	3.07 (3.02–3.12)	3.04 (3.00–3.09)	3.02 (2.96–3.09)	3.02 (2.94–3.11)	3.07 (3.00–3.14)	3.01 (2.89–3.14)
(Mean (95% CI))	*N* (missing)	3520 (0)	3605 (0)	2917 (499)	3000 (0)	2367 (0)	1951 (0)	1927 (0)	1175 (0)

***SSS = Subjective Social Status, **NMI = Nordic Morbidity Index**

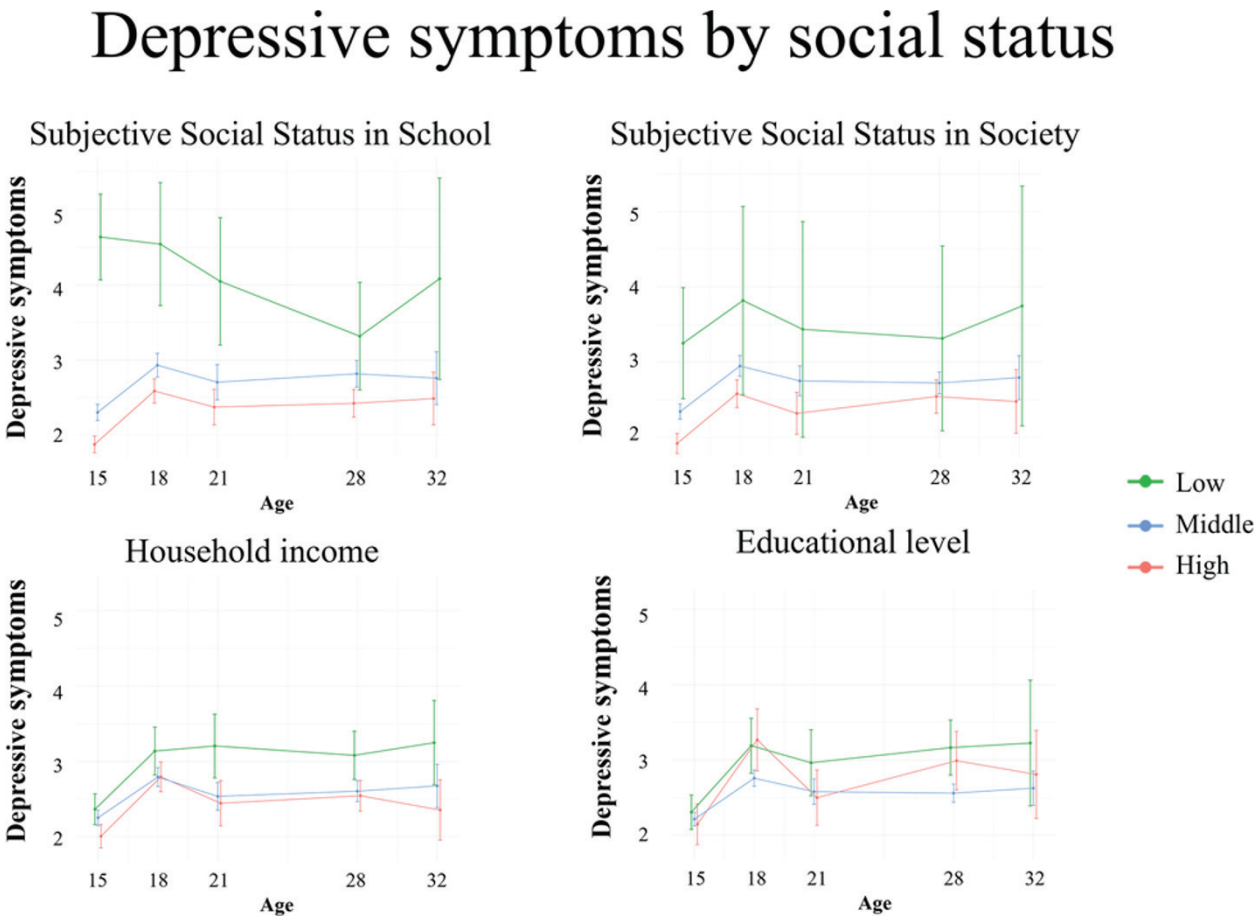

Figure 1. Prevalence of depressive symptoms stratified by SES measures.

score across all ages. When examining parental educational level and household income, the mean scores for the SES groups were nearly identical at ages 15 and 18 years, with similar means across all ages for educational level groups (Fig. 1).

For medication use, the highest prevalence was found in the low SES group across all ages and across all SES measures (Fig. 2).

The low SES group showed the highest incidence of mental disorder diagnosis across all ages and SES measures, while the middle and high SES groups showed comparable and lower incidences. At age of 32 years, the highest incidence of mental disorder diagnosis was found in the low SSS society group with 0.34 (CI: 0.21–0.48) and the low SSS school group with 0.32 (CI: 0.24–0.40) (Supplementary T2). When examining SES by parental educational level, the incidences of mental disorder diagnosis were comparable between the SES groups until age 19 years, then, at later ages, the low group had higher incidences (Fig. 3).

Sex-stratified analyses of depressive symptoms, medication use, and mental disorder diagnosis showed no differences in the SES-specific courses. The sensitivity analyses showed no difference in the results when using tertiles for income.

Developmental trajectories

By evaluating the BIC and group sizes, four groups were found most suitable for modelling trajectories of depressive symptoms from ages 15 to 32 years. APPA and OCC values were calculated for the 10 models with the lowest BIC value and with no groups containing less than 5% of the population (Supplementary T3). Based on the BIC, the group size, the APPA values and the OCC values, a model with four trajectory groups with the following shapes linear, cubic and quadric was build: low stable (46.3%), moderate stable (43.4%), decreasing (4.2%) and increasing trajectory (6.1%) (Fig. 4). The BIC value was –18 739 and the lowest among the tested models. The low stable and moderate stable trajectories had OCC values of 3.51 and 2.68, both below the recommended limit of 5, while the APPA value for the moderate stable trajectory was 65.5, also below the recommended limit of 70.

Characteristics of trajectory membership

Based on the highest probability, the individuals were assigned to the four trajectory groups. Descriptive results showed differences in the characteristics of the individuals in the four trajectory groups (Supplementary T4). The highest proportion of men was found in the low stable trajectory (58%), while the highest proportion of women was found in the decreasing trajectory (70%). Medication use and mental disorder diagnosis during the study period was most frequent in the increasing trajectory (60% and 41%) and the decreasing trajectory (47% and 36%) and less frequent in the low stable trajectory (22% and 15%) and moderate stable trajectory (31% and 20%). Regarding SES, the results showed the highest proportion of low SSS in school in the decreasing trajectory (22%), the highest proportions of low SSS in society in the

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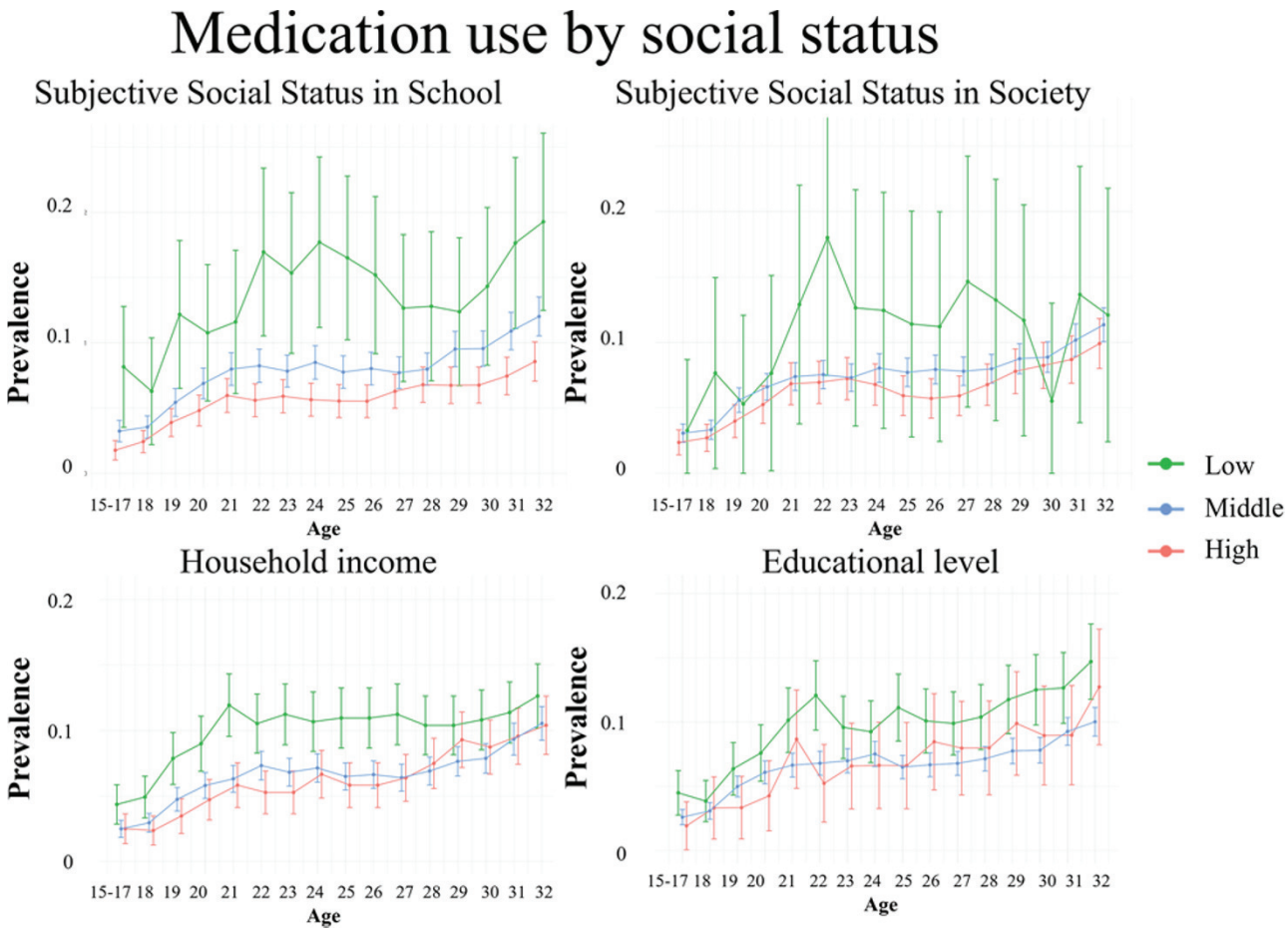

Figure 2. Prevalence of medication use stratified by SES measures.

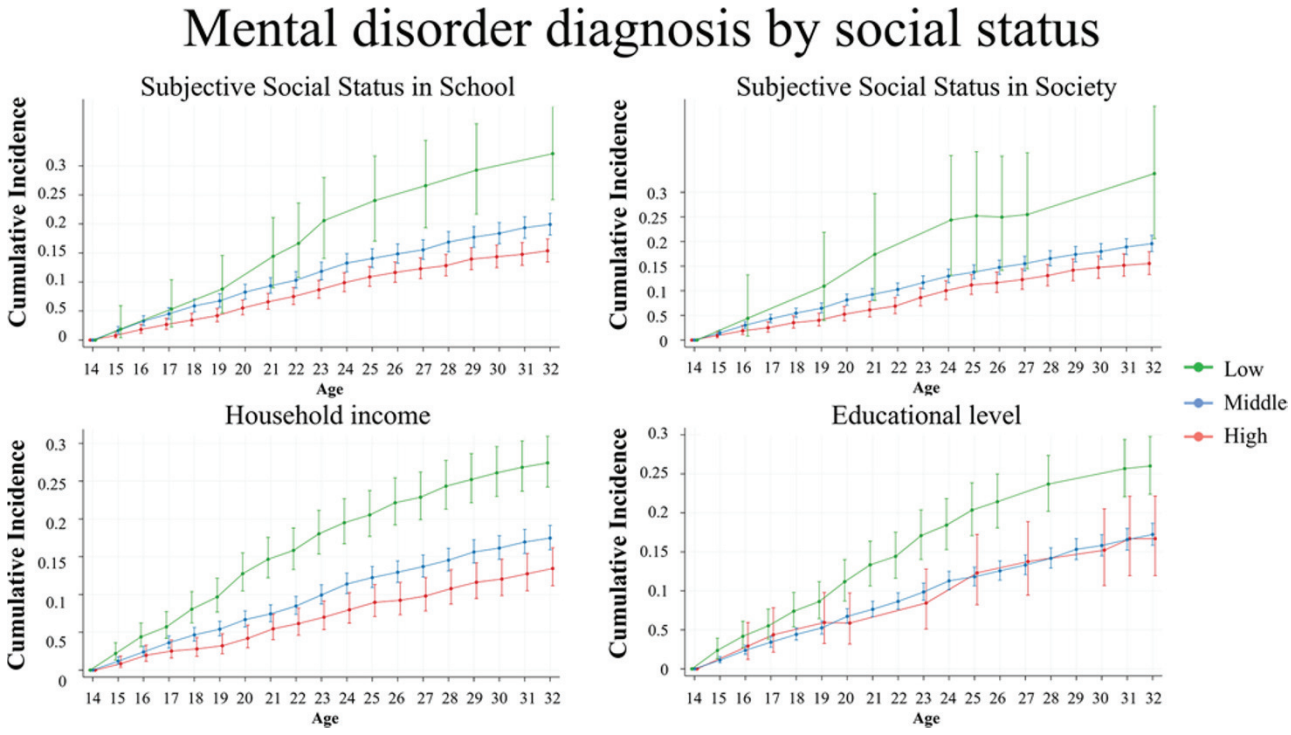

Figure 3. Cumulative incidence of first mental disorder diagnosis stratified by SES measures.

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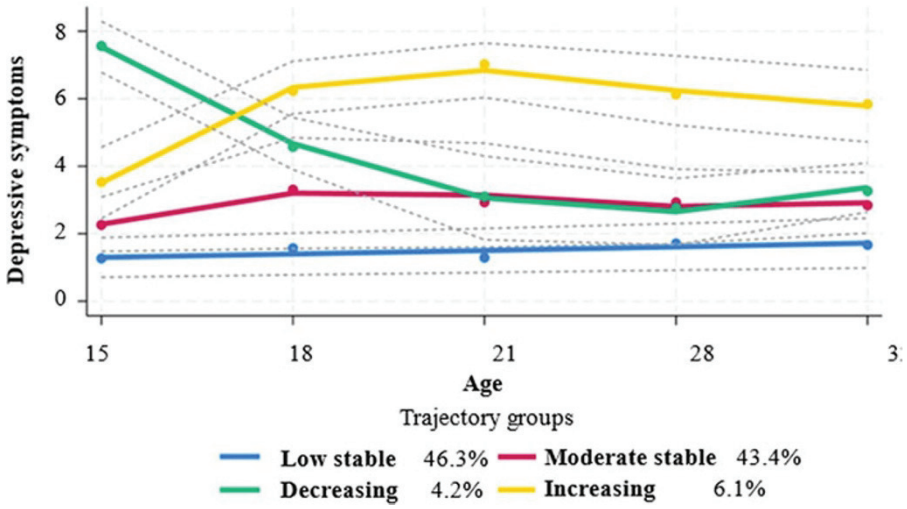

Figure 4. Depressive symptoms trajectories with 95% confidence intervals (dotted lines) and averages (dots) at ages 15–32 years.

decreasing and increasing trajectory (4%), the highest proportions of low educational level in the moderate stable and increasing trajectory (7%), and highest proportion of low-income in the low stable trajectory (22%). Generally, the increasing trajectory had the lowest proportions of social support measures.

Table 2 presents relative odds ratios (ROR) and 95% CI with two-level comparisons: each trajectory group versus the low stable trajectory and the characteristics to their reference. Being female, receiving medication in adulthood and during the study period, having a mental disorder diagnosis in adulthood and during the study period, having low SSS school, having parents not living together, being bullied, lacking support from classmates, lacking support from teachers, lower parental support and higher school pressure were associated with a higher ROR of membership in other trajectory groups compared to the low stable group. Moreover, experiencing high SSS in society resulted in a lower ROR of membership to the other groups compared to the low stable trajectory.

Receiving a mental disorder diagnosis in adolescence and a high parental educational level were associated with a higher ROR of membership in the moderate stable trajectory compared to the low stable trajectory, while reporting high SSS school was associated with a lower ROR of membership of the moderate stable trajectory compared to the low stable trajectory. Additionally, receiving medication in adolescence was associated with a higher ROR of membership in the decreasing trajectory compared to the low stable trajectory. Receiving medication in adolescence, receiving a mental disorder diagnosis in childhood and adolescence, low-income and low parental educational level were associated with a higher ROR of membership in the increasing trajectory compared to the low stable trajectory, while high SSS school was associated with a lower ROR of membership in the increasing trajectory compared to the low stable trajectory.

Discussion

Individuals with a low SES at age 15 years, measured by SSS school, SSS society, household income and parental educational level showed higher mean depressive symptoms, a higher prevalence of medication use and a higher cumulative incidence of mental disorder diagnosis through adolescence and adulthood (age 15–32 years). Four trajectory groups were identified for depressive symptom trajectories: low stable, moderate stable, decreasing and increasing trajectory. Odds of membership to trajectories of moderate stable, decreasing and increasing depressive symptoms were generally higher compared to the low stable trajectory for females, for low social status, for low social support, and for adolescents with other mental health outcomes.

Overall, the low SES groups showed a higher prevalence and incidence of negative mental health outcomes compared to the middle and high SES groups. The tendencies were most pronounced for the SSS measures and less clear for income and parental educational level measures. This could be explained by the low SSS groups only containing about 5% of the population, while the low-income and low education groups were larger, resulting in the low SSS group representing a more extreme segment of low social status than the other measures. However, a sensitivity analysis showed that shifting the low-income group to include the lowest 5% did not alter the results.

The prevalence of medication use may have changed since the present cohort was initiated in 2004, particularly for individuals up to 24 years old, due to a regulation introduced in 2014. This regulation requires young individuals to consult a psychiatrist rather than obtaining an antidepressant prescription from their general practitioner (Ministry of the Interior and Health, 2014). As a result, the prevalence of medication use among individuals under 24 years old may have decreased since 2014.

A Danish study by Dalsgaard et al. on a younger cohort of 18-year-olds found a cumulative incidence of any mental disorder of 0.15 (CI: 0.15–0.15). In contrast, Beck et al. reported cumulative incidences of mental disorder diagnoses at age 80 years of 0.31 (CI:0.31–0.31) for males and 0.34 (CI: 0.34–0.35) for females (Beck *et al.*, 2024; Dalsgaard *et al.*, 2020). These results differ from the present study, which estimated a cumulative incidence of 0.19 (CI: 0.17–0.20). A key distinction between our study and the earlier Danish studies lies in the age of the studied cohorts, which likely explains the observed differences in incidence rates. Specifically, the lower incidence reported by Dalsgaard et al. reflects their younger cohort, while the higher incidence observed by Beck et al. corresponds to their older cohort. Additionally, several other factors may contribute to the discrepancies with Beck et al.'s results. First, the geographical location of the study population in Western Jutland, as it is known that individuals living further from hospitals are less likely to receive a mental disorder diagnosis compared

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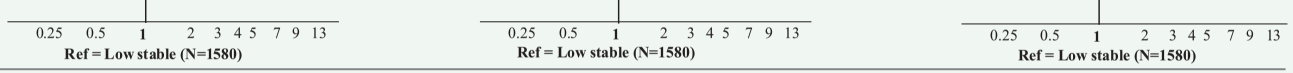
Table 2. Relative odds ratios (ROR) with 95% confidence intervals (95% CI) of membership to the different trajectory groups compared to the low stable groups for each characteristic

Variables		Trajectory groups		
		Moderate stable (N=1484) ROR (95% CI)	**Decreasing** (N=143) ROR (95% CI)	**Increasing** (N=209) ROR (95% CI)
Sex	Females (Ref. = Males)	1.56 (1.34-1.82)	3.15 (2.13-4.65)	3.15 (2.13-4.65)
Medication use	Child (age 4-12) (Ref = No)	1.69 (0.75-3.83)	N/A*	N/A
	Adolescence (age 12-17) (Ref = No)	1.00 (0.61-1.65)	2.64 (1.22-5.72)	2.64 (1.22-5.72)
	Adult (age 17-32) (Ref = No)	1.62 (1.35-1.94)	3.14 (2.16-4.57)	3.14 (2.16-4.57)
	Study period (age 0-32) (Ref = No)	1.52 (1.28-1.82)	2.71 (1.86-3.93)	2.71 (1.86-3.93)
Mental disorder diagnosis	Child (age 4-12) (Ref = No)	0.90 (0.53-1.53)	1.52 (0.56-4.08)	1.52 (0.56-4.08)
	Adolescence (age 12-17) (Ref = No)	1.48 (1.00-2.18)	1.69 (0.77-3.68)	1.69 (0.77-3.68)
	Adult (age 17-32) (Ref = No)	1.53 (1.22-1.92)	3.38 (2.25-5.09)	3.38 (2.25-5.09)
	Study period (age 0-32) (Ref = No)	1.40 (1.14-1.72)	3.05 (2.06-4.52)	3.05 (2.06-4.52)
SSS in school**	Low (Ref =Middle)	2.21 (1.21-4.02)	12.75 (6.46-25.19)	4.28 (1.99-9.24)
	High (Ref=Middle)	0.74 (0.62-0.88)	0.84 (0.55-1.27)	0.40 (0.24-0.66)
SSS in society**	Low (Ref =Middle)	0.78 (0.37-1.65)	2.16 (0.76-6.17)	1.93 (0.67-5.54)
	High (Ref=Middle)	0.74 (0.62-0.88)	0.64 (0.43-0.97)	0.48 (0.31-0.75)
Income	Low (Ref =Middle)	1.09 (0.88-1.33)	0.98 (0.61-1.59)	2.11 (1.45-3.06)
	High (Ref=Middle)	0.92 (0.76-1.11)	0.62 (0.38-1.02)	0.75 (0.49-1.16)
Educational level	Low (Ref =Middle)	1.18 (0.94-1.48)	1.46 (0.89-2.40)	2.24 (1.50-3.34)
	High (Ref=Middle)	1.46 (1.06-2.00)	1.53 (0.76-3.09)	1.42 (0.77-2.61)
Origin	Other (Ref = Denmark)	1.11 (0.79-1.57)	1.73 (1.19-2.52)	1.53 (0.76-3.09)
Cohabitation	No (Ref = Yes)	1.46 (1.24-1.73)	4.20 (2.86-6.17)	1.73 (1.19-2.52)
Bullied	Yes (Ref = No)	1.77 (1.44-2.17)	11.21 (6.82-18.42)	4.20 (2.86-6.17)
Support classmates	No (Ref = Yes)	1.63 (1.08-2.45)	3.58 (2.35-5.44)	11.21 (6.82-18.42)
Support teacher	No (Ref = Yes)	1.64 (1.28-2.09)	3.58 (2.35-5.44)	3.58 (2.35-5.44)
School pressure	Continous (Ref = 0)	1.21 (1.12-1.30)	1.43 (1.21-1.69)	1.32 (1.13-1.54)
Parents' support	Continous (Ref = 0)	0.86 (0.82-0.89)	0.64 (0.58-0.70)	0.76 (0.69-0.83)
NMI* **	Continous (Ref = 0)	1.09 (0.95-1.26)	1.08 (0.82-1.41)	0.95 (0.72-1.24)



*No observations of medication use in childhood in the decreasing and increasing group, ** SSS = Subjective Social Status, ***NMI = Nordic Morbidity Index
Note: Data are imputed and weighted

to those living closer to hospitals, which might explain the higher results found by Beck et al. in the nationwide cohort (Blæhr *et al.*, 2024; Dalsgaard *et al.*, 2020; Madsen *et al.*, 2015). Second, our cohort is born in 1989, while the Beck et al. included individuals born in 1995-2016 (Beck *et al.*, 2024); thus, temporal shifts in the age of onset may play a role, with more recent cohorts being diagnosed at younger ages than the cohort included in our study (Plana-Ripoll et al.). Third, we only obtained mental disorder diagnosis from 1995 for individuals born in 1989, since The Danish Psychiatric Central Research Register included only outpatient data since 1995. As a result, some individuals may have had a diagnosis during the first six years of their life that we did not include (Mors *et al.*, 2011).

Like many other studies, the present study identified four trajectory groups. Shubert et al. showed that most trajectory studies on depressive symptoms in late adolescence and adulthood typically report 3 to 4 trajectory groups, with most identifying a low stable trajectory, along with a moderate stable group (Schubert *et al.*, 2017). The combination of decreasing, increasing and low stable trajectories as identified in the present study has been reported before (Diamantopoulou *et al.*, 2011; Essau *et al.*, 2020; Minh *et al.*, 2021; Wickrama *et al.*, 2009; Williams and Merten, 2014), though few studies have reported a moderate stable trajectory group within this combination (Costello *et al.*, 2008; Wickrama and Wickrama, 2010). Most studies in the review reported a high stable group, which differs from the finding of the present study (Schubert *et al.*, 2017). As the present study, several studies have identified female sex as a risk factor for trajectories with higher levels of depressive symptoms (Costello *et al.*, 2008; Essau *et al.*, 2020; Minh *et al.*, 2021; Schubert *et al.*, 2017), and also low SES has been identified as a risk factor (Costello *et al.*, 2008; Ferro *et al.*, 2015; Minh *et al.*, 2021; Wickrama *et al.*, 2009). However, in aforementioned studies the timing of measuring SES during the life course differed from childhood SES to adolescent SES, like in the present study, which might affect the size of the association. A previous Danish study showed that the timing of SES measurement was associated with depressive symptoms, with the strongest associations observed between low-income in early childhood (age 0–8 years) and depressive symptoms at age 21 years, as well as low maternal labour market participation during late childhood (age 9–14 years) and depressive symptoms at age 21 (Poulsen *et al.*, 2020). Therefore, an earlier timing of SES measurement in the present study might result in stronger associations.

The study has several strengths. First, the use of register data on mental health with almost complete information limits the risk of selection bias. Second, the participation in the early waves of the survey was high (81.5% in 2004), which also limits the risk of selection bias. The use of IPW, built on rich register data and data from earlier waves, to correct for selection bias limits the risk of selection bias further, especially in the later waves of the surveys where the drop out is a larger problem. Third, the use of MI to account for missing data on the covariates limits the number of individuals excluded from the population. The fact that the MI are based on register information and survey information with limited amount of missing data, especially in the early waves, strengthens the quality of the MI. Forth, the use of several SES measures to capture different aspects of social status is a strength. The SSS measures showed poor correlation with income and education, which underlines that the measures cover different aspects of SES.

Some limitations of the study need to be addressed. First, the geographical area of the study population can limit the external validity, since the study population lives in a mostly rural area in 2004, and there might be differences in the constructs of social status and mental health from urban to rural areas. Second, some risk of reverse causality is present, as the depressive symptoms at age 15 years and the SSS measures are measured at the same time. Third, the measurement of depressive symptoms has shown poor psychometric properties in children, with poor reliability and acceptable structural validity (Sørensen *et al.*, 2022). The short four-item version of the CES-D has not been tested in adults. Therefore, the level of depressive symptoms should be interpreted with caution. Moreover, no validated cut-points of The MacArthur Scale exist. Earlier studies have used the categorization of low (steps 1–3), middle (steps 4–7) and high (steps 8–10) (Lange *et al.*, 2023; Poulsen *et al.*, 2020). However, in the samples in the present study this categorization resulted in a large high group and very small low group and therefore this categorization did not seem appropriate. Studies on the construct validity and the appropriate cut-points of the scale are requested to ensure appropriate interpretation of the scale. Forth, the APPA and OCC fit was not within the recommended limits on 70% and $>$ 5.0 for the moderate stable group (APPA = 65%, OCC = 2.7) and the low stable group (OCC = 3.6), i.e., the results should be interpreted with caution.

These findings highlight the relevance of targeting adolescents with low SES in mental health prevention efforts, particularly those with low SSS. The two SSS measures reflect perceptions of the adolescents' social standing in school and society respectively and therefore, the measures may capture vulnerable individuals not identified by traditional SES indicators such as income or parental education. Additionally, the strong association between low social support and more negative depressive symptom trajectories suggests that improving social support could be a promising avenue for intervention. Strengthening social support may also positively influence SSS, which encompasses not only academic or occupational achievement but also social relationships.

Conclusion

Individuals with low SES – particularly low SSS – experienced more negative mental health outcomes than individuals with middle or high SES from adolescence to adulthood (age 15–32 years). This indicates that subjective measures of social status may capture vulnerable individuals not identified by traditional SES indicator such as income and education. Odds of membership to trajectories of less favourable depressive symptoms – the moderate stable, decreasing, or increasing – compared to the low stable trajectory, were generally higher for females, individuals with low SES, individuals with low social support, and individuals with other mental health outcomes.

Preventive initiatives should focus on these high-risk groups. Notably, individuals in the increasing trajectory reported the lowest levels of social support, indicating that strengthening social networks for vulnerable adolescents may be particularly important for shaping long-term mental health trajectories.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S2045796025100073.

Data Availability Statement. Data have been made available for the first author specifically via Statistics Denmark and can therefore not be shared. The codes are available from the corresponding author on reasonable request.

Acknowledgements. We are grateful for the adolescents who took time to respond the questionnaires in the VestLiv.

Author contributions. C.L.B.S.: Conceptualization; Methodology; Formal analysis; Investigation; Project administration; Writing – Original draft preparation; Writing – Reviewing and Editing. K.B.: Conceptualization; Methodology; Supervision, Writing – Reviewing and Editing. T.N.W., O.P.R., U.B., P.B.S.: Conceptualization; Methodology; Writing – review & editing.

Financial support. This work was supported by KV fonden and Sygeforsikring Danmark (Grant number 2021-0105).

Conflict of Interest. None reported.

Ethical standards. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975.

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Supplementary

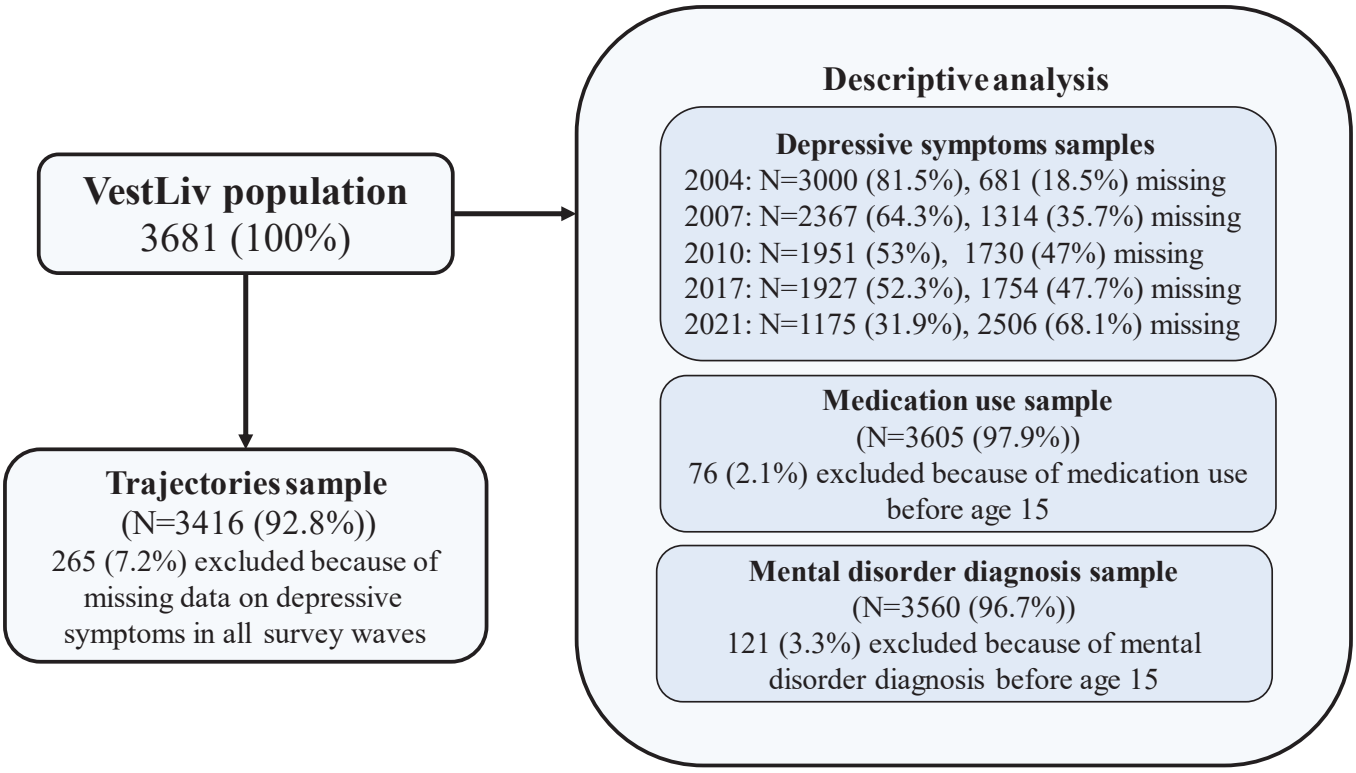
Supplementary 1: Detailed information about included covariates

Five covariates from the baseline survey in 2004 were included: school pressure, social support from teachers, social support from classmates, bullying, and parents' support. School pressure was measured with 2 items developed by Flemming Balvig, scored between 0-2, and 1 item from the Health Behaviour in School-aged Children (HBSC), scored between 0-3, resulting in a sum score of 0-7 (28, 29). The higher the score, the more school pressure. Social support from teachers was measured with 1 item scored 0-3 and developed for the PISA project by the OECD (30). The measure was handled as a dichotomous (score 0-1 = support, score 2-4 = no support). Social support from classmates was measured by 2 items from the HBSC each with a score of 0-3 and the measure was dichotomized (0-4 = no support, 5-8 = support) (29). Bullying was measured with 1 item developed for the VestLiv cohort and the answers were dichotomized (score 0 = not bullied, score 1-3 = bullied). Parents' support was measured by a shortened version of the Parental Bonding Instrument (PBI) with 4 items regarding each parent with an item score of 0-3. The measure was handled continuous using the average score of the parents' or, if only one parent, the score of that parent. The higher the score, the more support.
Six register-based covariates were included: sex, country of origin, family history of poor mental health, multimorbidity in family, multimorbidity in the adolescent, and parental cohabitation. Family history of poor mental health was defined as any mental disorder diagnosis since 1995 or any medication use related to mental health the year before the baseline survey, among legal parents or siblings younger than 25 years old living at the same address as the adolescent. Mental disorder diagnoses were obtained since 1995 or since birth, if born after 1995, because of changing in the registration in the register from 1995. Multimorbidity was defined according to a modification of the Nordic Multimorbidity Index (NMI), with exclusion of ICD-10 codes of mental disorder diagnosis (F10 and F17) and medication use related to mental health problems (ATC codes: N05A, N06A, N07BC) (31). The higher the score, the more multimorbidity.

Supplementary 2: Detailed information about inverse probability weights (IPW) and multiple imputations (MI)

MI with chained equations and 100 iterations were applied to compensate for missing values of SES measures and covariates in the baseline survey of 2004. The outcome of depressive symptoms was included in the MI of covariates, but MI was not applied to the outcome, since calculating imputations for the outcome based on the same model as the covariates does not add information to the analyses (30, 31). To compensate for unequal probability of participation in the VestLiv cohort, IPW was applied to all survey waves. The probability of being sampled in 2004, 2007 and 2010 was calculated according to sex, parents' mental disorder diagnoses, the adolescents' mental disorder diagnoses, parental educational level, and equalized family income, and for survey 2007 and 2010, the sum score of depressive symptoms in the earlier waves. The probability of being sampled in 2017 and 2021 was calculated by sex, parents' mental disorder diagnoses, the adolescents' mental disorder diagnoses, adolescents' mediation use, own educational level, equalized family income, labour market participation, and the sum score of depressive symptoms the earlier waves.

Supplementary F1: Flowchart of participant included in the different analyses



Supplementary T1: Characteristics of samples (without multiple imputations and inverse probability weights)

	Variables	Diagnosis sample	Medication sample	Trajectory sample	2004	2007	2010	2017	2021
		N=3520	N=3605	N=3416	N=3000	N=2367	N=1951	N=1927	N=1175
Sex	Males	1799 (51%)	1856 (51%)	1714 (50%)	1483 (49%)	1089 (46%)	857 (44%)	824 (43%)	454 (39%)
	Females	1721 (49%)	1749 (49%)	1702 (50%)	1517 (51%)	1278 (54%)	1094 (56%)	1103 (57%)	721 (61%)
Depressive symptoms	15 years	2.20 (2.12-2.28)	2.21 (2.13-2.29)	2.22 (2.14-2.30)	2.22 (2.14-2.30)	2.22 (2.13-2.32)	2.21 (2.11-2.31)	2.23 (2.13-2.34)	2.31 (2.17-2.45)
	N (missing)	2902 (618)	2954 (651)	3000 (416)	3000 (0)	2127 (240)	1772 (179)	1698 (229)	1073 (102)
	18 years	2.86 (2.76-2.95)	2.85 (2.76-2.94)	2.86 (2.85-2.86)	2.86 (2.76-2.96)	2.86 (2.76-2.95)	2.84 (2.73-2.96)	2.87 (2.76-2.99)	2.99 (2.84-3.14)
	N (missing)	2294 (1226)	2336 (1269)	2367 (1049)	2127 (873)	2367 (0)	1648 (303)	1461 (466)	955 (220)
	21 years	2.45 (2.34-2.55)	2.45 (2.35-2.56)	2.47 (2.37-2.57)	2.43 (2.33-2.54)	2.39 (2.28-2.50)	2.47 (2.37-2.57)	2.43 (2.31-2.55)	2.45 (2.30-2.61)
	N (missing)	1885 (1635)	1924 (1681)	1951 (1465)	1772 (1228)	1648 (719)	1951 (0)	1302 (625)	882 (293)
	28 years	2.54 (2.44-2.63)	2.55 (2.45-2.64)	2.55 (2.46-2.65)	2.47 (2.38-2.56)	2.49 (2.38-2.59)	2.47 (2.36-2.58)	2.55 (2.46-2.65)	2.49 (2.37-2.61)
	N (missing)	1866 (1654)	1895 (1710)	1927 (1489)	1698 (1302)	1461 (906)	1302 (649)	1927 (0)	946 (229)
	32 years	2.52 (2.40-2.64)	2.53 (2.41-2.64)	2.54 (2.42-2.65)	2.54 (2.42-2.66)	2.50 (2.38-2.63)	2.53 (2.40-2.67)	2.45 (2.33-2.58)	2.54 (2.42-2.65)
	N (missing)	2294 (1226)	2336 (1269)	2367 (1049)	1073 (1927)	955 (1412)	882 (1069)	946 (981)	1175 (0)
Medication use	Child (age 4-12)	23 (1%)	0 (0%)	41 (1%)	30 (1%)	21 (1%)	17 (1%)	15 (1%)	13 (1%)
	Adolescence (age 12-17)	79 (2%)	74 (2%)	113 (3%)	95 (3%)	76 (3%)	57 (2%)	48 (2%)	51 (3%)
	Adult (age 17-32)	942 (27%)	983 (27%)	985 (29%)	907 (27%)	767 (26%)	570 (24%)	454 (23%)	483 (25%)
	Study period (age 0-32)	1038 (29%)	1058 (29%)	1084 (32%)	1002 (29%)	847 (28%)	635 (27%)	510 (26%)	535 (28%)
Mental disorder diagnosis	Child (age 4-12)	0 (0%)	80 (2%)	126 (4%)	87 (3%)	62 (2%)	52 (2%)	43 (2%)	37 (2%)
	Adolescence (age 12-17)	117 (3%)	155 (4%)	172 (5%)	147 (4%)	120 (4%)	84 (4%)	71 (4%)	67 (3%)
	Adult (age 17-32)	576 (16%)	605 (17%)	611 (18%)	554 (16%)	457 (15%)	345 (15%)	285 (15%)	313 (16%)
	Study period (age 0-32)	602 (17%)	707 (20%)	743 (22%)	659 (19%)	539 (18%)	406 (17%)	338 (17%)	347 (18%)
SSS in school	High	1246 (35%)	1268 (35%)	1287 (38%)	1287 (43%)	920 (39%)	777 (40%)	732 (38%)	487 (41%)
	Middle	1445 (41%)	1470 (41%)	1493 (44%)	1493 (50%)	1072 (45%)	886 (45%)	861 (45%)	508 (43%)
	Low	116 (3%)	121 (3%)	123 (4%)	123 (4%)	76 (3%)	67 (3%)	65 (3%)	47 (4%)
	Missing	713 (20%)	746 (21%)	513 (15%)	97 (3%)	299 (13%)	221 (11%)	269 (14%)	133 (11%)
SSS in society	High	946 (27%)	959 (27%)	968 (33%)	968 (33%)	685 (33%)	567 (33%)	511 (31%)	335 (32%)
	Middle	1838 (52%)	1871 (52%)	1907 (65%)	1907 (65%)	1363 (66%)	1145 (66%)	1124 (68%)	700 (66%)
	Low	44 (1%)	47 (1%)	47 (2%)	47 (2%)	32 (2%)	27 (2%)	27 (2%)	19 (2%)
	Missing	692 (20%)	728 (20%)	133 (11%)	133 (11%)	133 (11%)	133 (11%)	133 (11%)	133 (11%)
Household income	High	714 (20%)	721 (20%)	701 (21%)	645 (22%)	527 (22%)	417 (21%)	413 (21%)	270 (23%)
	Middle	2124 (60%)	2172 (60%)	2077 (61%)	1847 (62%)	1470 (62%)	1238 (63%)	1195 (62%)	722 (61%)
	Low	682 (19%)	712 (20%)	638 (19%)	508 (17%)	370 (16%)	296 (15%)	319 (17%)	183 (16%)
Educational level	High	205 (6%)	211 (6%)	207 (6%)	192 (6%)	163 (7%)	147 (8%)	134 (7%)	92 (8%)
	Middle	2712 (77%)	2768 (77%)	2663 (78%)	2374 (79%)	1922 (81%)	1579 (81%)	1514 (79%)	947 (81%)
	Low	515 (15%)	536 (15%)	470 (14%)	370 (12%)	274 (12%)	222 (11%)	240 (12%)	123 (10%)
	Missing	88 (3%)	90 (2%)	76 (2%)	64 (2%)	8 (0%)	3 (0%)	39 (2%)	13 (1%)
Origin	Denmark	3304 (94%)	3385 (94%)	3238 (95%)	2864 (95%)	2270 (96%)	1890 (97%)	1860 (97%)	1142 (97%)
	Other	216 (6%)	220 (6%)	178 (5%)	136 (5%)	97 (4%)	61 (3%)	67 (3%)	33 (3%)
Cohabitation	No	1113 (32%)	1162 (32%)	1056 (31%)	874 (29%)	601 (25%)	498 (26%)	554 (29%)	319 (27%)
	Yes	2407 (68%)	2443 (68%)	2360 (69%)	2126 (71%)	1766 (75%)	1453 (74%)	1373 (71%)	856 (73%)
Bullied	No	2158 (61%)	2196 (61%)	2222 (65%)	2222 (74%)	1574 (66%)	1313 (67%)	1262 (65%)	794 (68%)
	Yes	717 (20%)	730 (20%)	750 (22%)	750 (25%)	537 (23%)	442 (23%)	423 (22%)	270 (23%)
	Missing	645 (18%)	679 (19%)	444 (13%)	28 (1%)	256 (11%)	196 (10%)	242 (13%)	111 (9%)
Support classmates	No	171 (5%)	178 (5%)	181 (5%)	181 (6%)	119 (5%)	117 (6%)	105 (5%)	74 (6%)
	Yes	2688 (76%)	2731 (76%)	2774 (81%)	2774 (92%)	1986 (84%)	1635 (84%)	1573 (82%)	988 (84%)
	Missing	661 (19%)	696 (19%)	461 (13%)	45 (2%)	262 (11%)	199 (10%)	249 (13%)	113 (10%)
Support teacher	No	453 (13%)	460 (13%)	467 (14%)	467 (16%)	295 (12%)	248 (13%)	244 (13%)	166 (14%)
	Yes	2421 (69%)	2464 (68%)	2503 (73%)	2503 (83%)	1815 (77%)	1508 (77%)	1442 (75%)	896 (76%)
	Missing	646 (18%)	681 (19%)	446 (13%)	30 (1%)	257 (11%)	195 (10%)	241 (13%)	113 (10%)
NMI	Mean (95%CI)	0.14 (0.13-0.16)	0.14 (0.13-0.16)	0.15 (0.13-0.17)	0.17 (0.15-0.19)	0.15 (0.13-0.17)	0.14 (0.12-0.16)	0.15 (0.13-0.17)	0.16 (0.13-0.19)
	N (missing)	3520 (0)	3605 (0)	3416 (0)	3000 (0)	2367 (0)	1951 (0)	1927 (0)	1175 (0)
Parents' support	Mean (95%CI)	9.31 (9.23-9.39)	9.30 (9.23-9.38)	9.30 (9.22-9.37)	9.30 (9.22-9.37)	9.38 (9.29-9.47)	9.31 (9.21-9.41)	9.27 (9.17-9.37)	9.22 (9.09-9.35)
	N (missing)	2865 (655)	2916 (689)	2960 (456)	2960 (40)	2104 (263)	1748 (203)	1676 (251)	1058 (117)
School pressure	Mean (95%CI)	3.04 (2.99-3.08)	3.04 (2.99-3.09)	3.04 (2.99-3.08)	3.04 (2.99-3.08)	3.00 (2.95-3.06)	2.98 (2.92-3.04)	3.02 (2.96-3.08)	2.94 (2.87-3.02)
	N (missing)	2829 (691)	2873 (732)	2917 (499)	2917 (83)	2078 (289)	1732 (219)	1663 (264)	1052 (123)

*SSS = Subjective Social Status

Supplementary T2: Cumulative incidence of mental disorder diagnosis at age 32

Variables		Cumulative incidence (95% Confidence interval)
Total		0.19 (0.17-0.20)
Household income	High	0.13 (0.11-0.16)
	Medium	0.17 (0.16-0.19)
	Low	0.27 (0.24-0.31)
Educational level	High	0.17 (0.12-0.22)
	Medium	0.17 (0.16-0.19)
	Low	0.26 (0.22-0.30)
SSS school	High	0.15 (0.13-0.17)
	Medium	0.20 (0.18-0.22)
	Low	0.32 (0.24-0.40)
SSS society	High	0.16 (0.13-0.18)
	Medium	0.20 (0.18-0.21)
	Low	0.34 (0.21-0.47)

Supplementary T3: Fit indices for different trajectory models

Polynomic function	Groups <5%	BIC	APPA				OCC			
			G1	G2	G3	G4	G1	G2	G3	G4
1323	0	-18739.0	.7443463	.654865	.7605767	.7770233	3.556109	2.678051	55.73622	39.42347
2323	0	-18742.98	.7499905	.6506791	.7686384	.7794708	3.473496	2.760712	59.02599	40.41907
3323	0	-18744.44	.7736531	.6411836	.7681257	.7710739	3.228473	3.198267	59.8737	41.62137
2332	0	-18746.12	.7677459	.6619402	.6538717	.6792948	2.796953	3.811602	34.83157	29.25854
1223	0	-18746.94	.7785233	.6603172	.5923931	.6182912	2.74738	4.078065	26.11354	24.01945
3332	0	-18746.99	.7154176	.6691424	.7598745	.768221	3.823975	2.412246	53.78057	32.81883
3223	0	-18747.81	.7584587	.635237	.7718942	.7760625	3.112618	3.053902	59.51336	39.4025
2223	0	-18750.94	.7252828	.6595263	.7589666	.7643776	3.602355	2.535337	54.14765	33.20676

Supplementary Table 4: Characteristics of trajectory groups

Variables		Trajectory groups			
		Low stable	**Moderate stable**	**Decreasing**	**Increasing**
		N=1580	N=1484	N=143	N=209
Sex (N (%))	Males	911 (58%)	680 (46%)	43 (30%)	80 (38%)
	Females	669 (42%)	804 (54%)	100 (70%)	129 (62%)
Depressive symptoms (Mean (95% CI))	15 years	1.00 (0.94-1.06)	2.64 (2.55-2.73)	8.31 (8.04-8.59)	3.85 (3.51-4.19)
	N (missing)	1378 (202)	1322 (162)	143 (0)	157 (52)
	18 years	1.35 (1.28-1.42)	3.77 (3.65-3.88)	4.34 (3.85-4.84)	6.69 (6.30-7.07)
	N (missing)	1098 (482)	1023 (461)	96 (47)	150 (59)
	21 years	1.09 (1.02-1.16)	3.19 (3.06-3.32)	2.98 (2.45-3.50)	7.33 (6.97-7.68)
	N (missing)	924 (656)	812 (672)	80 (63)	135 (74)
	28 years	1.45 (1.36-1.53)	3.13 (3.02-3.25)	2.76 (2.41-3.12)	6.55 (6.18-6.93)
	N (missing)	885 (695)	839 (645)	84 (59)	119 (90)
	32 years	1.48 (1.36-1.59)	3.02 (2.87-3.18)	3.08 (2.63-3.53)	6.08 (5.55-6.61)
	N (missing)	522 (1058)	514 (970)	63 (80)	76 (133)
Medication use (N (%))	Child (age 4-12)	11 (1%)	18 (1%)	0 (0%)	0 (0%)
	Adolescence (age 12-17)	38 (2%)	38 (3%)	10 (7%)	9 (4%)
	Adult (age 17-32)	299 (19%)	420 (28%)	65 (45%)	123 (59%)
	Study period (age 0-32)	345 (22%)	464 (31%)	67 (47%)	126 (60%)
Mental disorder diagnoses (N (%))	Child (age 6-12)	41 (3%)	30 (2%)	5 (3%)	11 (5%)
	Adolescence (age 12-17)	50 (3%)	74 (5%)	9 (6%)	14 (7%)
	Adult (age 17-32)	177 (11%)	241 (16%)	46 (32%)	90 (43%)
	Study period -(age 6-32)	230 (15%)	291 (20%)	52 (36%)	86 (41%)
SSS in school (N (%))	High	749 (47%)	581 (39%)	48 (34%)	51 (25%)
	Middle	802 (51%)	837 (56%)	64 (45%)	135 (65%)
	Low	29 (2%)	66 (4%)	31 (22%)	23 (11%)
SSS in society (N (%))	High	553 (35%)	420 (28%)	38 (27%)	44 (21%)
	Middle	1003 (64%)	1044 (70%)	98 (69%)	158 (75%)
	Low	24 (2%)	20 (1%)	6 (4%)	8 (4%)
Income (N (%))	High	272 (17%)	275 (19%)	26 (18%)	65 (31%)
	Middle	960 (61%)	912 (61%)	94 (66%)	111 (53%)
	Low	348 (22%)	297 (20%)	23 (16%)	33 (16%)
Educational level (N (%))	High	209 (13%)	218 (15%)	25 (18%)	51 (24%)
	Middle	1286 (81%)	1162 (78%)	112 (78%)	144 (69%)
	Low	85 (5%)	104 (7%)	6 (4%)	14 (7%)
Origin (N (%))	Denmark	1501 (95%)	1409 (95%)	133 (93%)	195 (93%)
	Other	79 (5%)	75 (5%)	10 (7%)	14 (7%)
Cohabitation (N (%))	No	410 (26%)	507 (34%)	57 (40%)	82 (39%)
	Yes	1170 (74%)	977 (66%)	86 (60%)	127 (61%)
Bullied (N (%))	No	1291 (82%)	1058 (71%)	73 (51%)	125 (60%)
	Yes	289 (18%)	426 (29%)	70 (49%)	84 (40%)
Support classmates (N (%))	No	1523 (96%)	1396 (94%)	96 (67%)	189 (90%)
	Yes	57 (4%)	88 (6%)	47 (33%)	20 (10%)
Support teacher (N (%))	No	187 (12%)	264 (18%)	46 (32%)	46 (22%)
	Yes	1393 (88%)	1220 (82%)	97 (68%)	163 (78%)
NMI (Mean (95% CI))	Mean (95%CI)	0.14 (0.11-0.16)	0.16 (0.13-0.19)	0.17 (0.08-0.27)	0.16 (0.08-0.24)
	N (missing)	1580 (0)	1484 (0)	143 (0)	209 (0)
Parents' support (Mean (95% CI))	Mean (95%CI)	9.74 (9.65-9.84)	9.09 (8.98-9.20)	7.48 (7.04-7.92)	8.27 (7.89-8.66)
	N (missing)	1580 (0)	1484 (0)	143 (0)	209 (0)
School pressure (Mean (95% CI))	Mean (95%CI)	2.89 (2.82-2.95)	3.14 (3.08-3.21)	3.38 (3.12-3.65)	3.34 (3.12-3.56)
	N (missing)	1580 (0)	1484 (0)	143 (0)	209 (0)

Study III

Title page

Title: Estimating the associations between personal-, health-, lifestyle-, and social factors on depressive symptoms from adolescence to adulthood: A fixed effect approach using panel data

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Abstract (247 words of 250 words**)**

Background: Numerous studies have tried to understand the causes of poor mental health, mostly focusing on single exposures. These approaches often fail to capture the complex and interconnected nature of poor mental health. This study aims to investigate the associations of age-specific changes in explanatory factors, encompassing personal-, health-, lifestyle-, and social factors and depressive symptoms in individuals aged 15 to 32 years.

Methods: Individuals born in 1989 were followed from 2004 to 2021 with surveys at ages 15, 18, 21, 28 and 32. Inverse probability weights and multiple imputations with chained equations were used to account for attrition and missing data. Descriptive characteristics for each wave were estimated as well as the changes in depressive symptoms and explanatory variables between each wave. Fixed effect regression models and dominance analyses examined the contribution of change in each explanatory variable to the change in depressive symptoms between each wave. Lastly, analyses of asymmetric change were estimated to detect asymmetric associations of explanatory variables and depressive symptoms.

Results: The relative importance of the explanatory variables changed between age-points. Between all age-points, stress was the most dominant variable with a relative contribution above 30% between all age-points, while the contribution of sense of coherence increased through the waves from 17% to 25%. Self-esteem, self-rated health and psychosomatic symptoms had also high dominance with shifting contributions through the ages.

Conclusion: The associations between explanatory factors and depressive symptoms are dynamic and preventive strategies should be tailored towards the different life stages.

Keywords: risk factors, mental health, life course, depressive symptoms

Introduction

Mental health problems are rising, affecting individuals across the globe and posing challenges to public health systems (1). In Denmark, this rise is reflected in increasing numbers of individuals with mental disorder diagnoses, use of psychotropic medications, and prevalence of self-reported poor mental health (2-6). Numerous studies have tried to understand the underlying causes of poor mental health, often focusing on single exposures, with several systematic reviews synthesizing these findings (7-9). However, these studies often fail to capture the complex and interconnected nature of mental health.

Understanding the underlying causes of this increase in mental health diagnoses and medication requires more than studying isolated factors (10, 11). Öngür and Paulus recently argued that traditional reductionistic approaches simplify mental health into linear cause-and-effect relationships, neglecting the multifaceted interactions between biological, psychological, social, and environmental factors. The authors suggest that mental health is best understood as complex dynamical systems that evolve through the interplay of multiple influences over time (12). Addressing mental health effectively demands a shift towards complex systems approaches, integrating multiple variables and accounting for their dynamic nature.

A key aspect of mental health complexity is the timing of exposures and their varying impact over the life course. For example, while social support is a strong protective factor in childhood and adolescence, its influence diminishes in adulthood (7). This underscores the importance of examining the temporal dynamics of risk and protective factors over time. In particular, the transition from adolescence to adulthood involves major biological, psychological, and social changes affecting depressive symptoms (13). Arnett's theory of emerging adulthood describes this life stage, that does not have the dependency of adolescence nor the responsibility of adulthood, as a distinct period of identity exploration that plays a crucial role in mental health development (14). Arnett argues that due to demographic shifts, such as delayed marriage, postponed parenthood, and extended education, the uncertainty and instability of this phase now extend to ages 18-25 (14). Given these unique challenges, studying mental health at multiple time points across adolescence, emerging adulthood, and adulthood is essential for understanding the time changing determinants present in different life stages.

This study aims to investigate the association between age-specific changes in explanatory factors, encompassing personal-, health-, lifestyle-, and social factors, and changes in depressive symptoms in individuals aged 15-32. By adopting a systems-based perspective and examining the longitudinal patterns and dynamics of mental health and its risk factors, we seek to provide insights into how preventive strategies can be tailored to different life stages.

Methods

Population and setting

The population consists of individuals living in the former Ringkjøbing Amt from the cohort VestLiv. All individuals born in 1989 and living in this area in 2004 were invited to participate (N=3,681). The surveys included 3,054 individuals (83%) aged 15 in 2004, 2,400 (65%) aged 18 in 2007, 2,145 (58%) aged 21 in 2010, 2,102 (57%) aged 28 in 2017 and 1,206 (33%) aged 32 in 2021. In the survey, questions about health, family life, social life, school, work, and well-being were asked. Data from the survey were linked with data from registers by using the individuals' unique identification numbers (CPR) from the Danish Civil Registration System (15).

Variables

Depressive symptoms

Depressive symptoms were measured using the 4-item version of the Center for Epidemiological Studies Depression Scale for Children (CES-DC4) at age 15, 18, and 21, while the adult version (CES-D4) was used at age 28 and 32. The four items of the scales are scored from 0-3, resulting in a sum score on 0-12. The higher the score, the more depressive symptoms (16).

Explanatory variables

A number of explanatory variables were selected from the surveys based on the holistic biopsychosocial model (17). The selection criterias for variables included that the variable must be (i) recognized in the literature as a risk or protective factor for mental health, (ii), measured consistently across all age points to allow for meaningful comparisons over time, and (iii) modifiable between survey waves, as these are essential targets for interventions aimed at reducing depressive symptoms, whereas fixed characteristics like gender or age may inform risk stratification but are not directly alterable through intervention (18-20). Since the data collection was not originally designed with the specific method of analyzing changes between time points, not all variables in the cohort were applicable for this study. The explanatory

variables (see details of origin and scoring in Supplementary Table 1) were categorized into four groups: Personal factors, including coping, self-esteem, and sense of coherence (21-23); Health factors, including stress, self-rated health, and psychosomatic symptoms (24-26); Lifestyle factors, including physical activity, Body Mass Index (BMI), and smoking (27-29); and Social factors, including bullying (30).

Characteristics

To describe the characteristics of the individuals in the analytical sample, six register-based covariates (sex, country of origin, mental disorder diagnosis, psychotropic medication use, parental education, and household income) and two variables from the survey at age 15 (subjective social status (SSS) in school and SSS in society) were included (see details about the variables in Supplementary Text 1). Socioeconomic status (SES), a complex but central determinant of mental health (31, 32), was represented using four indicators to reflect multiple dimensions; parental education, household income, SSS in school and SSS in society.

Statistical methods

Participation and missing data

The analytical sample included people who responded to depressive symptom questions in at least three waves, as fewer responses led to excessive missing data. To account for selection bias due to non-participation, Inverse Probability Weights (IPW) were used (33). The probability of being in the analytical sample was calculated by sex, mental disorder diagnoses, medication use, country of origin, mean depressive symptoms across surveys, parental mental disorder diagnoses, and several SES measures (parental education, own education, own labour market participation, and equalized household income). The covariates in the model were chosen based on a drawing of Directed Acyclic Graphs (Supplementary Figure 1).

To handle data in the analytical sample, multiple imputations (MI) with chained equations were used on explanatory variables and depressive symptoms in all surveys. Information across the surveys was used in the models together with register data on sex, SES, medication use, and mental disorder diagnosis (34). After imputation, the size of the population was the same across surveys.

A dropout analysis was conducted to evaluate if the analytical sample differed from the excluded sample, consisting of people answering the question about depressive symptoms in less than three survey waves.

Descriptive statistics

The characteristics of the analytical sample were described with counts and percentages for all levels of the categorical characteristics. Moreover, the depressive symptoms according to each of the characteristics were described for each age and the mean changes in depressive symptoms between age points. As the aim of the study was to examine age-specific changes, all analyses of change were done between the five age points separately: age 15-18, age 18-21, age 21-28, and 28-32.

The mean and prevalence of the explanatory variables and the within-person changes in the variables between the age points were described. As some change in the variable needed to be present to evaluate if changes in an explanatory factor were associated with changes in depressive symptoms, it was examined if any variables had less than 10% change between the age points to determine whether the variable should be included (35).

Analyses

Fixed effects (FE) regression models were used to examine the association between changes in explanatory variables and changes in depressive symptoms between each age point from age 15-32. The depressive symptoms score was the dependent variable and explanatory variables were independent variables. The estimates of the FE regression were compared with estimates of a pooled ordinary least squares (POLS) model using the Hausman test to confirm which models were the best fit for the panel data (35). As the FE regression is based on within-individual change, all time-invariant confounding was adjusted for in the models. All explanatory variables were included in the models and thereby mutually accounted for. Furthermore, the models were adjusted for the survey wave to control for changes in the outcome and explanatory variables due to aging of the cohort and time trends (35, 36). Dominance analyses were used to examine the relative importance of the explanatory variables. The method decomposes and compares the contribution to the explained variance in the model of each independent variable by applying the dominance analysis to the within variance of the FE regression. Thereby, the analyses show how much of the intra-individual variance in the depressive symptoms that was explained by the change in the single variables (37, 38).

Analyses were conducted to examine if the association between any of the explanatory variables and depressive symptoms were asymmetrical. A modified version of the first-difference method, developed by Paul D. Allison, was used (36). The first difference method was used in both the FE and the asymmetrical change analyses (35, 36).

Results

The descriptive analyses showed that the mean depressive symptoms were highest at age 18 (2.85 (95% confidence interval (CI): 2.73-2.97)) and the mean absolute changes in depressive symptoms between all age points ranged between 1.64-2.04 (Table 1). Females generally had higher mean depressive symptoms than males and showed larger mean absolute changes over time. Individuals of non-Danish origin had higher mean depressive symptoms at all age points except age 15. Different patterns were observed across SES measures. Individuals with low household income, low SSS in society, and low SSS in school generally reported higher mean depressive symptoms compared to those individuals in the middle and high SES groups. However, depressive symptoms were of similar magnitude between individuals with short and long parental education levels at several age points. Finally, individuals who received a mental disorder diagnosis or used psychotropic medication during the study period—including after the ages at which different surveys were responded to—had higher mean depressive symptoms and greater absolute changes in depressive symptoms at all age points compared to those individuals without a diagnosis or medication use.

The dropout analyses showed that the excluded sample, compared to the analytical sample, included more males, individuals born outside Denmark, lower levels of parental education, lower household income, more mental disorder diagnoses, and greater use of psychotropic medication (Supplementary Table 2). IPWs reduced these differences across all variables but did not fully eliminate differences between the excluded and analytical sample for sex, origin, parental education, household income, mental disorder diagnoses in adulthood and during the study period, or psychotropic medication use in adulthood and during the study period.

Descriptive analyses of changes in explanatory variables showed that the distribution of categorical variables and the mean of continuous variables differed between age points (Table 2). All variables had above 10% change between age points and therefore no variables had to be reconsidered for inclusion (Supplementary Table 3). The variables changing the least between age points were smoking and bullying, while the variables changing the most were coping, stress, and BMI.

The Hausman test found the FE model to be better fitting than POLS between all age points (Supplementary Table 4). Results from the FE analyses showed that the models explained between 0.25 to 0.29 of the total variance in depressive symptoms and that changes in most explanatory variables were associated with changes in depressive symptoms (Supplementary Table 5). For example, one unit change in stress between age 15-18 was associated with a 0.25 (0.19-0.30) change in depressive symptoms in the same period. The dominance analyses showed that the variable that contributed the most to the change in depressive symptoms between all age points was stress, while sense of coherence

contributed second most between all age points (Figure 1). The highest relative contribution to the explained variance for stress was at age 18-21 (36.13) and the highest relative contribution for sense of coherence was at age 21-28 (24.51). The variables that contributed the least to change in depressive symptoms were coping between age 15-18 and 18-21, BMI between age 21-28, and smoking between age 28-32. Self-esteem contributed third most to the explained variance between all age points except at age 15-18, where self-rated health and psychosomatic symptoms contributed more. The size of the dominance differed between age points. For example, self-rated health had a relative importance above 8% between all age points except at age 18-21 and sense of coherence had a relative importance of above 21% between all age points but not at age 15-18.

The analyses of asymmetrical changes showed that psychosomatic symptoms had asymmetric associations at age 15-18 ($p=0.03$; Table 3). A reduction of one score in psychosomatic symptoms between the ages 15-18 was associated with a reduction of 0.08 (95%CI: -0.18-0.01) in depressive symptoms, while an increase of one score in psychosomatic symptoms was associated with an increase of 0.24 (95%CI: 0.15-0.33) in depressive symptoms. An indication of asymmetry was found in the association of bullying between ages 28-32. However, the wide confidence intervals indicated considerable uncertainty around these estimates, making it difficult to draw firm conclusions about the asymmetrical effect of bullying ($p=0.35$).

The largest negative and positive associations with depressive symptoms were observed in stress, bullying, self-esteem, sense of coherence, and self-rated health with different sizes between the age points. These variables, with exception of bullying, were also the variables with the highest dominance (Figure 1). Between ages 15-18, improvements in bullying and stress was associated with the largest reductions in depressive symptoms, while worsening of bullying and psychosomatic symptoms was associated with the largest increases. Between ages 18-21, improvements in self-esteem and stress showed the largest reductions in depressive symptoms, whereas worsening of stress and sense of coherence showed to the largest increases. Between ages 21-28, improvements in self-rated health and sense of coherence showed the largest reductions in depressive symptoms, while worsening of self-rated health showed the largest increase. Lastly, between age 28-31, improvements in self-rated health and stress was associated with the largest reduction depressive symptoms the most, while worsening of self-rated health and bullying was associated with the largest increases.

Discussion

This study found that changes in personal, health, lifestyle, and social factors were associated with changes in depressive symptoms among individuals aged 15-32, and that the relative importance of these factors varied across age points. In general, personal- and health factors showed the strongest associations with depressive symptoms. These findings emphasize the developmental shifts in the factors influencing depressive symptoms, suggesting that targeted prevention strategies should be tailored to specific life stages.

To our knowledge, this is the first study to apply a Fixed Effects approach to examine the patterns and dynamic relationships between a range of explanatory factors and depressive symptoms across adolescence and adulthood. We identified stress, sense of coherence, self-esteem, self-rated health, and psychosomatic symptoms as the most dominant variables across five age points. All these factors have previously been found to be associated with mental health in studies focusing on individual risk factors (21-26). Importantly, the ranking and effect sizes of these variables shifted over time. While stress was the most dominant and sense of coherence the second most dominant factor through all waves, the size of the dominance changed. Self-esteem ranked third in the latest age points (ages 28–32) but only fifth during adolescence (ages 15–18). Low self-esteem, particularly when combined with identity challenges, has been shown to negatively affect mental health (22). This is consistent with the theory of emerging adulthood (ages 18–25) as a period of identity formation (14). However, the high dominance of self-esteem at age 28–32 is less often discussed and warrants further exploration. Self-rated health ranked third at ages 15–18 and fourth in later ages. While existing longitudinal studies—primarily in much older populations—have shown mixed findings, comparable research in younger age groups is lacking, making direct comparisons difficult (26). Our study provides insight into this relationship during earlier life stages. Psychosomatic symptoms ranked fourth at ages 15–18 and fifth in later ages, suggesting a slight decline in associations. Previous literature has primarily focused on psychosomatic symptoms in adolescence as predictors of early adult mental health (25). Bullying did not show high overall dominance but had a strong association with depressive symptoms between ages 15–18 (Table 3). Bullying is known to have serious and potentially long-lasting consequences for mental health in children and adolescents, but the temporal impact across developmental stages remains underexplored (30). This study emphasises that even though bullying is a rare phenomenon, when occurring, it has severe consequences.

While more variables could have been relevant in a systems-based approach on depressive symptoms, we selected factors representing four broad domains: personal, health, lifestyle, and social. Unfortunately, no consistently measured variables related to social connections, social support, or loneliness were available across all surveys, which likely contributed to the models explaining only 25–29% of the total variance. Future research should aim to include a broader range of social determinants to improve explanatory power.

While this study contributes to a better understanding of the patterns and dominance over time, future research should explore the potential mediators and interactions between variables. For example, individuals with high self-esteem may be more likely to use active coping strategies in response to stress, thereby protecting their mental health. Similarly, coping strategies are known to buffer the impact of stress (39). A deeper understanding of these mechanisms would provide valuable insights into the complexity of depressive symptoms over time.

Because changes in explanatory variables and depressive symptoms were measured concurrently, we cannot infer directionality. It remains unclear whether a change in an explanatory variable caused a change in depressive symptoms or vice versa. Therefore, no causal conclusions based on these data and methods can be drawn and we encourage future research into the causal relationships.

This study highlights the importance of age-specific prevention strategies to reduce depressive symptoms in young people. Across all ages, stress and sense of coherence consistently emerged as the most influential factors, emphasizing the roles as central targets for intervention. However, the results also suggest that the prominence of other factors may vary depending on the developmental stage. For adolescents aged 15-18, reducing stress and bullying may yield the greatest benefit, while among individuals aged 18-21, strategies aimed at improving self-esteem—alongside continued efforts to reduce stress and bullying—appear most relevant. In later ages, age 21-28 and age 28-31, improvements in sense of coherence and self-rated health seem especially important. It is worth noting, however, that the minimal detectable change for the 4-item CES-DC among 15- to 16-year-olds has been estimated at 3.85 points (95%CI: 2.91; 4.80), suggesting suggests that changes in a single factor may not be sufficient to produce a clinically meaningful reduction in depressive symptoms (40). Therefore, preventive efforts should take a multidimensional approach that targets several aspects simultaneously to achieve improvements in mental health.

One key strength of this study is the use of FE models, which control for all time-invariant confounders, thereby enhancing the internal validity of the results. The longitudinal design spanning multiple age points—from adolescence through adulthood—provides a unique opportunity to explore changes in depressive symptoms across key developmental transitions. Furthermore, the combination of self-reported and register-based data adds breadth to the analysis. The study also employed MI and IPW to handle missing data and reduce potential bias due to attrition, which helps to strengthen the generalisability of the findings. In addition, the inclusion of a broad set of explanatory variables allows for a more comprehensive examination of the complex interplay between personal-, health-, lifestyle-, and social factors in relation to mental health outcomes.

Nevertheless, several limitations must be considered. The time intervals between age points varied, with changes assessed over three years in the first two intervals, seven years in the third, and four years in the final interval. This variation complicates comparisons across models, as the magnitude of change may differ simply due to the length of the follow-up. Moreover, not all variables were measured identically across waves. For example, one item in the measure of sense of coherence was slightly reworded at age 15 to ensure age-appropriate comprehension. While necessary from a developmental standpoint, such changes may affect measurement consistency. Despite efforts to reduce bias using IPW, differences between the analytical sample and the excluded sample persisted on several characteristics, indicating a continued risk of selection bias. Finally, the models explained only 25-29% of the total variance in depressive symptoms, suggesting that additional unmeasured factors likely contribute to these changes and should be investigated in future research.

Conclusion

Our findings underscore the importance of considering age-specific changes when designing preventive efforts for depressive symptoms in young people. While changes in personal- and health-related factors had the strongest associations with changes in depressive symptoms, their relative importance varied across different age points. Bullying in adolescence also played a role in depressive symptoms, but our ability to fully capture the impact of social factors was limited by the available data. Future research should further explore the role of social determinants in depressive symptoms using a system-based approach to better inform targeted interventions across different life stages.

Acknowledgements

We thank the participant of VestLiv for using time on answering the surveys.

Funding

This work was supported by KV fonden and Sygeforsikring Danmark (Grant number 2021-0105). The funding organizations had no involvement in the design of the study, analyses, or interpretations of the results.

Conflict of interest

The authors declare no conflict of interest.

KeyPoints

- Age-specific changes in personal, health, lifestyle, and social factors are important to consider when designing preventive efforts for depressive symptoms in young people.
- Personal and health-related factors showed the strongest associations with changes in depressive symptoms, but their influence varied across age points.
- Stress and sense of coherence were the variables contributing most to change in depressive symptoms between all age points.
- Bullying in adolescence was associated with depressive symptoms, highlighting the relevance of early social experiences.

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Tables

Table 1: Characteristics of the analytical sample at baseline (2004) with mean depressive symptoms scores (CES-D(C)4) and absolute change between time points

		Depressive symptoms (Mean (95% CI))					Absolute change in depressive symptoms (Mean (95% CI))			
	N (%)	15	18	21	28	32	15-18	18-21	21-28	28-32
Total	2157 (100%)	2.23 (2.12-2.33)	2.85 (2.73-2.97)	2.50 (2.37-2.62)	2.65 (2.54-2.76)	2.69 (2.55-2.83)	2.04 (1.95-2.14)	1.95 (1.85-2.04)	1.87 (1.78-1.96)	1.64 (1.55-1.74)
Sex										
Males	1122 (52%)	1.89 (1.74-2.04)	2.44 (2.28-2.61)	2.23 (2.05-2.40)	2.58 (2.40-2.76)	2.63 (2.42-2.83)	1.83 (1.70-1.96)	1.75 (1.62-1.89)	1.80 (1.67-1.93)	1.64 (1.50-1.78)
Females	1035 (48%)	2.59 (2.44-2.74)	3.29 (3.14-3.44)	2.79 (2.63-2.94)	2.72 (2.58-2.86)	2.76 (2.58-2.94)	2.28 (2.15-2.40)	2.15 (2.03-2.27)	1.95 (1.84-2.06)	1.65 (1.53-1.76)
Country of origin										
Denmark	2035 (94.4%)	2.24 (2.13-2.34)	2.84 (2.72-2.95)	2.48 (2.36-2.60)	2.63 (2.52-2.74)	2.65 (2.52-2.79)	2.05 (1.96-2.14)	1.95 (1.86-2.05)	1.86 (1.78-1.95)	1.62 (1.53-1.72)
Other	122 (5.6%)	2.01 (1.26-2.76)	3.05 (2.35-3.75)	2.74 (2.08-3.40)	2.91 (2.23-3.59)	3.33 (2.61-4.06)	1.96 (1.33-2.58)	1.81 (1.24-2.38)	2.02 (1.50-2.54)	1.99 (1.45-2.52)
Parental education										
Long	128 (6%)	2.29 (1.94-2.64)	3.27 (2.83-3.70)	2.49 (2.10-2.89)	2.93 (2.56-3.30)	2.89 (2.46-3.33)	2.15 (1.83-2.47)	2.23 (1.89-2.57)	1.92 (1.62-2.21)	1.53 (1.23-1.82)
Middle	1670 (77%)	2.21 (2.10-2.32)	2.79 (2.67-2.91)	2.46 (2.33-2.58)	2.58 (2.47-2.69)	2.62 (2.47-2.76)	2.00 (1.90-2.10)	1.92 (1.82-2.01)	1.85 (1.76-1.94)	1.63 (1.53-1.72)
Short	359 (17%)	2.28 (1.92-2.64)	2.98 (2.60-3.35)	2.67 (2.28-3.06)	2.87 (2.48-3.26)	2.96 (2.54-3.38)	2.22 (1.91-2.52)	1.97 (1.66-2.29)	1.96 (1.68-2.24)	1.78 (1.50-2.05)
Household income										
High	413 (19%)	2.02 (1.82-2.22)	2.86 (2.63-3.09)	2.19 (1.96-2.42)	2.50 (2.29-2.70)	2.46 (2.22-2.71)	2.10 (1.91-2.30)	1.85 (1.67-2.02)	1.73 (1.56-1.89)	1.54 (1.38-1.70)
Middle	1333 (62%)	2.25 (2.11-2.38)	2.79 (2.65-2.92)	2.45 (2.31-2.59)	2.58 (2.44-2.72)	2.64 (2.49-2.79)	2.04 (1.93-2.15)	1.98 (1.87-2.10)	1.88 (1.77-1.98)	1.63 (1.52-1.75)
Low	411 (19%)	2.37 (2.06-2.68)	3.05 (2.72-3.38)	2.96 (2.61-3.31)	3.03 (2.71-3.34)	3.09 (2.73-3.46)	2.00 (1.74-2.25)	1.92 (1.68-2.16)	1.99 (1.75-2.23)	1.78 (1.56-2.00)
SSS* in society										
High	107 (5%)	4.72 (3.83-5.62)	4.60 (3.85-5.35)	4.15 (3.41-4.88)	3.56 (2.92-4.20)	3.78 (3.12-4.44)	2.78 (2.22-3.33)	2.27 (1.73-2.80)	2.35 (1.88-2.82)	1.96 (1.51-2.42)
Middle	1142 (53%)	2.27 (2.13-2.41)	2.96 (2.80-3.13)	2.58 (2.41-2.74)	2.78 (2.61-2.94)	2.80 (2.61-2.99)	2.12 (1.98-2.25)	1.99 (1.85-2.12)	1.90 (1.78-2.01)	1.69 (1.57-1.81)
Low	908 (42%)	1.88 (1.73-2.02)	2.50 (2.35-2.66)	2.20 (2.04-2.36)	2.37 (2.22-2.53)	2.42 (2.23-2.61)	1.87 (1.74-2.00)	1.86 (1.72-1.99)	1.78 (1.65-1.90)	1.55 (1.42-1.68)
SSS* in school										
High	46 (2%)	3.76 (2.85-4.67)	3.59 (2.56-4.62)	3.93 (2.66-5.20)	3.88 (2.59-5.18)	3.53 (2.42-4.63)	2.13 (1.46-2.81)	2.15 (1.37-2.94)	2.17 (1.49-2.84)	1.77 (0.94-2.61)
Middle	1469 (68%)	2.30 (2.16-2.43)	2.95 (2.80-3.10)	2.60 (2.45-2.75)	2.67 (2.53-2.81)	2.77 (2.61-2.94)	2.10 (1.98-2.21)	1.97 (1.85-2.09)	1.90 (1.79-2.00)	1.68 (1.57-1.79)
Low	642 (30%)	1.96 (1.77-2.15)	2.57 (2.38-2.75)	2.15 (1.96-2.34)	2.50 (2.31-2.69)	2.44 (2.23-2.65)	1.92 (1.77-2.07)	1.88 (1.73-2.03)	1.79 (1.64-1.93)	1.55 (1.42-1.69)
Mental disorder diagnosis										
Older child (5-12 years)	64 (3%)	2.24 (1.42-3.07)	2.51 (1.68-3.35)	2.68 (1.84-3.52)	3.20 (2.26-4.15)	2.70 (1.71-3.69)	1.82 (1.18-2.45)	1.78 (1.15-2.41)	1.86 (1.20-2.51)	1.53 (0.91-2.16)
Adolescent (13-17 years)	106 (5%)	3.08 (2.38-3.79)	4.19 (3.48-4.90)	3.47 (2.71-4.23)	3.59 (2.84-4.34)	3.00 (2.14-3.86)	2.94 (2.36-3.52)	2.19 (1.65-2.73)	1.98 (1.50-2.46)	1.98 (1.45-2.52)
Adult (18-32 years)	373 (17%)	2.88 (2.55-3.21)	3.60 (3.25-3.95)	3.53 (3.14-3.91)	3.67 (3.35-3.99)	3.85 (3.45-4.25)	2.51 (2.25-2.78)	2.15 (1.88-2.42)	2.15 (1.92-2.38)	1.95 (1.72-2.18)
Study period (5-32 years)	451 (21%)	2.76 (2.46-3.06)	3.51 (3.18-3.83)	3.32 (2.98-3.67)	3.42 (3.12-3.72)	3.48 (3.10-3.85)	2.49 (2.24-2.75)	2.13 (1.88-2.38)	2.05 (1.83-2.27)	1.86 (1.65-2.08)
None in study period	1706 (79%)	2.09 (1.97-2.20)	2.68 (2.56-2.79)	2.28 (2.16-2.39)	2.44 (2.33-2.56)	2.48 (2.35-2.62)	1.93 (1.83-2.02)	1.90 (1.80-1.99)	1.82 (1.73-1.92)	1.59 (1.48-1.69)
Medication use										
Older child (5-12 years)	22 (1%)	1.81 (0.64-2.98)	2.88 (0.82-4.94)	3.56 (1.25-5.87)	2.65 (0.90-4.40)	3.13 (0.70-5.55)	2.22 (0.56-3.88)	1.94 (0.75-3.13)	2.39 (1.13-3.64)	1.67 (0.50-2.84)
Adolescent (13-17 years)	66 (3%)	3.24 (2.46-4.02)	3.87 (2.99-4.76)	3.61 (2.70-4.51)	3.09 (2.26-3.92)	3.04 (2.06-4.01)	2.64 (2.03-3.25)	2.69 (2.15-3.22)	2.33 (1.83-2.83)	1.73 (1.21-2.25)
Adult (18-32 years)	601 (28%)	2.80 (2.54-3.05)	3.49 (3.21-3.76)	3.38 (3.09-3.67)	3.56 (3.30-3.81)	3.54 (3.24-3.84)	2.41 (2.22-2.59)	2.27 (2.08-2.46)	2.16 (1.99-2.33)	1.86 (1.69-2.03)
Study period (5-32 years)	667 (31%)	2.71 (2.47-2.95)	3.40 (3.15-3.66)	3.27 (3.00-3.55)	3.43 (3.19-3.67)	3.41 (3.13-3.70)	2.36 (2.18-2.53)	2.26 (2.08-2.43)	2.15 (1.99-2.31)	1.83 (1.67-2.00)
None in study period	1490 (69%)	2.01 (1.90-2.12)	2.60 (2.49-2.72)	2.15 (2.03-2.26)	2.30 (2.18-2.41)	2.37 (2.22-2.51)	1.92 (1.82-2.03)	1.83 (1.73-1.93)	1.74 (1.65-1.84)	1.55 (1.45-1.65)

***SSS = Subjective Social Status**

Table 2: Mean and prevalences of explanatory variables

	Mean (95% CI) / N (%)				
	Age 15	Age 18	Age 21	Age 28	Age 32
Personal factors					
Coping	16.90 (16.72-17.08)	19.11 (18.92-19.30)	15.60 (15.40-15.79)	15.41 (15.21-15.62)	15.48 (15.21-15.74)
Self-esteem	11.03 (10.89-11.17)	10.43 (10.28-10.58)	10.03 (9.86-10.20)	10.04 (9.87-10.22)	10.16 (9.96-10.36)
Sense of coherence	9.75 (9.65-9.86)	9.82 (9.70-9.94)	9.67 (9.54-9.81)	8.85 (8.70-9.00)	9.05 (8.88-9.21)
Health factors					
Stress	9.23 (9.11-9.36)	9.14 (9.00-9.28)	9.47 (9.31-9.63)	8.90 (8.75-9.06)	9.08 (8.89-9.27)
Psychosomatic symptoms	3.07 (2.94-3.20)	3.23 (3.10-3.36)	3.10 (2.96-3.25)	3.43 (3.29-3.57)	3.81 (3.69-3.94)
Self-rated health					
Excellent	626 (29%)	472 (22%)	670 (31%)	421 (20%)	372 (17%)
Very good	984 (46%)	860 (40%)	897 (42%)	941 (44%)	946 (44%)
Good	460 (21%)	645 (30%)	449 (21%)	586 (27%)	586 (27%)
Fair	80 (4%)	152 (7%)	123 (6%)	183 (9%)	214 (10%)
Poor	8 (0%)	29 (1%)	18 (1%)	27 (1%)	39 (2%)
Lifestyle factors					
Physical activity					
7+ hours	479 (22%)	328 (15%)	311 (14%)	236 (11%)	164 (8%)
4-6 hours	725 (34%)	616 (29%)	556 (26%)	490 (23%)	368 (17%)
2-3 hours	588 (27%)	657 (30%)	655 (30%)	674 (31%)	707 (33%)
1 hour	234 (11%)	319 (15%)	278 (13%)	318 (15%)	370 (17%)
1/2 hour	88 (4%)	126 (6%)	188 (9%)	205 (10%)	288 (13%)
None	43 (2%)	111 (5%)	169 (8%)	234 (11%)	259 (12%)
Smoking					
No	1889 (88%)	1536 (71%)	1449 (67%)	1600 (74%)	1727 (80%)
Rarely	96 (4%)	152 (7%)	139 (6%)	114 (5%)	89 (4%)
Weekly	45 (2%)	92 (4%)	117 (5%)	443 (21%)	77 (4%)
Daily	127 (6%)	378 (18%)	452 (21%)	0 (0%)	265 (12%)
BMI	20.29 (20.14-20.45)	22.53 (22.34-22.72)	23.80 (23.58-24.02)	25.55 (25.27-25.84)	26.30 (25.98-26.63)
Social factors					
Bullying					
Never	1567 (73%)	1792 (83%)	1964 (91%)	1998 (93%)	1960 (91%)
Once or twice	378 (18%)	267 (12%)	144 (7%)	94 (4%)	89 (4%)
Sometimes	153 (7%)	73 (3%)	21 (1%)	35 (2%)	56 (3%)
Weekly	31 (1%)	15 (1%)	22 (1%)	31 (1%)	52 (2%)
Several times a week	27 (1%)	9 (0%)	6 (0%)	0 (0%)	0 (0%)

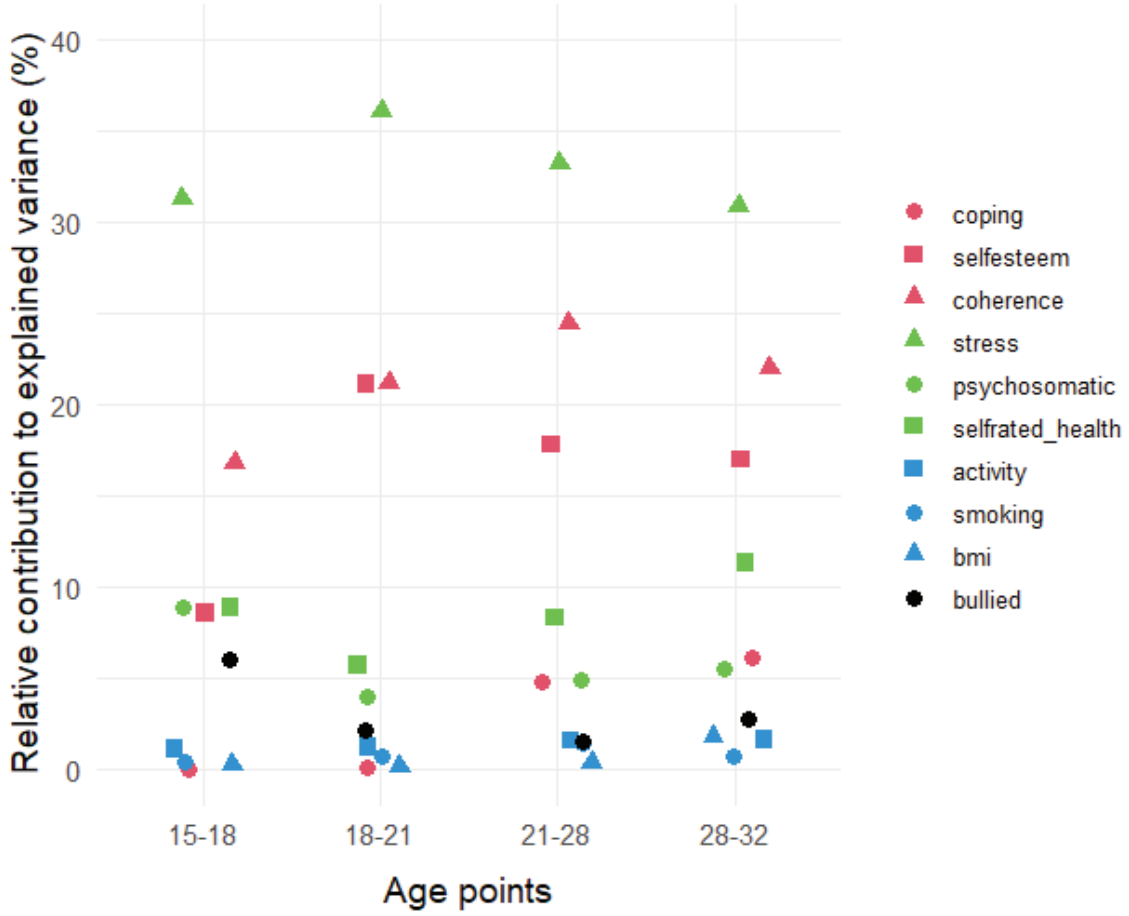
Table 3: Results from asymmetrical change analyses

	Change in depressive symptoms (mean (95% CI))			
	Age 15-18	**Age 18-21**	**Age 21-28**	**Age 28-32**
Personal factors				
Coping	p=0.16	p=0.59	p=0.59	p=0.53
1 positive change	-0.02 (-0.05;0.01)	0.01 (-0.04;0.06)	0.03 (-0.02;0.09)	0.03 (-0.02;0.09)
1 negative change	-0.03 (-0.08;0.02)	0.00 (-0.02;0.03)	-0.01 (-0.06;0.04)	-0.01 (-0.06;0.04)
Self-esteem	p=0.49	p=0.15	p=0.69	p=0.55
1 positive change	0.09 (0.01;0.16)	0.08 (0.01;0.16)	0.10 (0.03;0.16)	0.09 (0.02;0.15)
1 negative change	-0.04 (-0.11;0.03)	-0.18 (-0.25;-0.12)	-0.11 (-0.18;-0.04)	-0.07 (-0.13;-0.01)
Sense of coherence	p=0.15	p=0.67	p=0.16	p=0.36
1 positive change	0.21 (0.13;0.29)	0.17 (0.08;0.25)	0.11 (-0.00;0.21)	0.09 (-0.01;0.19)
1 negative change	-0.10 (-0.19;-0.02)	-0.15 (-0.23;-0.07)	-0.22 (-0.29;-0.15)	-0.16 (-0.23;-0.09)
Health factors				
Stress	p=0.18	p=0.31	p=0.62	p=0.56
1 positive change	0.20 (0.11;0.28)	0.18 (0.12;0.25)	0.21 (0.13;0.28)	0.20 (0.13;0.26)
1 negative change	-0.30 (-0.38;-0.22)	-0.25 (-0.34;-0.17)	-0.17 (-0.26;-0.09)	-0.20 (-0.26;-0.15)
Psychosomatic symptoms	p=0.03	p=0.63	p=0.44	p=0.54
1 positive change	0.24 (0.15;0.33)	0.09 (0.00;0.18)	0.09 (-0.00;0.17)	0.11 (0.01;0.22)
1 negative change	-0.08 (-0.18;0.01)	-0.08 (-0.17;0.01)	-0.03 (-0.13;0.07)	-0.11 (-0.20;-0.03)
Self-rated health	p=0.55	p=0.65	p=0.62	p=0.58
1 positive change	0.13 (-0.06;0.32)	0.12 (-0.14;0.38)	0.26 (0.08;0.44)	0.26 (0.10;0.42)
1 negative change	-0.25 (-0.54;0.03)	-0.16 (-0.33;0.01)	-0.24 (-0.47;-0.01)	-0.29 (-0.51;-0.07)
Lifestyle factors				
Physical activity	p=0.18	p=0.45	p=0.62	p=0.56
1 positive change	-0.09 (-0.22;0.04)	0.09 (-0.03;0.21)	0.02 (-0.13;0.18)	0.03 (-0.07;0.13)
1 negative change	-0.10 (-0.30;0.09)	-0.00 (-0.15;0.14)	0.03 (-0.11;0.17)	0.01 (-0.13;0.14)
Smoking	p=0.68	p=0.34	p=0.35	p=0.51
1 positive change	-0.06 (-0.19;0.08)	-0.04 (-0.20;0.12)	0.12 (-0.08;0.32)	-0.07 (-0.32;0.18)
1 negative change	0.02 (-0.39;0.43)	0.20 (-0.02;0.41)	0.01 (-0.12;0.14)	0.11 (-0.00;0.22)
BMI	p=0.43	p=0.45	p=0.59	p=0.57
1 positive change	0.01 (-0.05;0.07)	0.03 (-0.03;0.10)	-0.03 (-0.08;0.01)	-0.03 (-0.06;0.00)
1 negative change	-0.09 (-0.27;0.08)	0.04 (-0.11;0.19)	0.01 (-0.06;0.09)	0.03 (-0.04;0.09)
Social factors				
Bullying	p=0.73	p=0.33	p=0.51	p=0.35
1 positive change	0.29 (-0.03;0.60)	-0.14 (-0.52;0.24)	-0.03 (-0.37;0.32)	0.22 (-0.01;0.45)
1 negative change	-0.31 (-0.52;-0.11)	-0.17 (-0.51;0.17)	0.03 (-0.26;0.33)	-0.03 (-0.31;0.25)

Figure legends

Figure 1: Results from the dominance analyses showing the relative contribution to the explained variance of depressive symptoms for personal- (red), health- (green), lifestyle- (blue), and social factors (black).

Figures



Supplementary

Supplementary Table 1: Scoring and definition of the explanatory variables, including differences in measurement over time	
Explanatory Variable	
Personal factors	
Coping	7 items from "Brief COPE scale" each scored 1-4 (7-28 total score) (24). Questions in the subscale "Avoidant coping" have been discarded, as they represent undesirable coping strategies. Same questions for all surveys.
Self-esteem	6 items from Rosenberg's self-esteem scale each scored 1-4 (6-24 total score). Same questions for all survey.
Sense of coherence	4 items from the adapted version of Antonovsky's Orientation to Life Questionnaire, short form (SOC-13) fitted for adolescents each scored from 1-5 (sum score on 4-20) (25, 26). One question has a slightly different wording in the survey in 2004 compared to the rest of the waves.
Health factors	
Stress	4 items from the Perceived stress scale (PSS) scored 0-4 (total score 0-16) (27). Adolescent version in 2004-2010, adult version in 2017-2021.
Self-rated health	1 item from SF-36 scored 1-5 (28). Same question for all surveys.
Psychosomatic symptoms	5 items from the Hopkins Symptom Checklist 90 each scored 1-4 (5-20 total score) (29). Same questions for all surveys.
Lifestyle factors	
Physical activity	1 item from Youth Risk Behavior Survey 2003 with a score of 1-6 (30). In the surveys in 2017-2021, the most extreme category of 7+ hours is divided in two categories of 7-10 hours and 11+. These was categorized together to ensure same scoring in all survey waves.
Smoking	1 item from Youth Risk Behavior Survey 2003 scored 1-4 (30). In the surveys 2007-2021 the answer "No" is dived into "No, never smoked" and "No, but smoked previously". These was handled as "No" to secure same scoring of all surveys.
BMI	Based on self-reported height and weight. BMI = weight/height^2.
Social factors	
Bully	1 item from the Health Behavior in School Children study (HBSC) with a score of 1-5. In 2004, 2007 and 2010 the question concerns bullying at school/education (31). In 2007, 2017 and 2021 the question concern bullying at work. In 2007 the answer with the highest score of either bulling at work or education was used.

Supplementary text 1: Covariates

Data on sex and country of origin was obtained from the Population Register (31). Country of origin was defined as born in Denmark or outside Denmark.

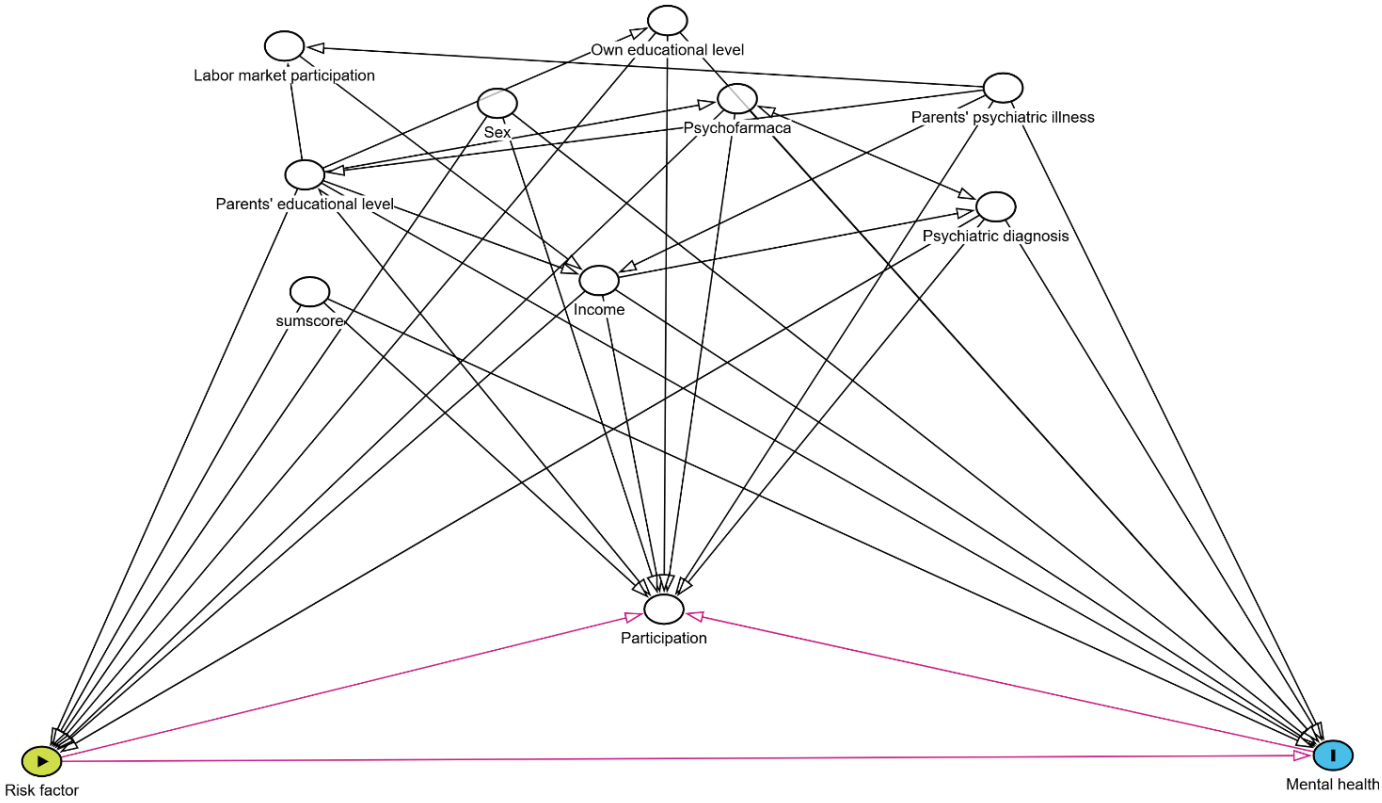
Mental disorder diagnoses were obtained from the Danish National Patient Register from 1995 and onwards and thereby from the age of 6 in the present population born in 1989 (32, 33). Diagnoses were obtained from both psychiatric and somatic units and both primary and secondary diagnoses were included. Diagnoses were defined by the ICD-10 codes F10-F69 and F80-F99, excluding organic disorders (F00-F09) and intellectual disabilities (F70-79) given that these disorders either have onset at old ages or are congenital. The mental disorder diagnoses were described as "any mental disorder diagnosis", a dichotomized measure of present/not present for each age of interest (15-32) and within the following categories: child (age 6-12), adolescent (age 13-17), adult (age 18-32), and throughout the study period.

Medication use was defined as prescriptions for psychotropic medication using Anatomical Therapeutic Chemical codes N05A (minus N05AN), N05AN, N05B, N05C, N06A, N06B, N06C (minus N06AX01 and N06AX02), N07BB and N07BC), obtained from the Danish National Prescription Register (34). The adolescents' medication use was described as present or not present for each age of interest (age 15-32) and within the following categories: young child (age 0-4), older child (age 5-12), adolescent (age 13-17), adult (age 18-32), and throughout the study period (age 0-32).

Equalized family income from 2004 to 2021 was obtained from the Register of Family Income. Three income groups were defined by the OECD definition of income quintile share ratio or the S60/S20 ratio: the low-income group was the families with the 20% lowest income, the high-income group was the families with the 20% highest income and the middle-income group was the families with incomes in between (35). The legal parents' highest educational level in 2004 was used as measure of parental educational level. Data on both legal parents' educational level was obtained from Register of the Highest Completed Education (36). The highest educational levels of the parents' were categorized into three groups: the low educational level group contained individuals with completion of up to secondary school (International Standard Classification of Education (ISCED): 0-2), the middle educational level group contained individuals with upper secondary school, vocational education, or short-cycle tertiary education (ISCED: 3-5) and the high educational level group contain individuals with a bachelor's degree or higher (ISCED: 6-8).

From the first survey wave in 2004, two measure of SES was used; subjective social status (SSS) in School and SSS in society. SSS in school and SSS in society were measured at age 15 with the MacArthur Scale of Subjective Social Status – youth version (MacArthur scale). The adolescents were asked to place themselves on a 10-step ladder representing the social hierarchy in their class (SSS in school) and to place their family on a 10-step social ladder representing the society (SSS in society) (37). Three groups of SSS were defined: low (steps 1-4), middle (steps 5-8) and high (steps 9-10).

Supplementary Figure 1: Directed Acyclic Graph of selection into the analytical sample



Note: “sumscore” is the mean of the depressive symptom scores across surveys.

Supplementary Table 2: Dropout analyses of characteristics of analytical sample and excluded at baseline (2004)

	Excluded	Analytical sample (without weights)		Analytical sample (with weights)	
Covariates N(%)	(N=1523)	(N=2157)		(N=2157)	
Sex			p<0.05		p<0.05
Male	980 (64.35%)	923 (42.79%)		1122 (52.00%)	
Female	543 (35.65%)	1234 (57.21%)		1035 (48.00%)	
Missing	0 (0% of total)	0 (0% of total)		0 (0% of total)	
Country of origin			p<0.05		p<0.05
Denmark	1368 (89.82%)	2092 (96.99%)		2035 (94.36%)	
Other	155 (10.18%)	65 (3.01%)		122 (5.64%)	
Missing	0 (0% of total)	0 (0% of total)		0 (0% of total)	
Educational level			p<0.05		p<0.05
Long	58 (4.03%)	157 (7.31%)		128 (5.95%)	
Middle	1072 (74.50%)	1756 (81.75%)		1666 (77.57%)	
Short	309 (21.47%)	235 (10.94%)		354 (16.48%)	
Missing	84 (6% of total)	9 (0% of total)		9 (0% of total)	
Household income			p<0.05		p<0.05
High	259 (17.01%)	476 (22.07%)		413 (19.16%)	
Middle	855 (56.14%)	1353 (62.73%)		1332 (61.77%)	
Low	409 (26.85%)	328 (15.21%)		411 (19.07%)	
Missing	0 (0% of total)	0 (0% of total)		0 (0% of total)	
SSS in society			p=0.44		p=0.98
Long	46 (4.91%)	581 (4.02%)		95 (4.74%)	
Middle	486 (51.92%)	1032 (51.22%)		1044 (51.82%)	
Short	404 (43.16%)	902 (44.76%)		875 (43.44%)	
Missing	587 (39% of total)	142 (7% of total)		142 (7% of total)	
SSS in school			p=0.376		p=0.07
Long	14 (1.48%)	34 (1.68%)		41 (2.01%)	
Middle	603 (63.61%)	1334 (65.94%)		1359 (67.16%)	
Short	331 (34.92%)	655 (32.38%)		624 (30.83%)	
Missing	575 (38% of total)	134 (6% of total)		134 (6% of total)	
Mental Disorder					
Older child (5-12 years)	63 (4.14%)	44 (2.04%)	p<0.05	64 (2.96%)	p=0.09
None as child	1460 (95.86%)	2113 (97.96%)		2093 (97.04%)	
Adolescent (13-17 years)	99 (6.50%)	79 (3.66%)	p<0.05	106 (4.92%)	p=0.08
None as adolescent	1424 (93.50%)	2078 (96.34%)		2051 (95.08%)	
Adult (18-32 years)	323 (21.21%)	310 (14.37%)	p<0.05	373 (17.30%)	p<0.05
None as adult	1200 (79.79%)	1847 (85.63%)		1784 (82.70%)	
Study period (5-32 years)	397 (26.07%)	361 (16.74%)	p<0.05	451 (20.93%)	p<0.05
None in study period	1126 (73.93%)	1796 (83.26%)		1706 (79.07%)	
Missing	0 (0% of total)	0 (0% of total)		0 (0% of total)	
Medication use					
Older child (5-12 years)	26 (1.71%)	13 (0.60%)	p<0.05	22 (1.02%)	p=0.13
None as child	1497 (98.39%)	2144 (99.40%)		2135 (98.98%)	
Adolescent (13-17 years)	65 (4.27%)	53 (2.46%)	p<0.05	66 (3.04%)	p=0.07
None as adolescent	1458 (95.61%)	2104 (97.54%)		2091 (96.96%)	
Adult (18-32 years)	520 (34.14%)	500 (23.18%)	p<0.05	601 (27.85%)	p<0.05
None as adult	1003 (65.86%)	1657 (76.82%)		1556 (72.15%)	
Study period (5-32 years)	575 (37.75%)	559 (25.92%)	p<0.05	667 (30.92%)	p<0.05
None in study period	948 (62.25%)	1598 (74.08%)		1490 (69.08%)	
Missing	0 (0% of total)	0 (0% of total)		0 (0% of total)	

Supplementary Table 3: Number and prevalence of with-in person change in explanatory variables between age point

	Changed N(%)			
	Age 15-18	Age 18-21	Age 21-28	Age 28-32
Personal factors				
Coping	2023 (94%)	2039 (95%)	1907 (88%)	1887 (87%)
Self-esteem	1825 (85%)	1743 (81%)	1768 (82%)	1698 (79%)
Sense of coherence	1806 (84%)	1777 (82%)	1790 (83%)	1750 (81%)
Health factors				
Stress	1858 (86%)	1860 (86%)	1865 (86%)	1847 (86%)
Psychosomatic symptoms	1763 (82%)	1735 (80%)	1782 (83%)	1663 (77%)
Self-rated health Excellent Very good Good Fair Poor	1235 (57%)	1217 (56%)	1244 (58%)	1122 (52%)
Lifestyle factors				
Physical activity 7+ hours 4-6 hours 2-3 hours 1 hour 1/2 hour None	1417 (66%)	1476 (68%)	1535 (71%)	1508 (70%)
Smoking No Rarely Weekly Daily	565 (26%)	462 (21%)	461 (21%)	421 (20%)
BMI	2146 (99%)	2119 (98%)	2111 (98%)	2088 (97%)
Social factors				
Bullying Never Once or twice Sometimes Weekly Several times a week	685 (32%)	424 (20%)	301 (14%)	308 (14%)

Supplementary Table 4: P-values of Hausmans test on FE and POLS

	2004-2007	2007-2010	2010-2017	2017-2021
p-values	0.295	0.063	0.099	0.117

Supplementary Table 5: Results from Fixed Effect (FE) regressions and dominance analyses of relative contribution to explained variance

	FE effects regression coefficients (95% CI)				Relative contribution to explained variance (%)			
	Age 15-18	**Age 18-21**	**Age 21-28**	**Age 28-32**	**Age 15-18**	**Age 18-21**	**Age 21-28**	**Age 28-32**
Explained total variance	0.29	0.25	0.27	0.29				
Personal factors								
Coping	0.00 (-0.02-0.02)	-0.00 (-0.02-0.02)	0.02 (-0.02-0.06)	0.05 (0.00-0.09)	0.05	0.09	4.79	6.08
Self-esteem	0.06 (0.01-0.11)	0.14 (0.09-0.18)	0.10 (0.05-0.15)	0.11 (0.05-0.17)	8.58	21.14	17.8	17.01
Sense of coherence	0.16 (0.10-0.21)	0.16 (0.11-0.21)	0.18 (0.12-0.24)	0.15 (0.08-0.22)	16.81	21.22	24.51	22
Health factors								
Stress	0.25 (0.19-0.30)	0.22 (0.17-0.27)	0.19 (0.13-0.24)	0.17 (0.11-0.22)	31.33	36.13	33.23	30.94
Psychosomatic symptoms	0.11 (0.07-0.15)	0.06 (0.01-0.10)	0.05 (0.01-0.10)	0.08 (0.03-0.12)	8.88	3.94	4.92	5.48
Self-rated health								
Excellent (ref)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)				
Very good	-0.15 (-0.38-0.08)	0.09 (-0.13-0.30)	0.21 (-0.02-0.44)	0.25 (-0.02-0.51)				
Good	0.12 (-0.18-0.42)	0.28 (-0.02-0.58)	0.49 (0.14-0.84)	0.52 (0.15-0.89)				
Fair	0.57 (-0.04-1.17)	0.48 (-0.13-1.09)	0.54 (-0.02-1.10)	0.85 (0.25-1.44)				
Poor	1.32 (0.14-2.50)	0.30 (-0.82-1.43)	0.95 (-0.34-2.23)	1.24 (0.10-2.38)	8.88	5.71	8.31	11.31
Lifestyle factors								
Physical activity					1.1	1.22	1.59	1.62
7+ hours (ref)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)				
4-6 hours	0.14 (-0.12-0.41)	-0.04 (-0.32-0.25)	0.15 (-0.17-0.47)	0.11 (-0.23-0.45)				
2-3 hours	0.19 (-0.12-0.50)	0.05 (-0.26-0.36)	0.20 (-0.14-0.53)	0.15 (-0.21-0.51)				
1 hour	-0.03 (-0.41-0.36)	0.07 (-0.33-0.48)	0.00 (-0.39-0.40)	-0.03 (-0.46-0.40)				
1/2 hour	-0.11 (-0.68-0.45)	0.28 (-0.21-0.76)	0.19 (-0.28-0.67)	0.08 (-0.39-0.55)				
None	0.12 (-0.51-0.76)	0.23 (-0.29-0.75)	0.06 (-0.51-0.63)	-0.10 (-0.64-0.43)				
Smoking					0.37	0.68	1.42	0.71
No (ref)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)				
Rarely	0.07 (-0.33-0.46)	-0.09 (-0.49-0.31)	0.27 (-0.14-0.68)	0.14 (-0.30-0.57)				
Weekly	-0.10 (-0.60-0.41)	-0.39 (-0.87-0.08)	-0.17 (-0.75-0.41)	-0.10 (-0.87-0.66)				
Daily	-0.22 (-0.65-0.21)	-0.22 (-0.70-0.26)	0.11 (-0.30-0.51)	0.03 (-0.45-0.51)				
BMI	0.01 (-0.04-0.07)	0.02 (-0.04-0.07)	-0.03 (-0.07-0.01)	0.05 (-0.01-0.10)	0.22	0.16	0.38	1.8
Social factors								
Bullied								
Never (ref)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)	0.00 (.- .)				
Once or twice	0.21 (-0.10-0.52)	0.22 (-0.17-0.60)	0.05 (-0.49-0.60)	0.27 (-0.30-0.83)				
Sometimes	0.67 (0.16-1.18)	0.35 (-0.60-1.29)	-0.21 (-1.35-0.93)	0.25 (-0.53-1.04)				
Weekly	1.32 (0.33-2.32)	-0.20 (-1.76-1.35)	-0.25 (-1.65-1.15)	0.48 (-0.47-1.43)				
Several times a week	0.19 (-1.16-1.54)	-1.00 (-3.87-1.88)	-0.27 (-2.79-2.25)	0.00 (.- .)	6.03	2.18	1.53	2.72

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Declaration of co-authorship concerning article for PhD dissertations

Full name of the PhD student: Christine Leonhard Birk Sørensen

This declaration concerns the following article/manuscript:

Title:	Social inequality in mental disorder diagnoses and psychotropic medication use among 15-year-old adolescents in Denmark from 2002–2022
Authors:	C.L.B. Sørensen, O. Plana-Ripoll, U. Bültmann, T.N. Winding, P. B. Steen, K. Biering.

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preperation ☐

If published, state full reference: Sørensen CLB, Plana-Ripoll O, Bültmann U, Winding TN, Steen PB, Biering K. Social inequality in mental disorder diagnoses and psychotropic medication use among 15-year-old adolescents in Denmark from 2002–2022. Social Psychiatry and Psychiatric Epidemiology. Ahead of print. doi:10.1007/s00127-025-02943-y

If accepted or submitted, state journal:

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

Your contribution

Please rate (A-F) your contribution to the elements of this article/manuscript, **and** elaborate on your rating in the free text section below.

A. Has essentially done all the work (>90%)
B. Has done most of the work (67-90 %)
C. Has contributed considerably (34-66 %)
D. Has contributed (10-33 %)
E. No or little contribution (<10%)
F. N/A

Category of contribution	Extent (A-F)
The conception or design of the work:	A
Free text description of PhD student's contribution ***(mandatory)*** The study was designed in collaboration with the supervisors.	
The acquisition, analysis, or interpretation of data:	A
Free text description of PhD student's contribution ***(mandatory)*** The analyses was conducted by the PhD student and the results were interpreted together with the supervisors.	
Drafting the manuscript:	A
Free text description of PhD student's contribution ***(mandatory)*** The PhD student drafted the manuscript and revised according to comments from the supervisors.	
Submission process including revisions:	A

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Free text description of PhD student's contribution ***(mandatory)***
The PhD student have done all the work in the submission proces, have drafted review response and consulted the supervisors regarding the review response.

Signatures of first- and last author, and main supervisor

Date	Name	Signature
27/6-25	Christine Leonhard Birk Sørensen	
27/6 -25	Karin Biering	

Date: 27/6 -25

Signature of the PhD student

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Declaration of co-authorship concerning article for PhD dissertations

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Authors:	C.L.B. Sørensen, O. Plana-Ripoll, U. Bültmann, T.N. Winding, P. B. Steen, K. Biering.

The article/manuscript is: Published ☒ Accepted ☐ Submitted ☐ In preperation ☐

If published, state full reference: Sørensen CLB, Plana-Ripoll O, Bültmann U, Winding TN, Steen PB, Biering K. Developmental trajectories in mental health through adolescence and adulthood: does socio-economic status matter? Epidemiology and Psychiatric Sciences. 2025;34:e33. doi:10.1017/S2045796025100073

If accepted or submitted, state journal: Epidemiology and Psychiatric Sciences

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Submission process including revisions:	A

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27/6-25	Karin Biering	

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Signature of the PhD student

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Authors:	C.L.B. Sørensen, F.B. Larsen, O. Plana-Ripoll, U. Bültmann, T.N. Winding, P. B. Steen, K. Biering

The article/manuscript is: Published ☐ Accepted ☐ Submitted ☒ In preperation ☐

If published, state full reference:

If accepted or submitted, state journal: European Journal of Public Health

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

Your contribution

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