Master's thesis

NTNU
Norwegian University of Science and Technology
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Department of Sociology and Political Science

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A systematic review and meta-analysis of the association between educational attainment and COVID-19 mortality

Master's thesis in sociology
Supervisor: Terje Andreas Eikemo
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Abstract

Background:
The association between education and health has continuously been confirmed throughout the years. It is thus reasonable to assume that educational attainment has had an impact on health outcome facing the COVID-19 pandemic. As the issue of social inequalities in health is of vital importance for policymakers when deciding on future policies meant to improve disparities, a need exists to systematically gather and synthesize all studies available on the topic. As an answer to this need, this study aims to analyse the relationship between educational attainment and COVID-19 mortality for adults in Europe.

Methods:
This study is a comprehensive systematic review and meta-analysis examining the effect of educational attainment on adult COVID-19 mortality in Europe. A global literature search was conducted in June 2022 across 7 different databases. Abstracts and full-texts were screened for eligibility by a pair of reviewers working separately before reconciling on any discrepancies. Effect estimates in odds ratio and hazard ratio were extracted from the studies, examining the relationship between low and medium educational attainment and COVID-19 mortality with high educational attainment as the reference category. Random-effects meta-analyses were conducted using the data program RStudio compatible with the programming language R.

Results:
The systematic literature search identified 15 859 records reviewed for inclusion according to defined criteria. A total of 8 articles met the inclusion criteria containing individual-level data from the European region and were included in this qualitative synthesis. Five of these were eligible for meta-analyses. Results from the meta-analyses showed an overall odds ratio of 1.09 (95% CI 1.03-1.16) for low educational attainment and an estimate of 1.05 (95% CI 1.01-1.10) for medium educational attainment, whereas an overall hazard ratio of 1.36 (95% CI 1.07-1.73) for low educational attainment and an estimate of 1.29 (95% CI 1.09-1.53) for medium educational attainment. The educational gradient in COVID-19 mortality for both odds ratio and hazard ratio estimates visualized a stepwise decrease in mortality risk for each additional level of education achieved.

Conclusion:
The results from this study confirm that educational attainment is associated with COVID-19 mortality for adults in Europe and shows that individuals with lower educational attainment have increased risk of mortality compared to those with high educational attainment. These findings provide support for evidence-based policymaking to reduce inequalities in health across the educational gradient and improve access to education for all.

Sammendrag

Bakgrunn:
Sammenhengen mellom utdanning og helse har blitt bekreftet opp gjennom årene. Derfor er det rimelig å anta at utdanningsnivå har hatt en innvirkning på helseutfall i forbindelse med COVID-19-pandemien. Ettersom spørsmålet om sosiale ulikheter i helse er av avgjørende betydning for beslutningstakere når fremtidig politikk for å utjevne forskjellene skal utformes, er det behov for å systematisk samle og syntetisere alle tilgjengelige studier om temaet. Som et svar på dette behovet har denne studien som mål å analysere sammenhengen mellom utdanningsnivå og COVID-19-dødelighet blant voksne i Europa.

Metode:
Denne studien er en omfattende systematisk gjennomgang og metaanalyse som undersøker effekten av utdanningsnivå på dødeligheten av COVID-19 hos voksne i Europa. I juni 2022 ble det gjennomført et globalt litteratursøk i 7 ulike databaser. Sammendrag og fulltekster ble gjennomgått av et par forskere som arbeidet hver for seg, før eventuelle uoverensstemmelser ble avgjort. Effektestimater i form av odds ratio og hazard ratio ble hentet ut fra studiene for å undersøke sammenhengen mellom lavt og middels utdanningsnivå og COVID-19-dødelighet, med høyt utdanningsnivå som referansekategori. Random-effects metaanalyser ble utført ved hjelp av dataprogrammet RStudio, som er kompatibelt med programmeringsspråket R.

Resultat:
Det systematiske litteratursøket identifiserte 15 859 artikler som ble gjennomgått for inklusjon i henhold til definerte kriterier. Totalt 8 artikler som oppfylte inklusjonskriteriene og inneholdt data på individnivå fra den europeiske regionen ble inkludert i denne kvalitative syntesen. Fem av disse var kvalifisert for metaanalyse. Resultatene fra metaanalysene viste en samlet odds ratio på 1.09 (95 % KI 1.03-1.16) for lavt utdanningsnivå og et estimat på 1.05 (95 % KI 1.01-1.10) for middels utdanningsnivå. De viste også en samlet hazard ratio på 1.36 (95 % KI 1.07-1.73) for lavt utdanningsnivå og et estimat på 1.29 (95 % KI 1.09-1.53) for middels utdanningsnivå. Utdanningsgradienten i COVID-19-dødelighet for både odds ratio og hazard ratio estimater visualiserte en trinnvis reduksjon i dødelighetsrisiko for hvert ekstra utdanningsnivå oppnådd.

Konklusjon:
Resultatene fra denne studien bekrefter at utdanningsnivå er assosiert med COVID-19-dødelighet for voksne i Europa, og viser at personer med lavere utdanningsnivå har økt risiko for dødelighet sammenlignet med personer med høy utdanning. Disse funnene gir støtte til evidensbasert politikkutforming for å redusere ulikheter i helse på tvers av utdanningsgradienten og forbedre tilgangen til utdanning for alle.

Acknowledgements

This master´s thesis marks the end of five years at the Social Science with Teacher Education programme at NTNU in Trondheim. The process I have been looking forward to for so many years is finally coming to an end. The professional relevance of this master´s thesis is evident through my research contribution to support evidence-based policymaking aimed at reducing inequalities in health across the educational gradient and improve access to education for all. To conduct the master´s project as part of an international research project has been both educational and demanding. It has made the master´s process less lonely, while at the same time requiring systematically reviewing a large amount of data material that will be used beyond this thesis. Not surprisingly, it has sparked an interest in pursuing a career in research. Working on this thesis has mostly been exciting and rewarding, but not without challenges along the way. I would therefore like to thank some of those who have been of particular importance in the journey towards the final result.

First, I would like to thank my supervisor Terje Andreas Eikemo for contributing to the project with great disciplinary and research expertise. From day one, you have believed that I can do everything I set out to do. This has been hugely appreciated. I would also like to give a special thanks to my good friend and fellow student Maria Isabel Abrante for all support and enjoyable moments during long days of intense writing. Thank you to my older brother for assisting me while conducting the analysis with R.

Finally, I would like to thank my dear mother for all the uplifting conversations and useful discussions regarding the master´s project throughout the semester. Thank you for sharing my passion for research and for always cheering me on.

With this, I proudly present my largest independent research project so far.

Amelia Stokke Grønseth
Trondheim, June 2023

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1.0 Introduction

This master thesis is a sociological contribution in three ways. First, it aims to understand the consequences of educational inequality in COVID-19 mortality. Second, it is a contribution in that sociological theories are applied to explain this inequality. Third, it represents an initiative to methodology development within the field of sociology. To synthesise all relevant studies examining the association between educational attainment and adult COVID-19 mortality in Europe it makes use of techniques such as systematic review and meta-analysis. Through applying these research methods, which is most often used in medicine, it demonstrates how these can be innovative in social sciences. This sociological contribution therefore suggest that sociology is a key discipline to understanding the field of medicine, and that sociology itself can be enriched by new methodological thinking.

1.1 Background

The first cases of an unusual pneumonia were detected in China December 2019. The novel disease, which seems to have jumped from an animal population into humans, was later named SARS-COV-2 or COVID-19 (Bambra et al., 2021, p. 1). In short time the virus progressed into a global pandemic, impacting people and health care systems across the world. As early cases of the virus included high profiled, powerful, and wealthy individuals, it gave the impression that the COVID-19 virus does not discriminate and that we are all in it together (Bambra et al., 2021, p. 2). This is partly true; once someone has been infected by the virus, it can result in severe illness or death regardless of who is infected. However, wealth and power do provide layers of protection from the virus, as they reduce the likelihood of being exposed to the virus and suffer its worst effects (Bambra et al., 2021, p. 2). The COVID-19 pandemic is therefore said to have occurred against a backdrop of inequalities in social determinants of health (Bambra et al., 2020, p. 965). People are exposed to such determinants to varying degrees, causing some to groups to be placed at elevated risk of disease. When health conditions are further deteriorated by various social and systematic disparities, the question arises as to whether we might be dealing with a syndemic disease. As the pandemic developed, the unequal nature of the virus became evident. In example, in countries with high income inequality, the virus spread faster and mortality rates grew higher (UN, 2021). Social disparities have placed societies and populations in a more vulnerable position when facing the pandemic, which leads to a disproportionate distribution of burden. The COVID-19 pandemic has thus made social inequalities visible in a whole new way.

While the pandemic drags on, examining how social conditions impacts COVID-19 outcome is thus becoming increasingly relevant. Existing research suggests that the connection between social inequalities and mortality is quite complex. Studies published on this topic have used a number of different methodologies and examined the impact of different social inequality variables, including the impact of education. To study education as a measure of socioeconomic status is beneficial as it is a consistent component of an individual´s social and economic position, while also easier to compare between countries and over time than other measures influenced by subsequent health (Valkonen, 1993, p. 410). Ross and Wu (1995) stress that educational inequality allocates people into different life positions, which in turn are associated with various risks and resources (p. 720). This consequently influences an individual’s quality of life which enables an impact on health situation. As low educational attainment has previously shown to be associated with higher rate of disease, self-reported poor health, and mortality (Ross & Wu, 1995, p. 719), the impact of education on COVID-19 mortality is especially interesting. Because the positive association between education and health has continuously been confirmed throughout the years, it is reasonable to assume that educational attainment also has had an impact on health outcome facing the COVID-19 pandemic. As the issue of social inequalities in health is of vital importance for policymakers when deciding on future policies meant to improve disparities, a need exists to systematically gather and synthesize all studies available on the topic. Only this approach will allow us to fully uncover and understand the influence of social inequalities in COVID-19 mortality.

1.1.1 The European study region

The European sample countries for this synthesis is limited by the accessible and comparable existing studies that quantitatively examines the association between education and adult COVID-19 mortality. From a sample of 15 859 records identified across several databases, this amounted to 8 articles eligible for synthesis. Those 8 articles constitute a study population of Sweden, United Kingdom, Spain, and Turkey. All four countries which have relatively high life expectancy compared to other countries in the world. Life expectancy at birth in Turkey is assumed to be 76 years, whereas in United Kingdom this is measured to 81 years. In Sweden and Spain people are expected to live until they are approximately 83 years old.

Despite overall good estimates of life expectancy, other tendencies may point to some important differences between these countries. They vary considerably in their Human Development Index (HDI) ranking, where Sweden is highest ranked as country number 7 while Turkey receives the lowest ranking of these as number 48. United Kingdom and Spain fall in between and ranks respectively as number 18 and 27 (United Nations Development Programme, 2021). This trend continues when looking into the latest available Gini Index from the World Bank. The high-income countries of Sweden and United Kingdom have values of 28.9 and 32.6, whereas the value for Spain is set to 34.9 and for Turkey to 41.9. According to the World Bank, the Gini Index measures the extent to which the distribution of income is equally spread across the population. A Gini Index of 0 represents perfect income equality, whereas an index of 100 indicates total inequality in the distribution of income. Consequently, the Gini Index of 41.9 for Turkey indicates that there is relatively high income disparity within the country. As income inequality may be connected to educational inequality, these are important facts to establish before studying an impact of education on health.

1.2 Research problem and question

One of the United Nations Sustainable Development Goals is to reduce inequalities within and among countries. The UN emphasizes that reducing inequality is essential to improve population health and strengthen societal resilience (FN-sambandet, 2023). As the pandemic has led several social developments in the wrong direction, it is important to address the problem to avoid a continuation of these trends. The World Health Organization (WHO) has therefore requested various research efforts on the topic of COVID-19 mortality and the project that this master thesis is part of constitutes one of these. The project has been requested to do a global and comprehensive analysis of inequality and inequity in the risk and experience of COVID-19 mortality (WHO, 2023). This will generate more precise data that is useful for understanding the effect of socioeconomic factors on health. Ultimately, policy decisions to reduce social inequalities and improve health must be informed by evidence-based research. This project therefore systematically synthesises all available research on social inequalities in COVID-19 mortality to provide a basis for policy decisions and improve coordination between research and policymakers.

An introduction to the project is given in the article by Friedman and colleagues (2022). This short article also includes an invitation to voluntary collaboration. From this, the research team was composed by crowdsourcing, and coordinated by the Centre for Global Health Inequalities Research (CHAIN). The team has consisted of between 30 and 40 researchers with varying capacities throughout the period, as the project is based on voluntary effort. Because most researchers have contributed to this project alongside their regular employment and my contribution has been crucial for obtaining data material for my master thesis, my work effort has been considerably greater than any other voluntary researcher. Together with another master student, I have thus been an important contributor to the project´s progress in all phases.

Within the frame of this project and in line with existing research on the education variable as a factor of social inequality in health, this master´s thesis seek to empirically explore the impact of education on adult COVID-19 mortality. To delimit the study to fit the scope of a master´s thesis, the study region is set to Europe. The research question thus reads as follows: *Is educational attainment associated with COVID-19 mortality for adults in Europe?* To answer this research question, various methodological approaches has been applied. First, a systematic review of the existing literature was carried out. This made it possible to identify, summarize and critically review the literature already available on the topic of social inequalities in adult COVID-19 mortality. The next phase of the research involved extracting the relevant data examining the education variable from the literature reviewed and included in the study, before conducting quantitative meta-analysis of the data material. In an attempt to unravel and understand the mechanisms behind educational inequality, several sociological theories were explored and tested in the context of the overall effect estimates generated in the analysis.

1.2.1 Sociological relevance

To highlight the sociological relevance of this master thesis, several aspects should be considered. Numerous of researchers have previously argued that health is influenced by social determinants (in example Braveman et al., 2011; Dahlgren & Whitehead, 2021). Disease and well-being must therefore be examined as social causes. Sociology is thus needed to move beyond an epidemiological perspective on health. This thesis contribution to the understanding of the social phenomenon that exists in the relationship between educational attainment and COVID-19 mortality implies its sociological relevance. More importantly, the findings from this study will offer support for evidence-based policymaking to reduce health inequalities across the educational gradient. This indicates possible real-world implications of the research conducted in this thesis. Sociological perspectives should also be included in future evaluations of the COVID-19 pandemic burdens. To make the field of sociology more attractive and applicable amongst various lines of research, its methodologies must improve. The innovative methodological approach taken in this master thesis may advance sociological research practices in the future.

1.3 Thesis structure

This master thesis is divided into six chapters, all containing several subsections. The following chapter introduces some theoretical perspectives that are relevant to explore when aiming to understand the relationship between education and COVID-19 mortality. This includes syndemic theory, fundamental cause theory and a theoretical perspective of pathways linking education to health. In closing of the theory chapter, the thesis hypothesis is formulated. Further on, the third chapter will present data material and methods. This includes all phases of the systematic review that led to the data material, as well as an introduction to meta-analysis as method of research. As this study involves particularly advanced methods of research, this part also contains a discussion of methodological evaluations. A reflection on the quality criteria reliability and validity is covered in closing. The results are presented in the thesis fourth chapter. This will outline both a qualitative synthesis with descriptive statistics of the studies included in the meta-analysis, in addition to the findings generated. Following the results is the discussion, where the findings will be discussed in relation to the theoretical perspectives explored in the theory chapter. Finally, the last chapter outlines the conclusion where the most important findings are summarized, and the thesis research question is answered. In closing, some implications for further research are suggested.

2.0 Theoretical perspectives

The following chapter will explore some theoretical perspectives that are considered useful in an attempt to understand the complicated relationship between education and mortality. First, syndemic theory will be introduced as a perspective to explain how the COVID-19 pandemic interacts with already existing conditions of inequality which in sum exacerbates the negative effect of disease. Second, as a gateway to discussing resources and risk factors in relation to inequalities in COVID-19 mortality, the sociological theory of fundamental cause is then outlined. Third, three pathways linking education to health described by Egerter et al. (2009) is elaborated and visualized. Together these perspectives may partially explain the interplay between educational attainment and adult COVID-19 mortality. Finally, the master´s thesis hypothesis is outlined.

2.1 Syndemic theory

Medical anthropologist Merrill Singer was the first to introduce the concept of syndemics back in the 1990s. Singer made use of the concept to create an understanding of the interconnection between cases of HIV/AIDS, substance use, and violence. The idea was to study the reasons why these components often clustered and tended to affect specific individuals or groups of people. Since the 1990s and what has been called the SAVA (substance abuse, violence, and AIDS) syndemic, the term syndemic has been applied within different contexts of health research. Singer (2009) explains that the term syndemic is a *portmanteau* word, meaning a blend that brings together two distinct concepts to convey a new meaning (p. 28). Hence, the neologism of syndemic is made up of two words. The first word is *synergy*, which is derived from the Greek word *synergos*, indicating that two or more agents working together will create a greater effect than the sum of each of them working alone (Singer, 2009, p. 28). This is close to the exact definition of what happens in a syndemic. The second word in the neologism is *demic*, which is a verbal suffix that derives from the Greek word *demos*, or "people" (Singer, 2009, p. 28). This implies that the effect referred to is inflicted on people. This verbal suffix is used in syndemic as it has previously been used in core public health concepts: epidemic, used to describe greater disease frequency than expected within a given population; pandemic, an epidemic that spreads across multiple populations or even worldwide; and endemic, a disease that is well established in a population of people and therefore remains year after year (Singer, 2009, p. 29).

Furthermore, Singer (2000) defines a syndemic as "a set of closely intertwined and mutual enhancing health problems that significantly affect the overall health status of a population within the context of a perpetuating configuration of noxious social conditions" (p. 13). This definition acknowledges that health problems are taking place within the context of already existing social conditions that affect how these problems unfold among people. A collective term often used for such conditions are social determinants of health. Social determinants of health have been estimated to account for 80-90 % of a person's health outcome (Magnan, 2017, p. 1). These are key factors in ones living environment, such as working conditions, unemployment, housing, health care, access to different services, food, or education. Following Singer, Bambra et al. (2020) further describe that a syndemic occurs when risk factors are interactive and cumulative and thus adversely exacerbate the disease burden through increasing its unfavorable effects (p. 965). In syndemic theory, social determinants of health therefore account for potential risk factors in unfortunate combination with certain health problems. These risk factors apply to some people more than others, causing the disease burden to be unevenly distributed throughout the population.

For a situation to be referred to as a syndemic, Singer et al. (2017) lists three criteria: 1) two (or more) diseases or health conditions cluster within a specific population, 2) contextual and social factors create the conditions in which these diseases or health conditions cluster, and 3) the clustering of diseases results in unfavorable disease interaction which increases the health burden of the populations affected (p. 942). However, syndemics are not only characterized by co-occurring conditions, but rather exemplify the nature of the changes and exchanges that exacerbate the severity or progression of disease (Singer et al., 2017, p. 943). In general, a syndemic approach is interested in understanding why certain diseases or health conditions cluster. Yet more specifically, the approach examines the pathways through which these diseases interact biologically in individuals and populations and therefore multiply their overall disease burden, while also considering the ways in which social environments contribute to this disease clustering and interaction as well as vulnerability (Singer et al., 2017, p. 941).

Given that social conditions can contribute to the formation, clustering and progression of diseases, a biosocial concept like syndemic enables a more holistic approach to addressing synergistic disease and its context interactions (Singer et al., 2017, p. 942). Furthermore, syndemic theory aims to provide a framework for analysing these kinds of biosocial connections, including their consequences for human life and wellbeing (Singer et al., 2017, p. 942). Because of this, the conceptual syndemic framework has over time gained extensive recognition within various fields of research. The concept continues to spread across health-related fields, leading to syndemic research appearing in diverse publication journals (Singer et al., 2017, p. 942). In this case the syndemic approach bridges collaboration between the field of public health and sociology through explaining how biological and social factors interact to produce health inequalities. Moreover, syndemic theory demands that biomedical conceptions of disease critically examines comorbid social problems, both at individual and population levels (Mendenhall, 2016, p. 464). This emphasizes the fundamental role of social conditions in health outcomes and disease processes. Thus, it is entirely appropriate to proceed to the theory of fundamental causes.

2.2 Fundamental cause theory

For several decades research has revealed many examples where the social structuring of disease is evident. Most obvious is the prevalent and often strong link between socioeconomic status and health (Link & Phelan, 1995, p. 81). Nevertheless, the development from these findings into a theory of fundamental cause has been long. Already in the 19th century, the strong association between indicators of poverty and health led physicians to understand medicine as a social science (Link & Phelan, p. 86). The reason for this link was assumed to be the living and working conditions entailed by poverty. Fortunately, with extensive efforts targeting the dimensions thought to be the reasons why poor people were infected by diseases to a greater extent, the incidences of disease were reduced. Also, access to health care for the poor significantly increased in modern welfare states. By the 1960s, there was an expectation that the association would decline and disappear, as many factors linking socioeconomic status to disease had already been addressed (Link & Phelan, 1995, p. 86). However, after a while it became clear that the association did not diminish but rather revealed an increasing effect. This disclosure shifted the focus in research towards other risk factors than those previously assumed and studied. Studies thus revealed that the risk factors mediating the association between socioeconomic status and health had changed (Link & Phelan, 1995, p. 86). While some risk factors were erased, others emerged or had newly been discovered. And as new risk factors became apparent, people of higher socioeconomic status were more likely to know about the new risks and hold resources that enabled them to avoid these (Link & Phelan, 1995, p. 86). Because risk factors seemed to be transformable, the mechanisms that create grounds for these to occur needed to take centre stage.

The idea that multiple mechanisms may contribute to a persistent association between cause and effect was put forward by sociologist Stanley Lieberson in 1985 (Link & Phelan, 1995, p. 87). He then introduced the concept of basic causes, which is what the theory of fundamental causes builds on. With this concept, Lieberson suggested that basic causes have a lasting effect on a dependent variable which is evident when the effect of one mechanism declines and another one emerges or becomes more prominent (Link & Phelan, 1995, p. 87). Since this concept was introduced, many scientists have used it to create an understanding of the connection between socioeconomic status and mortality. With this backdrop, Bruce Link and Jo Phelan have developed the fundamental cause theory ever since 1995, with elaboration from others in later years.

Link and Phelan (2013) lists four essential features of fundamental causes of health inequalities. First, fundamental causes influence several disease outcomes (Link & Phelan, 2013, p. 106). This indicates that they are not limited to affecting only one or a small number of diseases or health issues, but rather have extensive ability to influence health. Second, the fundamental causes impact disease outcomes through multiple risk factors (Link & Phelan, 2013, p. 106). Thus, there is not a straight line between fundamental causes and disease outcomes. However, the fundamental causes are what allows the risk factors to influence health. Third, fundamental social causes involve access to resources that are beneficial in avoiding risk factors or minimizing the consequences of disease once it has occurred (Link & Phelan, 2013, p. 106). Such resources range from money, social power and prestige to knowledge and interpersonal resources like social networks or social support. These flexible resources operate at both individual and contextual levels. At the individual level, flexible resources can be understood as the "causes of causes" or "risks of risk" that shape individual health behaviour by influencing whether people know about, have access to, can afford, and receive social support in their efforts to adopt healthy or protective behaviours (Link & Phelan, 2013, p. 107). Also, such resources impact access to broad contexts where the risk profiles associated and protective factors vary dramatically (Link & Phelan, 2013, p. 107). In example, living in a neighbourhood of high socioeconomic status may give access to health positive facilities such as parks and playgrounds as well as health-facilities of high standards. Likewise, by using educational qualifications to secure a high-status job this is likely to include a health safe workspace and health care benefits (Link & Phelan, 2013, p. 107). Finally, an essential feature of fundamental causes is that the replacement of intervening mechanisms ensures that the association between a fundamental cause and health is constantly reproduced over time (Link & Phelan, 2013, p. 106).

In addition to the risk mechanisms constantly being replaced, the knowledge about these risks as well as the diseases affecting humans and the effectiveness of treating those diseases also undergoes continuous change (Link & Phelan, 1995, p. 87). In a dynamic system where these changes are continuously taking place, fundamental causes are likely to be found. The reason for this is that resources like money, prestige, power, social connectedness, and knowledge are transportable between situations, and as situations of public health change, those who holds the most resources are best equipped to avoid both risks, diseases, and the most fatal consequences that these may cause (Link & Phelan, 1995, p. 87). This indicates that those who have high socioeconomic status will be less affected regardless of which diseases that afflict public health situations.

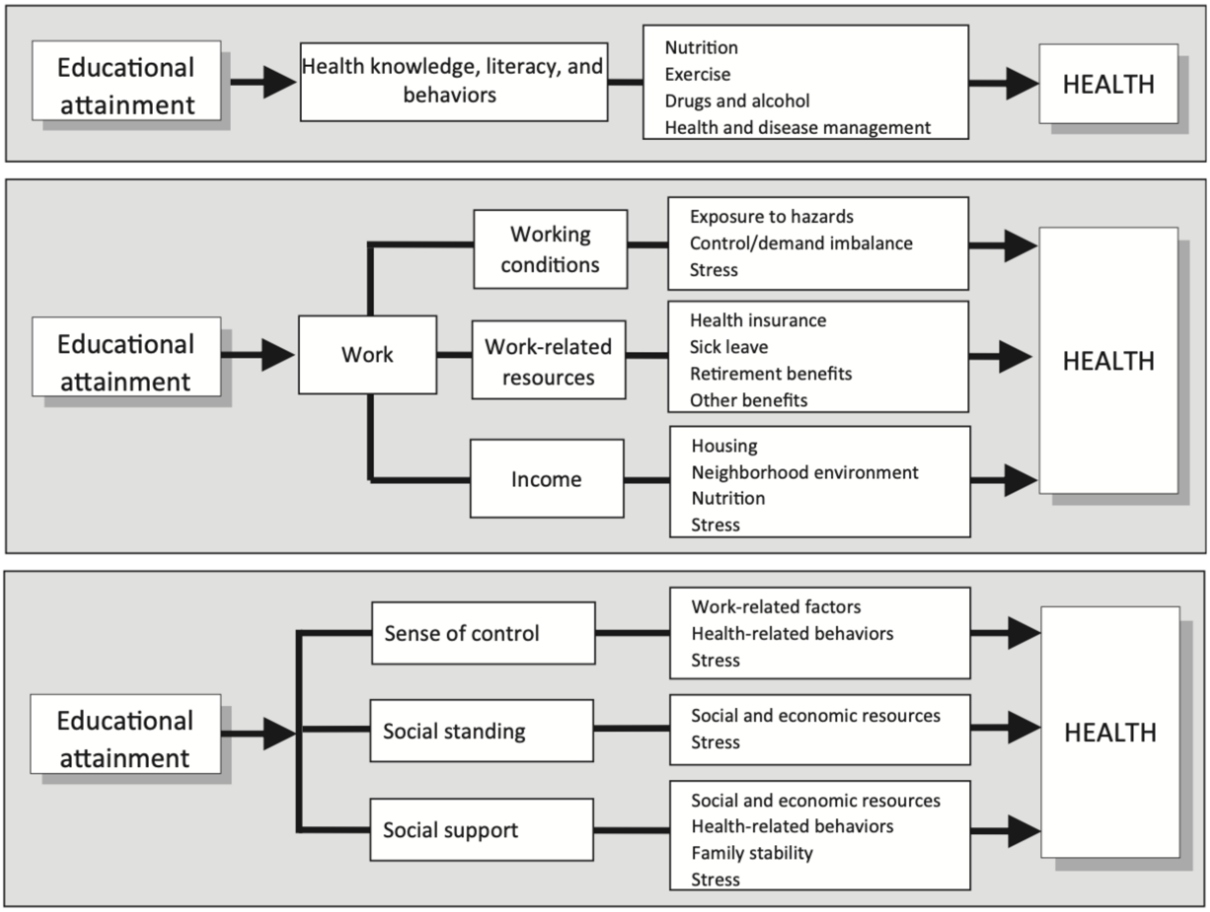
2.3 Pathways linking education to health

Egerter et al. (2009) describes three interrelated pathways linking education to health. The first pathway explains how education can lead to improved health by increasing health knowledge and thus healthy behaviours (Egerter et al., 2009, p. 5). This may be the most obvious pathway that people think of when trying to understand the association between the two variables. As education can increase knowledge and cognitive skills, it enables people to make informed health-choices for both themselves and their families (Egerter et al., 2009, p. 5). Educated individuals are more likely to maintain a healthy lifestyle including eating healthy, exercising on a regular basis and avoid health-damaging behaviours such as smoking or heavy alcohol consumption. Those who are more educated also tend to respond quicker after new evidence, health advice or public health campaigns have been put forward, by modifying their health-related behaviour as suggested (Egerter et al., 2009, p. 5). Additionally, more education typically leads to higher-paying jobs which provides the necessary income to live in less stressful neighbourhoods where stores offer affordable healthy foods and the area surrounding it provides access to recreational facilities (Egerter et al., 2009, p. 5). Therefore, education lay grounds for health-promoting environments designed to enable healthy living. The link that this pathway proposes through health knowledge is probably partly connected to level of literacy. The degree to which individuals have the competence to acquire, process, and understand basic health information needed to make informed health decisions and obey to disease management protocols increases in accordance with educational attainment (Egerter et al., 2009, p. 6).

The second pathway describes how education provides opportunities for employment and elaborates on several different ways in which this can shape health outcomes. Greater educational attainment increases the chances of being employed at all, in addition to obtaining a job with healthy working conditions, better benefits, and higher wages (Egerter et al., 2009, p. 6). Workers with low levels of education or training more often hold lower-paying jobs with more work-related risks, such as environmental and chemical exposures, as well as poor working conditions in general (Egerter et al., 2009, p. 7). These conditions may lead to substantial psychological stress, which may be challenging if one is not trained in problem-solving or have developed coping skill mechanisms through general education. This in turn can have notably impact on both current and long-term health situation. Also, different jobs and occupations offer health-related benefits at different scales. Well-paid jobs might provide paid sick or personal leave, wellness programs and employer-insurance, whereas lower-paying jobs may offer only a few or none of these health-benefits. Limited access to benefits in addition to low income makes it difficult to maintain health-promoting behaviour. Higher-paying jobs offer greater economic security, which enables individuals to seek health care when necessary, to maintain a healthy diet with nutritious food, and to live in safer and healthier homes and neighbourhoods where supermarkets and recreational facilities are available (Egerter et al., 2009, p. 7). Income may also impact health through pathways involving stress, and because lower-paid workers have fewer financial resources to cope with they tend to experience stress to a larger extent (Egerter et al., 2009, p. 7). As mentioned, this can have negative impact on the state of health.

Egerter et al. (2009) claims with the third pathway that education is linked with social and psychological factors, such as the sense of control, social standing, and social support, which in turn can improve health through reducing stress, influencing health behaviour, and providing practical or emotional support (p. 8). As education gives prospects for career and financial stability, it creates a sense of being able to control future life circumstances. People with high educational attainment perceive greater personal control, habits, and attitudes, such as problem-solving, determination, and confidence, which thus contribute to an expectation that personal actions and behaviour may shape outcomes (Egerter et al., 2009, p. 8). This naturally also applies to health behaviour and health outcomes. Furthermore, in addition to income and occupation, educational attainment seems to be an important factor for where individuals rank within social hierarchies which in turn reflects status and societal influence (Egerter et al., 2009, p. 8). If someone has high level of education, they are usually considered to have high social standing. This tend to be linked with status of health. Even subjective perception of social standing has shown to powerfully predict health status (Singh-Manoux et al., 2003). Social support, either emotional or practical, is another factor linking education to health outcomes. This can include having someone to count on in difficult times or in need of advice, or someone who can help with practical challenges that life presents. As formal educational settings may encourage development of friendship and interpersonal skills, higher educational attainment increases one’s likelihood of having close friends to rely on and of experiencing great family stability (Egerter et al., 2009, p. 9). By reducing the negative emotional and behavioural responses to stressful situations, social support can reduce the health-damaging effects that these otherwise could have caused (Egerter et al., 2009, p. 9). In sum, greater social support is associated with improved physical and mental health. Social networks can also be a gateway for work, accommodation, or other health-improving resources. The attitudes within a social group towards behaviours such as smoking, physical activity and alcohol use might also affect individuals’ health. All three pathways suggested by Egerter et al. (2009) are modelled in Figure 1 below.

Figure 1: Interrelated pathways linking educational attainment to health



Note. Overview from Egerter et al. (2009).

2.4 Hypothesis

Exploring syndemic theory indicates that there should be a connection between social inequalities and COVID-19 outcome. In line with the theory by Link and Phelan, education has been suggested as a fundamental cause by previous research (Rydland et al., 2020). With basis in this and the theoretical elaboration above, it is reasonable to assume education as a fundamental cause and thus determining access to resources that are critical in avoiding COVID-19 disease or minimizing the outcome if already infected. The pathways described by Egerter and colleagues (2009) brings further substance to the assumption of a connection between educational inequality and COVID-19 mortality. Based on previous research and presented sociological theory I therefore expect that lower educational attainment is associated with increased COVID-19 mortality among adults in Europe.

3.0 Materials and methods

The thesis research question is answered using a quantitative research design for analysis. The choice of method can easily be justified by the fact that a quantitative research design enables an investigation of the topic in a larger part of a population than by using a qualitative design. Thus, it will be possible to generalize any findings to apply to the rest of the general population, to a greater extent than in qualitative research. This chapter of the thesis will present the data material that the analysis is based on, in addition to explaining every step of the methodological process of research, which includes both the systematic review and meta-analysis. Because the research design has a particular focus on methodological accuracy, some methodological evaluations will also be discussed. In closing, the data material will be assessed regarding quality criteria such as reliability and validity.

3.1 Systematic review and research material

Research is conducted to make sense of the world. Theories and concepts are developed, and data collected to create insights and answer a vast variety of research questions related to different interests or disciplines (Gough et al., 2017, p. 1). Most often, new primary research is conducted. However, it is also sensible to collate and examine already existing research. In order to know "what is known" or to identify the needs for further research it is crucial to assess what has already been studied. This can be done through a systematic review.

A systematic review is a literature review designed to locate, inform, and synthesize the best available evidence related to a specific research question, with the aim of providing informative and evidence-based answers (Dickson et al., 2017, p. 2). Because their objective is to synthesize available evidence, systematic reviews may also be called synthetic reviews. They seek to produce novel insights from an already existing evidence base by combining studies or their findings through using different analytical methods (Haddaway et al., 2023, p. 3). Systematic reviews aim to be comprehensive, accurate and precise while at the same time being transparent and replicable (Haddaway et al., 2023, p. 3). Hence, minimizing methodological bias is always the goal when conducting systematic reviews. Due to this high methodological standard, several disciplines consider systematic reviews as the gold standard for synthesizing the findings of multiple studies investigating the same research question (Dickson et al., 2017, p. 2). As a method of research, the systematic review follows well-defined and transparent steps. These always require defining the research question of interest, identifying, and critically evaluating the available evidence, synthesizing the findings, and drawing relevant conclusions (Dickson et al., 2017, p. 2). To bring findings together systematically, these steps require a variety of methods (Gough et al., 2017, p. 2). These range from more qualitative methods in the phase of literature search and article screening to more quantitative methods such as reviewing and analysing the statistical data extracted from the research material.

In addition to playing an important role in production of research knowledge, systematic reviews are also essential to the process of interpreting and applying research into benefiting society (Gough et al., 2017, p. 2). This means that the information gathered through systematic reviews can be used in meaningful ways, for example to underpin policy changes. Hence, this kind of research is not only conducted to make sense of the world but also to facilitate change in the world.

3.1.1 Search strategy

A systematic literature search was carried out by the teams' librarians in June 2022, using several different databases: Pub-Med, Web of Science, Scopus, EMBASE and Global Health (CAB), EconLit, and Sociology Source Ultimate. The search was limited to papers on the subject published later than February 2020 and had no restrictions regarding language, sample size or characteristics (Friedman et al., 2022, p. 648). The phenomenon of interest was adult COVID-19 mortality based on social position, which was broadly defined by using a range of social markers such as gender, education, wealth, income, race, ethnicity, urbanicity, employment, and if available, insurance status (Friedman et al., 2022, p. 648). The search landed 15 859 records which at a later stage were screened for relevant articles. The same database of records was then leveraged to identify theoretical articles explaining social inequalities in COVID-19 mortality as well as quantitative articles that measure the association between social position and COVID-19 mortality. The literature search string is presented in Appendix A.

3.1.2 Abstract and full article screening

The screening phase was structured in a two-stage process. First, references were screened based on title and abstract using pre-determined criteria before the included articles from the abstract screening phase went through a second screening of full text (Brunton et al., 2017, p. 120). In the first stage, all titles, and abstracts of the 15 859 identified references were screened by a pair of researchers, and by a third researcher in case of discrepancy. When more than one person is doing the screening, it is important to ensure that all individuals operate according to the same practice. This includes creating a common understanding of how the inclusion/exclusion criteria should be applied. Therefore, all researchers attended the same training before starting the screening phase. In fact, to have more than one person undertaking the screening was beneficial for several reasons. Firstly, it opened for discussion about individual papers which helped to clarify the scope of the review for those involved (Brunton et al., 2017, p. 120). Secondly, it was a way to ensure that every citation was reviewed by at least two people. Also, having more than one person undertaking the review may have helped to prevent reviewer fatigue (Brunton et al., 2017, p. 120). The stage of abstract screening identified 3526 relevant references.

The full article screening was also performed by researchers working in pairs and applying the inclusion/exclusion criteria which was previously identified by the team. When completing a batch of full article screening, each pair of researchers had a reconciliation meeting to discuss potential articles in conflict. In cases of discrepancy after a reconciliation meeting, a third researcher would full read the article and apply the same criteria. The majority decision would then be decisive of whether to include the article for the extraction phase. The stage of full article screening reduced the number of relevant references to 1028.

3.1.3 Inclusion and exclusion criteria

Inclusion criteria describe the specific attributes that a study must have to be included in the review, while exclusion criteria are the attributes that disqualify a study from being included (Cherry & Dickson, 2017, p. 50). Often the inclusion and exclusion criteria are mutually exclusive, meaning that the occurrence of one outcome supersedes the other. Such criteria may for example concern study design, methods, or publication type. The inclusion and exclusion criteria should be clearly connected to the review question and contain sufficient details to enable one to include and exclude studies from the review in an accurate and appropriate fashion (Cherry & Dickson, 2017, p. 50). As the objective of this systematic review is to understand and quantify the magnitude of social inequalities in COVID-19 mortality, the inclusion/exclusion criteria were designed thereafter.

In the abstract screening phase, we included a) all studies that either present a framework or theoretical construct to make sense of the observed social inequalities in COVID-19 and b) all quantitative studies that explicitly report on the association of social marker with COVID-19 mortality. To harmonize the decision process all researchers attended training and followed the same exclusion/inclusion criteria presented in the Table 1 and Table 2.

Table 1: Theoretical COVID-19 Disparities Explanation of Exclusion Criteria

Theoretical COVID-19 Disparities Explanation of Exclusion Criteria	
Exclusion criteria	**Explanation of the exclusion criteria**
No COVID-19 outcome	COVID-19 is not the disease of interest
No axis of social inequality*	Does not seek to understand disparities from a specific inequality axis
No framework	Does not include a framework (Answers no to: "Does this author provide a clear, systematic structure, outlining possible pathways through which socioeconomic disparities potentially impact COVID-19 outcomes/mortality?")
Distinction should be made between included articles that: a) explicate framework b) doubts on framework explication *Included social inequality axis: education, socioeconomic status, occupation, essential worker, precarious work, unemployment, income, wealth, poverty, overcrowding/housing conditions, rural/urban, healthy food access/food insecurity, unionization, incarceration, exposure to pollutants, stigma, refugee, migrant, ethnicity, race, addiction, underserved, LGBT, and gender.	

Table 2: Quantitative COVID-19 Disparities Explanation of Exclusion Criteria

Quantitative COVID-19 Disparities Explanation of Exclusion Criteria	
Exclusion Criteria	**Explanation of the exclusion criteria**
No humans	The study population is not human
No COVID-19 mortality	COVID-19 deaths or mortality rates are not an outcome of interest including excess deaths during COVID-19
Not representative	Single or multiple centre studies
No axis of social inequalities*	Does not analyze disparities in COVID-19 mortality from a specific social inequality axis
Publication type	Conference proceeding, editorial, letter, comment, survey note or a doctoral thesis. Erratums or corrections if they do not apply to included records.
Methods	Simulation/Prediction/Forecasting studies
Between country	Study examines between country disparities in COVID-19 mortality
Population: Total population of study location Concept: Any country with individual level data or any geographical level within the country (neighbourhood, town, city, municipality, region)	

Excluded social inequality axis: age *Included social inequality axis: education, socioeconomic status, occupation, essential worker, precarious work, unemployment, income, wealth, poverty, overcrowding/housing conditions, rural/urban, healthy food access/food insecurity, unionization, incarceration, exposure to pollutants, stigma, religion, refugee, migrant, ethnicity, race, addiction, underserved, LGBT and gender.

After completing the abstract screening phase, we had a team meeting to discuss challenges and potential changes to be made before the second stage of the screening. This resulted in a more thorough explanation of some exclusion criteria, outlined in Table 3.

Table 3: Quantitative COVID-19 Disparities Explanation of Exclusion Criteria

Quantitative COVID-19 Disparities Explanation of Exclusion Criteria	
Exclusion Criteria	**Explanation of the exclusion criteria**
No human	The study population is not human.
No adult	The study does not analyze separately the age groups 18 years old and older
No COVID-19 mortality	COVID- 19 deaths or mortality rates are not an outcome of interest. Or the study examines combined outcomes: COVID-19 mortality with COVID-19 severity/ ICU admission etc.
No axis of social inequalities	Does not report either: i) descriptive data that would allow us to do our own calculation*** ii) tables with effect estimates on the association between a socioeconomic axis and COVID-19 mortality iii) graphs plotting the relationship of at least one socioeconomic axis and COVID-19 mortality
No social group comparison	The article does not compare between social groups or does not provide estimates for comparable social groups that we could use for our own calculations.
Publication type	Erratums or corrections if they do not apply to included records. Conference preceding, editorial, letter, comment, survey note or a doctoral thesis. Conference preceding abstracts should not be searched for full text.
Methods	Simulation/Prediction/Forecasting studies/Single-few case series/Imaging/Drug-protocol testing studies
Between country	Study examines between country disparities in COVID-19 mortality

To ease the process of the upcoming extraction phase, we also used different labels during the full article screening to identify the type of socioeconomic axis as well as the representativeness of a study. The labelling criteria is listed in Table 4.

Table 4: Labelling for full article screening

Labelling for full article screening	
Labelling for representativeness	**Explanation of the label**
Representative of population	To be used for studies that analyses data from governmental records/registries and multiple or single center studies that claim to be representative of the general population

Representativeness of target population	To be used for studies that analyses data from governmental records/registries and multiple or single center studies that claim to be representative of a specific population
Multiple center study	To be used for multiple center studies that focus on a target population
Single center study	To be used for single center studies that focus on a target population
Not clear	To be used as a last resort when it is not possible for the study to be classified in one of the above categories.
Labelling for socioeconomic axis	**Explanation of the label**
Sex inequalities	To be used for studies that comply with all other inclusion criteria but only report sex inequalities in COVID-19 mortality in the results.
Geographical	Use the label geographical inequalities for studies except environmental related ones.
Environmental	Use the label only for studies that examine exposure to pollutants, air quality, climate, pollution, humidity, UV levels, etc.
Ethnicity	Use the label for studies examining ethnicity, race, ethnic minorities, refugees
Wealth	Use the label for studies examining wealth, income, poverty, socioeconomic status, healthy food access/food insecurity, overcrowding/housing conditions
Education	Use the label for studies examining education level, years of education, literacy.
Work	Use the label for studies examining occupation, employment situation, essential worker, precarious work, unionization.
Other axis	Use the label for studies examining marginalization, underserved, stigma, addiction, LGBT, religion, incarceration, etc.
Labelling for data reporting	**Explanation of the label**
Only graphs	To be used for studies that reports the results of their socioeconomic analysis of COVID-19 mortality only though graphs
Own calculation	To be used for studies that require our team to do our own calculations based on the reported information.

3.1.4 Articles not written in English

In this systematic review, language was not a limiting factor and articles not written in English was therefore also included in the search results. These articles would be reassigned to a reviewer within the team with proficiency in the relevant language. As an international research group formed the review team, most articles in other languages than English could be screened without difficulties. Team members were proficient in languages such as Italian, Spanish, Portuguese, German, and Arabic, to list a few. However, some articles were written in languages that no member of the review team was proficient in. These were screened by paid translators in assistance of the research groups coordinator. For the full article screening, this for example included articles written in Russian and Chinese. For the data extraction on articles examining the social axis of education, no articles were written in other languages than English.

3.1.5 Data extraction

As all relevant references were now identified, we moved on to data extraction and preparations towards conducting a meta-analysis. In a joint meeting session, the research group decided to start extraction of data material concerning the education variable and conduct a meta-analysis on this, before moving on to a second social inequality variable. Of 1028 relevant references included, articles containing quantitative data measuring the association between education and COVID-19 mortality amounted to 76. However, only 20 of these articles reported individual-level data and were eligible for the meta-analysis and thus data extraction.

Together with another master student and the research assistant employed on the project, I participated in preparing the extraction tools and materials for the team of extractors. This enabled the entire group to collaborate on systematically extracting the relevant information from the empirical studies identified in the screening phase. Articles for extraction were assigned in pairs, where each extractor completed the extraction before meeting and agreeing on any discrepancies with their teammate. To get a comprehensive overview and better understanding of the data material for this thesis, I did the data extraction for all studies conducted in Europe. This included 8 articles in total.

Data was then extracted using a standardized excel extraction template provided by Institute for Health Metrics and Evaluation (IHME), which was adapted to the COVID-review by CHAIN. This template included general information such as study setting, location, cohort baseline, comorbidities, confounding variables, COVID-19 assessment and definition, method of measuring exposure (education) and outcome (mortality) etc. More importantly it also included information such as subgroup analysis, definitions of potential educational groups, effect size measure and effect size estimates with confidence intervals, and absolute number of deaths. For articles that reported level of education in categories, ISCED mappings provided by UNESCO were used to translate this information into the corresponding number of years of education. During the extraction phase, an extraction manual was available to the team. This manual contained an elaboration of all information to be reported in the excel extraction template and how this information should be retrieved from an included article. A quality assessment of each data extraction was conducted by the research coordinator and research assistant, who gave individual feedback to each pair with instructions and explanations on how to improve the quality of extraction. All work following the data extraction was completed as an individual researcher.

3.2 Meta-analysis

According to the psychologist Geoff Cumming (2012), meta analytic thinking can be described as "the consideration of any result in relation to previous results on the same or similar questions, and awareness that combination with future results is likely to be valuable." (p. 9). This translates to an interest of cumulating evidence across different studies. As meta-analysis also focuses on estimates and uncertainty, it is also a type of estimation thinking (Cumming, 2012, p. 9). When evidence is cumulated over studies by a meta-analysis, the estimates are usually more precise. This is often evident by a shorter confidence interval than in single studies.

In short, a meta-analysis can be defined as a set of statistical procedures that enables combining or comparing results from different studies (Bordens & Abbott, 2018, p. 256), where the results are sufficiently similar for an overall result to be of interest. Using standardization makes it possible to compile results from studies with different measuring methods and different statistical analyses in one meta-analysis (Pripp, 2022). Different statistical analyses often report different effect sizes such as odds ratio, hazard ratio, relative risk, or a single p-value. If different effect sizes are to be summarized in a meta-analysis, they should express the same phenomenon or outcome, be sufficiently described in publications, have certain statistical properties and be possible to interpret (Pripp, 2022). By using statistical and mathematical methods one can recreate the effect sizes from different studies into a standardized mean difference. These methods translate vastly different effect sizes such as correlation, mean difference and odds ratio to a comparable statistical measure based on the relation between the estimated effect scattering in the data (Pripp, 2022).

As the point of such an analysis is to find and analyze already existing research, the meta-analysis is also a form of archival research (Bordens & Abbott, 2018, p. 256). This enables statistically guided decisions about the strength of observed effects in addition to reliability of results across studies (Bordens & Abbott, 2018, p. 256). An advantage of doing a quantitative meta-analysis is the accuracy and objectivity in the results being generated. The conclusion is likely to be more precise than looking at each study separately. Whereas a traditional literature review may be characterized by subjective interpretations or conclusions, a meta-analysis is more likely to reflect accurate strengths of relationships examined in the review (Bordens & Abbott, 2018, p. 256). Nevertheless, a thoroughly plan for the systematic literature review and the meta-analysis, in accordance with established guidelines, as well as transparency about chosen studies and data extraction is just as important as the advanced statistics for the results to have social utility (Pripp, 2022). A good systematic literature review and meta-analysis of high-quality studies can possibly decrease social inequality in health in the long run.

3.2.1 Meta-analyses with R

The finished extraction template was converted into a dataset compatible to use in the data program RStudio, which was used to generate the meta-analysis. This program is compatible with the programming language R, a standard programming language which is widely used for data analysis due to its numerous advantages and features. R has an extensive collection of built-in statistical packages, ranging from basic descriptive statistics to advanced modelling and hypothesis testing. The packages are designed to solve specific problems or address various needs. They typically provide a set of functions, which can be applied when a package is installed (Harrer et al., 2021). Thus, it provides a comprehensive environment to perform statistical analyses and exploring data. R also provides tools for manipulating and transforming data, which is convenient for preparing data before an analysis. In addition, R offers various data visualization capabilities which is crucial for identifying trends and communicating results efficiently.

What is though the main advantage of conducting specifically meta-analyses in R, is that the packages used to carry out such analyses are created of and for researchers. To perform the meta-analysis for this thesis the packages {meta}, {metafor}, {dmetar} and {dplyr}were downloaded to the RStudio program. The {meta} and {metafor} packages contain functions which make it easy to run different types of meta-analyses

(Balduzzi et al., 2019; Viechtbauer, 2010). The {meta} package also contains the function used to visualize the results of the meta-analysis through forest plots. Although these packages enable a large proportion of the analysis to be conducted, there are still some aspects which they are not programmed for. To fill this gap, the {dmetar} package was developed to provide additional functionality for the {meta} and {metafor} packages (Harrer et al., 2021). The {dplyr} package is widely used for data transformation, making it easy to manipulate and visualize data in R (Wickham et al., 2019). All data packages referred to are cited in the reference list and the RScript is attached in Appendix B.

3.3 Methodological evaluations

Evaluation is an integral part of research, which is under continuous assessment until a study is completed and reported. To evaluate the impact of this specific study, methodological evaluations need to be assessed. Therefore, the following subsections contain full transparency discussing the critiques and possible drawbacks of the methods applied in this study.

3.3.1 Challenges and critiques of conducting a systematic review

There are several conceptual and methodological challenges to conducting a systematic review. Related to the conceptual challenges, the systematic review does not have as strong empirical base underpinning its methods as other methods of research have (Gough et al., 2017, p. 9). More empirical data is needed to support the conceptuality of systematic review methods. Related to the methodological issue, there is a challenge in the lack of agreed terminology used to describe, discuss, and develop methods (Gough et al., 2012). Some of this stems from basic arguments about the function of research within knowledge production as well as ambiguous distinctions between qualitative and quantitative methodology. In example, the term "meta" might be confusing as it holds different meanings. In relation to research, it is often used to mean "about" or "beyond", and therefore meta-evaluations will be evaluations of evaluations (Gough et al., 2017, p. 9). This indicates that systematic reviews can be understood as meta-evaluations.

In addition, many of the words used in reviews may give misleading expectations. The word "synthesis" may suggest aggregation to some people whereas others will expect a configuring of findings (Gough et al., 2017, p. 10). While configuring syntheses essentially arrange findings from primary studies with an aim to generate new theory or explore the salience of existing theory, aggregative syntheses predominantly add up the findings from primary research with the objective to test theories or hypotheses (Gough et al., 2017, pp. 63-64). Studies included in aggregative syntheses are also much more homogenous, concerning either methods or conceptualisations of the phenomena of interest, which makes it possible to compile findings to generate results of greater precision. As this systematic review has the objective to add up previous findings, test an expected hypothesis, and ensures homogeneity in conceptualisations through well-defined inclusion criteria, it is thus an aggregative synthesis. This approach begins with a pre-determined conceptual view and make assumptions about generalizability based on the statistical properties of the populations and the observed results (Gough et al., 2017, p. 64). For this specific study the pre-determined conceptual view is that there are social inequalities in adult COVID-19 mortality, which are caused by inequities in educational attainment which existed before the pandemic outbreak and can be generalized beyond the study population.

Research constraints may pose another challenge to systematic reviews. As reviews are major pieces of research that require both time and resources, the availability of these will impact what type of review can be undertaken (Gough et al., 2017, p. 10). The research project that this master thesis is part of has been time consuming, but with voluntary researchers contributing it has been possible to conduct the study on the scale envisaged. No funding has been received to conduct this research. Another possible challenge to systematic reviews is the capacity constraints in terms of individual and organizational skill and infrastructure to undertake reviews (Gough et al., 2017, p. 10). As the methodological development of conducting systematic reviews is quite recent, relatively few people have the advanced review skills needed. For this specific project the Centre for Global Health Inequalities Research (CHAIN) at NTNU in Trondheim has the organizational skills and infrastructure needed to organize this review and facilitate training for those individual researchers joining the project who are not familiar with the methodologies. This has enabled the study to be undertaken, while also allowing more people to gain review skills.

Yet another challenge are the capacity constraints for using the results from systematic reviews. This does not only involve the capacity to read and understand this kind of research, but also knowledge about how to interpret and apply the findings in meaningful and useful ways (Gough et al., 2017, p. 11). For research to be applied there needs to exist an active engagement between those conducting the research and those applying it. Because this research was requested by the World Health Organization with the intention to guide future policy on health inequalities, this capacity is most likely assured already.

Another criticism of systematic reviews is that they often consider relatively few studies and therefore is ignoring much relevant research on the given topic (Gough et al., 2017, p. 11). However, this criticism does not apply to this review. Because there was conducted a broad literature search in seven different databases, limited to articles being published after February 2020 which is only two months after the first cases of COVID-19 were detected, this most probably involves nearly all articles on the topic of social inequalities in COVID-19 mortality. In addition, to justify the narrowing of topic boundaries must be defined. The boundaries for this specific study are thoroughly defined through the exclusion criteria presented in Table 1, Table 2, and Table 3. The inclusion/exclusion criteria of systematic reviews can include issues as the topic focus, method of primary research, and the research quality (Gough et al., 2017, p. 11). Researchers within different fields and paradigms will have different perspectives of what constitutes good quality and relevant evidence (Gough et al., 2017, pp. 11-12). Nevertheless, this is the nature of academic discourse and occurs in both primary research and systematic reviews. The research group conducting this systematic review consists of researchers from various disciplines, such as biology, medicine, economics, and sociology. However, my perception is that this has been a strength rather than a weakness. I found the boundaries to be more elaborated and justified as they were discussed among the group in which different perspectives were present.

3.3.2 Drawbacks to meta-analysis

Meta-analysis can be a powerful tool for evaluating results across studies (Bordens & Abbott, 2018, p. 258) and adopting them for more precise measurements. However, while many researchers have welcomed this method of research, others raise criticism for several reasons. The most common criticism is probably the issue of publication bias. This implies that a bias in the published literature carries over to a meta-analysis based on this literature (Borenstein, 2009, p. 278). However, the issue of publication bias is not unique to meta-analyses. It affects the researcher writing a narrative review and even the clinician searching a database for primary papers (Borenstein, 2009, p. 277). The reason why it has received more attention in regard to meta-analyses is possibly because these are promoted to be more accurate than other synthesising research approaches (Borenstein, 2009, p. 277). Studies that report positive and significant evidence are more likely to be published and will create the basis for all further research. As publication bias thus is relevant in all research, it is unfair that meta-analyses get all this criticism.

Another possible drawback and problem that has been criticised is how to deal with uneven quality of research (Bordens & Abbott, 2018, p. 259). Should the data from articles weigh the same even if they are published in journals with unequal referrals? Unfortunately, there is no existing agreement to this question. However, a journal being referred does not ensure the quality of published research. In fact, research using new methods may sometimes be rejected from journals even if they are methodologically sound and of high quality (Bordens & Abbott, 2018, p. 259). Likewise, publication in a peer-reviewed journal can be an indication that the published research is of high quality although it is never a guarantee. The data material can also be weighed according to soundness of methodology, regardless of the quality of the journal it is published (Bordens & Abbott, 2018, p. 259). The 5 studies included in this meta-analysis have been systematically reviewed and tested for eligibility through several phases of the research process and are therefore considered to be of high quality. As the different data material was assessed to be rather equal in terms of methodology and quality, the random-effects model generated the weights.

That it is difficult to understand the comparability of studies with widely varying materials, methods, and measures is yet a common criticism of meta-analysis (Bordens & Abbott, 2018, p. 260). This is often referred to as the "apple-versus-oranges argument", which was introduced by statistician and researcher Gene Glass in 1978. However, this criticism is not valid. Rosenthal (1991) points out that comparing results from different studies is like averaging across heterogeneous subjects within an ordinary experiment (p. 129). If averaging across subjects is accepted, then averaging across heterogenous studies should also be approved of. Therefore, the core issue is not whether averaging should be done across heterogeneous studies but rather whether the difference in methods relates to different effect sizes (Bordens & Abbott, 2018, p. 260). All effect sizes extracted from the included studies revealed estimates above 1, indicating a positive relationship between the group of exposure and the outcome studied. Despite the apparent similarity in effect sizes, the analyses indicated high level of heterogeneity. If methodological differences appear to be related to the outcome of research, studies could simply be blocked from the meta-analysis to determine its effects (Rosenthal, 1991, p. 130). As heterogeneity measures differences or variations within sample effect sizes, methodological differences were not considered to determine these variations and no studies were blocked from the thesis meta-analysis on this basis.

Furthermore, conducting a meta-analysis is a massive task. Studies examining the same issue or topic may use a great variety of methods and statistical techniques. Also, some studies may not provide sufficiently information needed to conduct a meta-analysis

(Bordens & Abbott, 2018, p. 260). This may be the cause of some studies having to be eliminated. The problem of insufficient of inaccurate information can lead to an unrepresentative sample of studies being included in the meta-analysis (Bordens & Abbott, 2018, p. 260). For this specific study including 8 references chosen out of 1028 included articles in the project, this should not be considered a drawback. Critics also question whether the result of a meta-analysis is any different from traditional research. In answering this, Cooper & Rosenthal (1980) notes that a meta-analysis is generally more willing to reject the null hypotheses than traditional research (p. 448). Therefore, using meta-analysis may lead to a reduction in type II decision errors, meaning to conclude that a variable has no effect when it does have one (Bordens & Abbott, 2018, p. 261). Lastly, it is worth noting that using the statistical approach inherent in meta-analysis follows the same research strategy as the statistical analysis of data from traditional experiments (Bordens & Abbott, 2018, p. 261). That means statistical analysis are applied to evaluate whether associations exist. Rather than looking at studies speculating about possible associations, it can be argued that it is better to apply a statistical analysis to results of different studies to determine whether significant associations do exist (Bordens & Abbott, 2018, p. 261).

3.4 Quality criteria

Different attributes can be used to assess the quality of a measure in research. In quantitative research, the attributes of generalizability, reliability and validity are often referred to as the main quality criteria. The generalizability implies if the findings from the analyses can be considered as valid for the rest of the population from which the study sample was drawn. This is affected by the level of significance in the meta-analyses, which is provided for each of the effects in the analysis subsection. The overall generalizability of the findings is then commented on in the discussion. The following subsection will explain the quality criteria of reliability and validity, enabling a reflection on the quality of both the data material and the thesis findings in total.

The reliability of a measure concerns its ability to produce similar results given that the repeated measurements are reproduced under identical conditions (Bordens & Abbot, 2018, p. 130). If the results from several measurements correspond to a large extent, the study can be assumed to have high reliability. As the meta-analysis of this master´s thesis is based on data material derived from systematically synthesizing available research on the topic, which includes results from several measurements that most likely corresponds to a large extent, this study can be argued to have high reliability. More specifically, the meta-analysis is a compilation of findings from various studies, where the idea is that generating these into one single analysis will provide more precise and accurate knowledge. To make use of findings from various studies in the same analysis, the measured values must be of the same nature. This prerequisite obviously underscores the reliability. Moreover, reliability is also of interest when two or more researchers conduct the same work. This is called interrater reliability and indicates the degree to which multiple researchers agree in their classification or decision (Bordens & Abbott, 2018, p. 234). In this research project, consensus indicates that researchers interpret the given criteria the same way. Theoretically, if the researchers are well trained and the criterion well defined, there should be a minimum of disagreements (Bordens & Abbott, 2018, p. 234). However, disagreements are likely to arise despite performing with best efforts. Researchers may differ in how they understand and implement the criteria. In my experience, there were quite few disagreements on whether to include or exclude specific records during the full article screening phase. As all disagreements were discussed and corrected, or decided by a third researcher if an agreement could not be made, I would argue that the interrater reliability of this study is high.

The validity of a study is the extent to which it measures what it was intended to measure (Bordens & Abbott, 2018, p. 133). A study with high validity will have a logical link between the project design and findings, as well as the research questions it seeks to answer. Also, high reliability is a prerequisite for high validity. While the reliability is a solely empirical question, the validity also involves a theoretical assessment (Skog, 2004, p. 114). Such a theoretical evaluation is possible if all steps in the research project is sufficiently described. Furthermore, the understanding of validity in research is often divided in two important but sometimes conflicting attributes, namely internal and external validity.

Internal validity is the ability of the research design to adequately test the hypothesis put forward (Bordens & Abbott, 2018, p. 115). A study of high internal validity therefore presents a research design with ability to test the hypothesis or multiple hypotheses that it was designed to test. As this study seeks to test the hypothesis that lower educational attainment is associated with increased COVID-19 mortality, a systematic review and meta-analysis seems like an adequate way of testing this assumption. The methods applied will generate precise results merged from already existing research on the topic, enabling to either confirm or reject the hypothesis presented. In a correlational study like this one, testing the hypothesis also includes showing that changes in the value of the criterion variable only relate to changes in the value of the predictor variable and not to changes in other covariate variables (Bordens & Abbott, 2018, p. 115). Consequently, internal validity can be threatened to the extent that such extraneous variables can provide alternative explanations for the study findings (Bordens & Abbott, 2018, p. 115). Huck and Sandler (1979) call these rival hypotheses. The substantial heterogeneity revealed in the meta-analysis can be an indication of the confounding variables controlled for in some of the included studies. Bordens and Abbott (2018) claim that although confounding variables is always a matter of concern, it does not automatically represent a serious threat to internal validity (p. 116). If the effects of the confounding variables are known, a study may include confounding variables and still maintain a reasonable degree of internal validity (Bordens & Abbott, 2018, p. 116). As the research design is adequate for testing the hypothesis and information about all confounding variables is available in the respective included studies, I argue that this study retain a fair level of internal validity. Hence, there is no basis for assuming rival hypotheses.

External validity, on the other hand, reflects to what degree the results of a study can be extended beyond the limited research setting and sample where they were originally obtained (Bordens & Abbott, 2018, p. 119). For findings to be generalized immediately to real-world situations and to larger populations, studies should be conducted with great external validity (Bordens & Abbott, 2018, p. 119). As the results of this study summarize findings from previously conducted studies that claim to be generalizable, while also giving more precise measurements, they can be considered as applicable to larger populations. Hence, it is reasonable to assume that this study has high external validity.

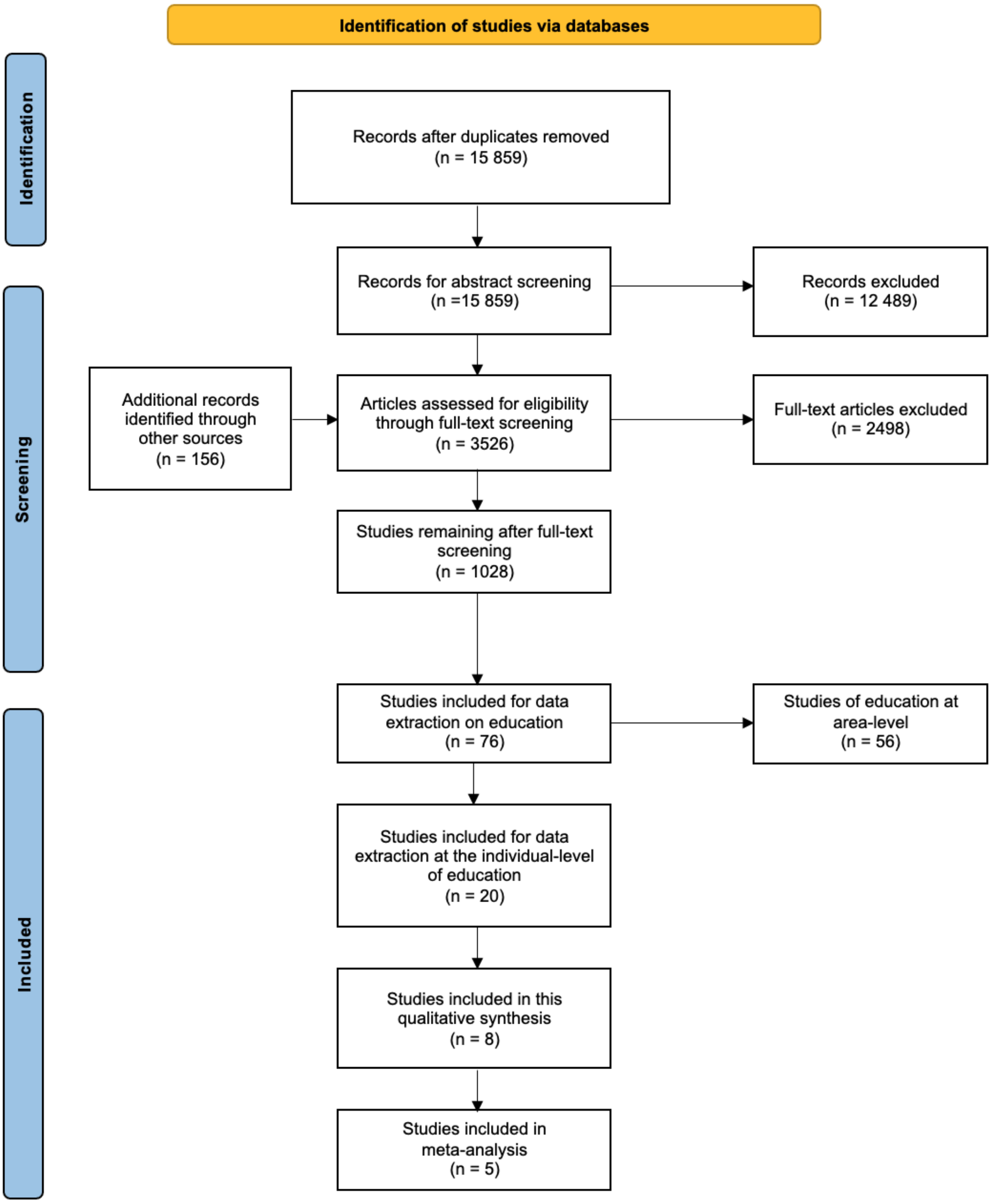
4.0 Results

The following chapter will present the results from the systematic review and meta-analysis. This means that the included articles from the systematic review first will be presented through a qualitative synthesis and descriptive characteristics, which creates a better understanding of the data material included in the following analysis. Then the findings emerged in the meta-analysis will be presented through plots and textual explanations. The findings will be interpreted based on the effect size of the association between the variable and the outcome studied.

4.1 Qualitative synthesis of included articles

The initial literature search conducted in seven different databases landed 15 859 records to be reviewed in the abstract screening phase. Of these 15 859 records, 3526 were eligible for full article screening. This identified 1028 records that all included effect estimates for associations between some axis of social inequality and adult COVID-19 mortality. Because articles in the full article screening phase were labelled by socioeconomic axis and representativeness, in line with the criteria listed in the methods chapter above, this enabled an overview of the number of records investigating the different social inequality axes. For the education variable as a socioeconomic axis this amounted to 76 articles. Out of these 76 studies, only 20 measure education at the individual level. The rest are area-based studies that examine educational inequalities by percentage of population dying from COVID-19. While individual level data enables a study of causal mechanisms of COVID-19 mortality, area-based estimates would be subject to a lot of noise and simply offer a correlation between education and mortality which is not connected at the individual level. This means that the outcome is not directly linked with education and may show an effect influenced by several factors. As the intention is to study the association between educational attainment and COVID-19 mortality, only the studies reporting individual level data was relevant for data extraction. In total, 8 of the individual level studies examining education was conducted within Europe. The number of records within each phase of the systematic review is visualized in a Prisma Flow diagram in Figure 2 below. Number of records per exclusion reason for full-text articles excluded are not listed, as the project is still in progress and work remains.

Figure 2: Prisma Flow diagram



Note. Diagram adapted from Page et al. (2021).

Of the 8 studies included in this synthesis, six are retrospective cohort studies whereas two are prospective cohort studies. Across all studies, a total of 58 885 845 individuals were studied with 90 425 reported deaths. From the total of 58 885 845 participants included, 47 100 396 (79,9 %) were participants from Spain. This high percentage is due to the study by Soriano et al. (2022), where the entire Spanish population in 2020 constituted the study population. In Sweden there were a total of 11 142 722 (18,9 %). However, because of the overlapping use of statistical data sources there is a risk of double-counting individual observations across studies. The total number of Swedish participants also exceeds the population figure in Sweden of just over ten million people.

From United Kingdom, 633 514 (1,1 %) participants were reported where 159 964 of them were participants in an all-male study. The study conducted in Turkey examined 9213 (0,02 %) individuals with type 2 diabetes mellitus and the association between education and COVID-19 mortality in this group.

Half of the studies used administrative registry for measuring individual education, while one study used self-reporting methods and others failed to report their method of measuring educational attainment. However, all studies retrieved data from national databases or statistical registries. Therefore, it is reasonable to assume that this information was either self-reported when being registered or that information is based on national overviews. All studies used ICD-codes to determine mortality in participants, where two of the studies applied ICD-codes in combination with administrative records as their assessment of death. Five studies defined mortality in terms of "COVID-19 deaths by ICD-codes". The rest of the studies were less specific in their mortality definition, such as the Turkish study with the definition "mortality at any point of hospitalization" (Sonmez et al., 2021). One of the Swedish studies only reported "death from COVID-19" (Wallin et al., 2022) as a possible mortality definition, while the Spanish study considered mortality as "death attributed to COVID-19 virus identified and COVID-19 virus not identified (suspicious)" (Soriano et al., 2022). Even though some studies could have been more specific when reporting their mortality definition, they all used ICD-codes as their method for assessment of death. This indicates that the participants in the studies that did die, with high probability died from the COVID-19 virus. The length of follow-up for these cohort studies varied from 56 days to a year.

Table 5: Descriptive characteristics of included studies

Author	Study size	Male population	Number of deaths	Country
Drefahl et al., (2020)	7 775 054	49 %	3126	Sweden
Elliott et al., (2021)	473 550	45 %	459	United Kingdom
Gustafsson et al., (2022)	72 728	42 %	5863	Sweden
Rostila et al., (2022)	1 778 670	50 %	1454	Sweden
Sonmez et al., (2021)	9213	43 %	1250	Turkey
Soriano et al., (2022)	47 100 396	49%	74 839	Spain
Wallin et al., (2022)	1 516 270	49 %	2996	Sweden
Yeap et al., (2022)	159 964	100 %	438	United Kingdom

4.1.1 Qualitative synthesis of association between educational attainment and mortality

All the 8 cohort studies gave estimates for the entire study population, including estimates from Sweden, United Kingdom, Turkey, and Spain. To study the association between educational attainment and COVID-19 mortality in a somewhat larger sample of the included studies than could be used for the meta-analysis, the reported effect estimates for these 8 studies are presented in Table 6 below. This synthesis mostly presents effect sizes reported for low or medium educational groups compared with the highest educational group studied. In the study of Yeap et al. (2022) the only effect size reported is a measure of the association between the highest educational group and COVID-19 mortality, compared to all participants that did not fit into this category. Sonmez et al. (2021) reported an effect size for the association between 9 years or more education and COVID-19 mortality, assumably compared to all participants not eligible for this education group. It should also be noted that the educational categories used within the studies correspond to different numerical years of education. This means that a complete comparison of the effect estimates is not possible. A majority of the estimates also controlled for age and sex by education.

Most studies included in this qualitative synthesis already reported calculated effect estimates, while the study by Sonmez et al. (2021) did not. However, the study reported sufficient information to calculate effect sizes and examined educational categories compatible with the meta-analysis. Using the information about study sample and distribution of mortality in each educational category, odds ratios were calculated using the formula below.

$$OR = (a/b) / (c/b),$$

where *a* is the number of individuals from the exposed groups who experienced the outcome, *b* is those in the same group who did not experience the outcome, while *c* is the number of individuals in the unexposed group who experienced the outcome and *d* is those is the same group who did not experience the outcome. This means that the number of COVID-19 mortalities in the educational group studied were compared to COVID-19 mortalities in the reference group.

A majority of the effect estimates (78,6 %) reported in the studies suggests a statistically significant association between either low or medium level of education and COVID-19 mortality. One estimate from the study by Elliott et al. (2021) includes the null value of 1 in the confidence interval, indicating that the estimate does not show a statistically significant association. The studies by Sonmez et al. (2021) and Yeap et al. (2022) reported the only two effect estimates showing a negative association between education and mortality. The odds ratio of 0.53 by Yeap et al. (2022) indicates that the odds of mortality in participants with high educational level are lower than the same outcome for participants in the reference group consisting of people without higher education. As the assumption is that low level of education is associated with COVID-19 mortality, an effect estimate of the association between high education and mortality is thus expected to show a negative effect. Also, because the reference category includes all participants that do not fit into the highest educational group this can be a contributing factor to the odds ratio measure. More importantly, this type of combination of low and medium education groups into one category gives an average measure that may not account for all inequalities that exist within and between groups. Both studies representing entire countries (Drefahl et al., 2020; Soriano et al., 2022) showed a positive significant association between level of educational attainment and COVID-19 mortality. Most estimates accounted for a number of control variables, none of which led to noticeable abnormalities in comparison to other studies. The estimate from the study by Wallin et al. (2022) controlled for no confounding variables and reported the highest hazard ratio estimate of association.

All studies were categorized for representativeness, based on criteria described in the extraction manual which included a star system ranging from 0 to 5 stars. As shown in Table 6 below, a majority of the studies were rated 5 stars in representativeness. This indicates that they are studies based on governmental records or national registers that claim to represent the entire population. The studies by Sonmez et al. (2021) and Yeap et al. (2022) were both rated 4 stars representativeness indicating that the studies are based on governmental records or national registers and claim to represent a target population. The study population in the Turkish study was limited to inpatients, whereas the all-male study from United Kingdom targeted a certain age group across 22 assessment centres. Wallin et al. (2022) and Rostila et al. (2022) both received 3 starts of representativeness. As they both study the population in Stockholm, they are considered regional representative studies.

Table 6: Reported effect sizes for entire sample in included studies

Study	Effect size	Confidence interval	Ages	Representativeness	Education groups compared
Odds ratio					
Elliott et al., (2021)	1.17	[1.02-1.34]	40-69	5 stars	Low High (ref)
Elliott et al., (2021)	1.11	[0.94-1.30]	40-69	5 stars	Intermediate High (ref)
Sonmez et al., (2021)	0.66	[0.43-1.02]	18 +	4 stars	Education (=>9 years) Not specified (ref)
Soriano et al., (2022)	1.08	[1.04-1.13]	18-99	5 stars	Primary Professional training (ref)
Soriano et at., (2022)	1.05	[1.01-1.10]	18-99	5 stars	Secondary Professional training (ref)
Yeap et al., (2022)	0.53	[0.42-0.66]	40-69	4 stars	College/university No college/university (ref)
Hazard ratio					
Drefahl et al., (2020)	1.34	[1.20-1.49]	20 +	5 stars	Primary Postsecondary (ref)
Drefahl et al., (2020)	1.30	[1.17-1.44]	20 +	5 stars	Secondary Postsecondary (ref)
Gustafsson et al., (2022)	1.11	[1.02-1.19]	26 +	5 stars	Primary (<10 years) Tertiary (ref)
Gustafsson et al., (2022)	1.12	[1.04-1.20]	26 +	5 stars	Secondary (10-12 years) Tertiary (ref)
Wallin et al., (2022)	1.70	[1.50-1.90]	25 +	3 stars	<= 9 years >12 years (ref)
Wallin et al., (2022)	1.50	[1.30-1.60]	25 +	3 stars	10-12 years > 12 years (ref)
Relative risk					
Rostila et al., (2022)	1.59	[1.37-1.83]	21 +	3 stars	Primary Tertiary (ref)
Rostila et al., (2022)	1.47	[1.28-1.68]	21 +	3 stars	Secondary Tertiary (ref)

Note. Studies coloured in green suggests a statistically significant association between lower educational groups and COVID-19 mortality. The studies in yellow suggests a statistically significant association between medium educational groups and COVID-19 mortality, while the study coloured in orange suggests a non-significant association for the same relationship. The study in red suggests a negative association between high educational group and COVID-19 mortality, whereas the study in blue suggests a negative association between education (=> 9 years) and the same outcome.

4.2 Results of meta-analysis

Of the 8 studies included in the qualitative synthesis, 5 studies were eligible to be included in the meta-analysis. There were two reasons why articles in the qualitative synthesis were disqualified from the meta-analysis. First, the study by Rostila and colleagues (2022) reported effect estimates in relative risk, whereas the rest of the studies reported effect sizes in odds ratio or hazard ratio. As the study did not contain sufficient information about the study sample and the distribution of mortality and survival within the different educational categories, it was not possible to calculate any other effect estimates. Thus, with different effect estimates these were incompatible to include in the meta-analysis. Second, the study by Yeap and colleagues (2022) only reported an effect size for association between the highest educational group and COVID-19 mortality, compared to those without higher education. As only this study reported an estimate for this specific relationship, it was impossible to merge this in the meta-analysis. The same reason applies to the study conducted by Sonmez and colleagues

(2021), which reported an effect size of mortality risk for those with 9 years or more education compared to all participants that did not fit into this category. Nor was this specific relationship comparable with any other effect estimates in a meta-analysis. All studies qualified for inclusion in the meta-analyses already reported calculated effect estimates.

For the meta-analysis, low educational attainment was classified as primary school or according to the UNESCO International Standard Classification of Education (ISCED) groups (1) and (2). Medium level of education was classified as intermediate or secondary education, or ISCED groups (3) and (4). The highest educational level was categorized as postsecondary, tertiary, or college/university and was classified by ISCED groups (5), (6), (7), and (8).

Table 7: Years of education for ISCED groups by country

Country	ISCED grouping	Years of education
Sweden	(1) (2)	1 to 9
	(3) (4)	10 to 12
	(5) (6) (7) (8)	> 12
United Kingdom	(1)	1 to 6
	(2) (3) (4)	7 to 11
	(5) (6)	> 11
Spain	(1)	1 to 6
	(2) (3) (4)	7 to 12
	(5) (6)	> 12

Note. Information retrieved from UNESCO Institute of Statistics (2023).

As the studies included in the meta-analysis reported effect sizes in either odds ratio or hazard ratio, which are statistical measures not comparable to each other, the studies were divided into two separate streams of analyses. Whereas the odds ratio compares the odds of an event occurring between two groups, a hazard ratio measure compares the risk of an event occurring between two groups over time. Furthermore, when deciding to include a group of studies in a meta-analysis, an assumption exists that they have enough in common and it makes sense to synthesize the information (Borenstein et al., 2009, p. 69). One can assume that the studies and effect sizes they report are similar but not identical. To address the possible variation across studies, a random-effects meta-analysis was conducted (Borenstein et al., 2009, p. 70). Statistical significance was measured by p-value below 0.05 for all analyses.

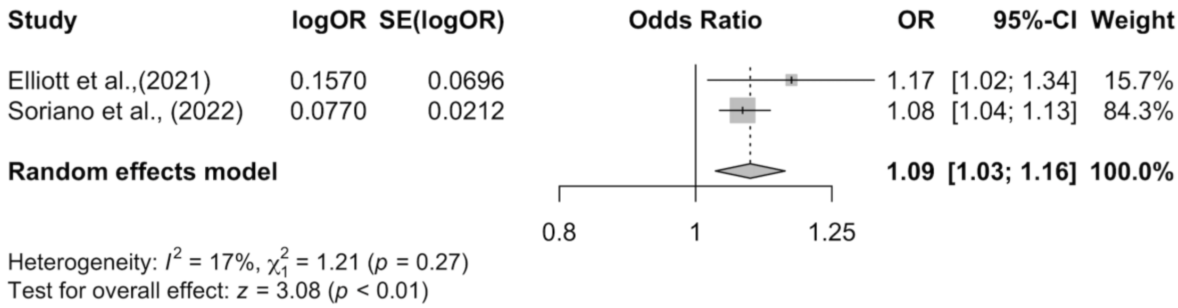
4.2.1 Analysis of the association between educational attainment and COVID-mortality

Five studies reported sufficient information to be included in the analyses between predetermined educational categories and adult COVID-19 mortality in Europe. As the studies were divided into two streams of analyses, the results from odds ratio analyses will be presented first followed by results from hazard ratio analyses.

Figure 3 shows the odds ratio of COVID-19 mortality for low educational attainment, with the highest educational group as the reference category. The figure displays the individual studies and their calculated or reported odds ratio (OR) bounded by their 95 % confidence intervals (CI) along with standard error (SE) and respective weight for the random-effects model, while also providing a forest plot visualization which includes a graphical representation of the effect size for all individual studies. This is visualized by a point estimate, supplemented by a line representing the range of the confidence interval for the observed effect size (Harrer et al., 2021). The point estimate is also surrounded by a square. The weight of the effect size determines the size of this square; studies with a higher weight have a larger square, while studies with a lower weight are given a smaller square (Harrer et al., 2021). What determines the weight itself is the precision and standard error of the effect sizes. Estimates with a high precision, meaning a smaller standard error, will be given a greater weight (Harrer et al., 2021). Thus, a smaller square indicates a higher SE and larger uncertainty. Squares located to the right of the line placed on the null value 1 indicate an effect size and therefore a larger risk of COVID-19 mortality by low educational attainment. The more to the right a square is located, the more the effect size and risk of mortality increases. A value of 1 would imply no additional risk of COVID-19 mortality for those with low educational attainment compared to those with higher education. This entails that a confidence interval including the null value of 1 will never be significant (Bordens & Abbott, 2018, p. 443).

For this analysis odds ratios ranged from 1.08 to 1.17, with no confidence intervals including the null value of 1. The overall estimate generated from the random-effects model revealed an OR of 1.09. An odds ratio greater than 1 indicates a positive association, meaning that the exposure or risk factor being studied increases the odds or likelihood of the outcome. For this specific analysis it can be interpreted that individuals with low educational attainment have approximately 1.09 times higher odds of COVID-19 mortality compared to individuals with higher educational attainment. As the odds ratio of 1.09 has a corresponding 95 % CI of 1.03 to 1.16, this ultimately denotes the effect low educational attainment has on COVID-19 mortality as significant ($z = 3.08$, $p = 0.01$). The random-effects model assumes that the heterogeneity causes the true effect sizes of studies to differ within a meta-analysis, and therefore includes an estimate to quantify the variance and still calculate the pooled effect (Harrer et al., 2021). The *Q* statistic and accompanying I^2 statistic were included to assess heterogeneity between studies in these meta-analyses. The *Q* values in R prints as x^2 and therefore corresponds to x^2 in the forest plots. As the *Q* statistic was not statistically significant ($x^2 = 1.21$, p = 0.27) and the I^2 value is 17 % this suggests low and non-significant heterogeneity. Since the lack of significance may be due to low power, a non-significant p-value for the *Q* statistic should not be considered evidence that the effect sizes are consistent (Borenstein, 2009, p. 113). The small number of studies might cause a non-significant p-value even if there exist substantial variances between study estimates.

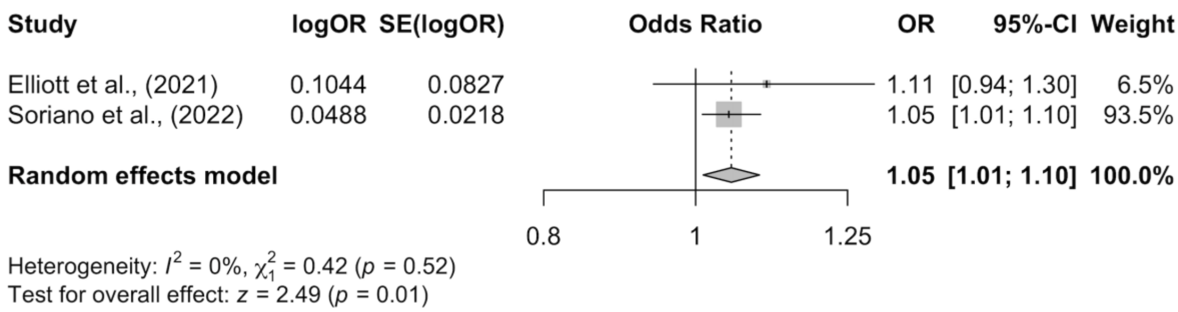
Figure 3: Forest plot for low educational attainment compared to high in odds ratio



Note. Low educational attainment equates to primary education, while high educational attainment equates to postsecondary or tertiary education. High educational attainment is the reference category.

Figure 4 illustrates the meta-analysis and forest plot comparing the association between medium educational attainment and COVID-19 mortality with high educational attainment. For this analysis the odds ratios ranged from 1.05 to 1.11, with the confidence interval of the estimate from the study by Elliott et al. (2021) including the null value of 1. The random-effects model generated an overall effect estimate of 1.05 odds ratio. Like the previous estimate, this also suggests a positive association between the group studied and the mortality risk. This means that individuals with medium educational attainment have a slightly lower odds than those with low educational attainment, but still 1.05 times higher odds of COVID-19 mortality compared to individuals with higher education. As the odds ratio of 1.05 has a corresponding 95 % CI of 1.01 to 1.10, which does not include the null value of 1, this implies that the effect medium educational attainment has on COVID-19 mortality is significant (z = 2.49, p = 0.01). The Q statistics were again not statistically significant (x^2 = 0.42, p = 0.52), and the I^2 value estimates that 0 % of the variation between studies is caused by heterogeneity. As mentioned, this does not ultimately indicate that the effect sizes are consistent. The lack of significance may be due to low power (Borenstein, 2009, p. 113), as only two studies are included in the analysis.

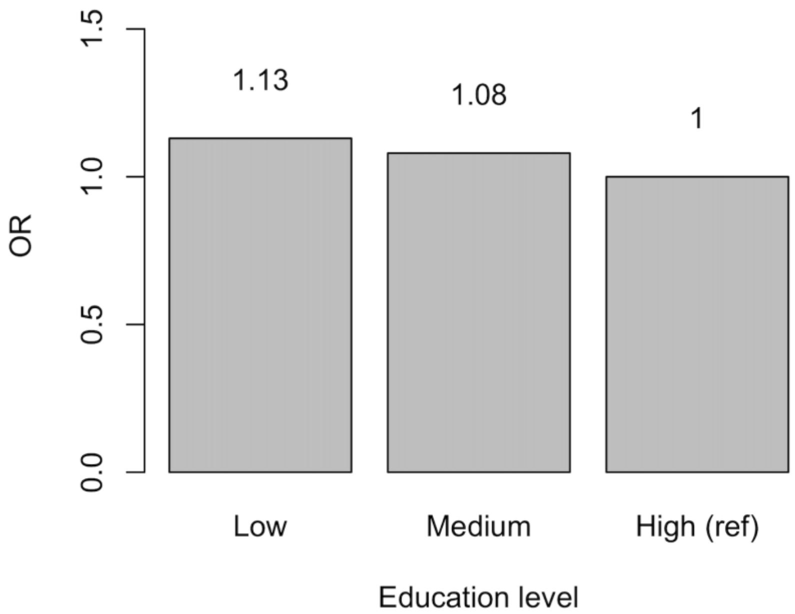
Figure 4: Forest plot for medium educational attainment compared to high in odds ratio



Note. Medium educational attainment equates to intermediate or secondary education, while high educational attainment equates to postsecondary or tertiary education. High educational attainment is the reference category.

In Figure 5, the educational gradient in COVID-19 mortality with average odds ratio estimates for low and medium level of education is portrayed. The gradient shows that for each additional level of education achieved there is a small stepwise decrease in mortality risk. Those with low level of education experience 1.13 times the odds of COVID-19 mortality, while those with medium level of education experience 1.08 times the odds of COVID-19 mortality compared to those with higher education. In addition to the educational gradient in COVID-19 mortality, the barplot visualization also shows a gap effect of education. This gradient substantiates that people with low educational attainment have a higher risk of COVID-19 mortality than those with medium educational attainment compared to those with higher educational attainment.

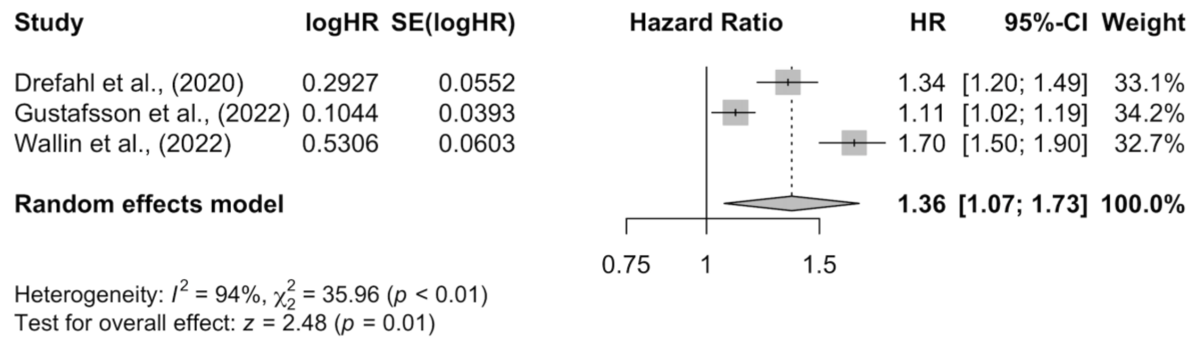
Figure 5: Educational gradient in COVID-19 mortality in odds ratio



Note. Average odds ratio for COVID-19 mortality by education level.
Higher level of education is the reference category.

Figure 6 shows the hazard ratio for COVID-19 mortality for low educational attainment compared to high. For this analysis the hazard ratios ranged from 1.11 to 1.70, with no confidence intervals including the null value of 1. The overall estimate from the random-effects model was a hazard ratio of 1.36. A hazard ratio greater than 1 indicates a higher risk of the event in the group being studied compared to the reference group. The interpretation of this specific analysis is that individuals with low educational attainment have a hazard of experiencing COVID-19 mortality which is approximately 36 % higher compared to those in the high education group. As the overall hazard ratio of 1.36 has a corresponding 95 % confidence interval of 1.07 to 1.73 which does not include the null value of 1, this ultimately signifies that the association between low educational attainment and COVID-19 mortality is significant (z = 2.48, p = 0.01). The Q statistic was statistically significant ($x^2 = 35.96$, $p < 0.01$) and the I^2 value suggested high heterogeneity of 94 %.

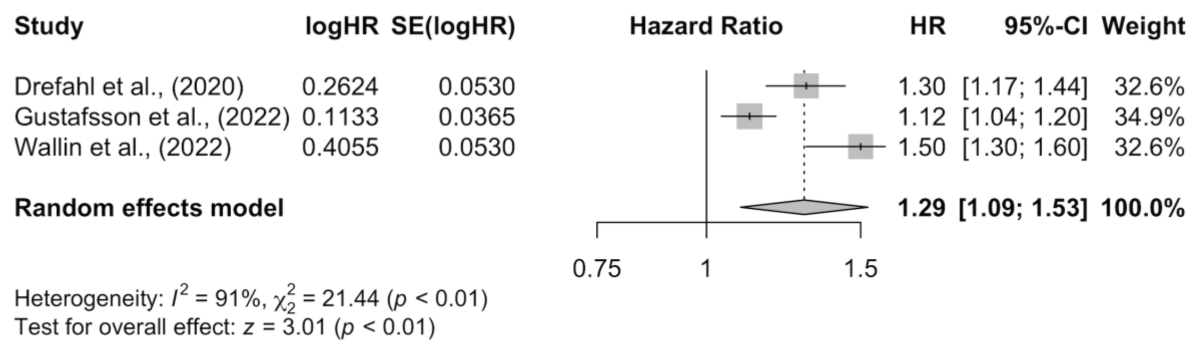
Figure 6: Forest plot for low educational attainment compared to high in hazard ratio



Note. Low educational attainment equates to primary education, while high educational attainment equates to postsecondary or tertiary education. High educational attainment is the reference category.

Figure 7 illustrates the meta-analysis and forest plot comparing COVID-19 mortality risk of people with medium educational attainment to those with higher education. The hazard ratios included in this analysis ranged from 1.12 to 1.50, where neither of the estimates had a confidence interval including the null value 1. The random-effects model showed an overall estimate of 1.29 HR. In line with the previous estimate, this also suggests a higher risk of the outcome in the exposed group compared to the reference category. Thus, do individuals with medium educational attainment have a somewhat lower risk of mortality than those with low educational attainment, yet a hazard of experiencing COVID-19 mortality that is 29 % higher than individuals with higher education. As the 95 % CI corresponding to the overall estimate ranges from 1.09 to 1.53 the association is significant (z = 3.01, p < 0.01). Once again the Q statistic was statistically significant (x^2 = 21.44, p < 0.01), while the I^2 value suggests that 91 % of the variation in true effect sizes is caused by heterogeneity rather than chance. This again is considered high heterogeneity.

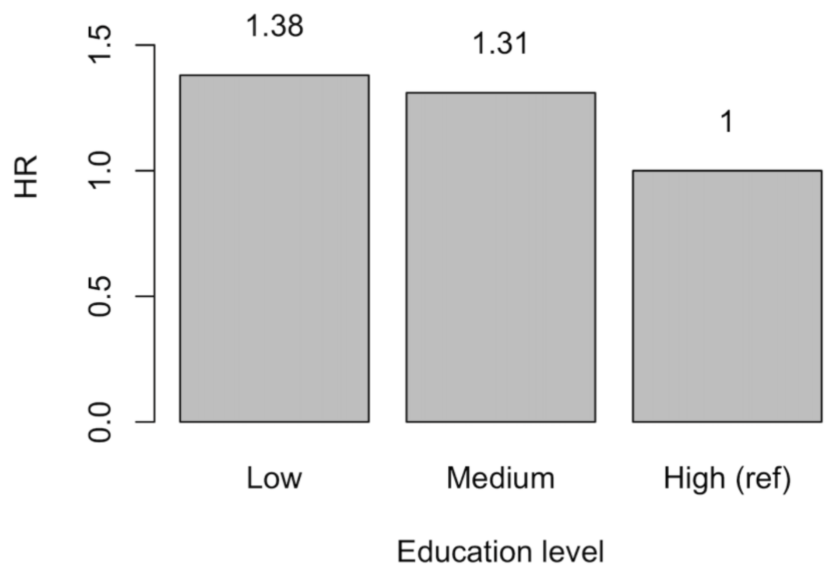
Figure 7: Forest plot for medium educational attainment compared to high in hazard ratio



Note. Medium educational attainment equates to intermediate or secondary education, while high educational attainment equates to postsecondary or tertiary education. High educational attainment is the reference category.

In Figure 8, the educational gradient in COVID-19 mortality with average hazard ratio estimates for low and medium education levels is illustrated. There is a small stepwise decrease in the mortality risk for each additional level of education achieved, which is slightly larger than for the odds ratio educational gradient. The barplot visualizes that people with low level of education experience 1.38 times the mortality risk, while people with medium level of education experience 1.31 times the risk of COVID-19 mortality compared to those with high educational attainment. Like the educational gradient for odds ratio, this also demonstrates the gap effect of education. For this hazard ratio gradient, the gap between medium and high level of education is more noticeable in difference between the bars than in the odds ratio gradient. It proves that adults with low educational attainment have a higher risk of COVID-19 mortality than those who have completed medium educational attainment in comparison with individuals of higher educational attainment.

Figure 8: Educational gradient in COVID-19 mortality in hazard ratio



Note. Average hazard ratio for COVID-19 mortality by educational level.
High level of education is the reference category.

5.0 Discussion

The following part of the thesis contains a discussion of the results emerged in the analysis above. The results will be discussed considering the theoretical perspectives explored in the theory chapter. Findings which are relevant for answering the research question will be subject of discussion. As mentioned in the introduction, the overall research question for this master thesis reads as follows: *Is educational attainment associated with COVID-19 mortality for adults in Europe?*

5.1 Effect of educational attainment on COVID-19 mortality

This study is the most comprehensive systematic review and meta-analysis to date examining the association between educational attainment and adult COVID-19 mortality. Although the meta-analysis only includes merging analyses of 5 previous studies, these are the European studies of the education social axis that are accessible and comparable in a meta-analysis, from a sample of 15 859 records identified on social inequalities in COVID-mortality across several different databases. By systematically screening the existing literature on the topic, completing a qualitative synthesis of included studies, and thereafter conducting meta-analysis, this study contributes with important insights towards understanding the relationship between educational attainment and COVID-19 mortality in adults. The meta-analysis results suggest that low and medium educational attainment are associated with an increase in COVID-19 mortality for adults in the European countries studied. More specifically, they indicate that individuals with low educational attainment have an even higher mortality risk than those with medium educational attainment, when the highest educational group serves as a reference category. All findings are statistically significant, measured by p-value below 0.05.

As most effect sizes included in the meta-analysis were statistically significant when reported in their respective studies, the overall effects generated in the analyses were also expected to be of statistical significance. However, significant initial effect sizes do not indicate that they are without differences. Heterogeneity refers to the presence of differences or variations within a sample. As mentioned, the random-effects model assumes that heterogeneity causes true effect sizes to differ within a meta-analysis (Harrer et al., 2021). The high heterogeneities of the overall hazard ratio results, implies that the true effect sizes vary across education subgroups or levels being studied. Confounding variables can be an explanatory cause for the high heterogeneity. For the hazard ratio analyses, the effect sizes reported in Gustafsson et al. (2022) controlled for income, marital status, wealth, and housing conditions, while Drefahl et al. (2020) controlled for income, marital status, and country of birth. The effect estimates from the study by Wallin et al. (2022) did not control for any confounding variables. This provides an understanding of the high heterogeneity measures, in otherwise quite similar studies where equivalent subgroups of education are compared. In cases of substantial heterogeneity, this can lead to larger standard deviations and thus wider confidence intervals around the estimates, which potentially make it more difficult to achieve statistical significance. Despite high heterogeneity of the hazard ratio overall effect estimates, these were not considered substantial, and the findings were denoted significant.

Another possible threat to significance could be that the total sample size of studies is too low. A factor contributing to the low sample size of studies in each analysis is the different effect measures. As the five studies compatible for meta-analysis reported effect sizes in odds ratio and hazard ratio, which are measures not comparable to each other, these had to be split into different analyses creating an even lower sample size per analysis. However, the thorough work in the systematic review shows that there are not enough studies of high quality with individual-level data which examines the association between education and COVID-19 mortality in adults. The results thus reflect the tendencies found in existing research and are measured well within the margin of significance 0.05. Furthermore, the significance level affects the generalizability of the study. Generalizability implies that the findings from the analyses can be interpreted as valid for the rest of the population from which the sample was drawn. It is essential that the sample is both representative of the population and large enough to capture general trends for such generalization to be possible. As the data material examines a relatively large sample of 58 885 845 individuals from five studies of high representativeness, it is reasonable to assume the analyses would generate generalizable results.

5.2 Limitations and strengths

5.2.1 Limitations

The validity of the results and their interpretations should be considered regarding their limitations. Most studies were rated 5 stars of representativeness, indicating nationally representativeness, while the study by Wallin et al. (2022) were rated to 3 stars due to its regional representativeness. The overall representativeness of included studies is arguably high, but as only three European countries are represented in the meta-analysis sample, one cannot conclude that the findings apply to the entire European region. The results may have shown a weaker or stronger association if other European countries were included in the analysis. Another limiting factor to the analysis is the chance of double counting of individuals. This is most likely a fact for the Swedish studies included, as most of these used data from the database of Statistics Sweden. There is also the possibility of miscalculation of educational attainment. As much of the exposure to education is self-reported, the years of education reported would depend on whether these are reported as years of education started or completed.

5.2.2 Strengths

The results may not be representative for all of Europe, but they should still be considered valid results. They are synthesised from a systematic review carried out as a global literature search across several different databases, which allowed almost complete coverage of all relevant records published on the topic since the start of the COVID-19 pandemic. This prevented any articles of interest from being excluded from the search by default. There were no language restrictions to the search, allowing for inclusion of studies in any language.

The study also benefits from using education as a measure of socioeconomic status, as this is a consistent component of an individual’s social and economic position in society. Whereas income or other wealth-related measures may vary over a life course, educational attainment is likely to stay consistent throughout adult life. The variable can be defined on the same basis for both the economically active and inactive population (Valkonen, 1993, p. 410), making it a neutral measure that does not differentiate.

Furthermore, education is more comparable between countries and over time than other measures influenced by subsequent health such as income or occupation may be (Valkonen, 1993, p. 410). When measured quantitatively education functions as consistent categories, which allows for comparison in meta-analyses. This makes it possible to compare the effect of different levels of educational attainment and how this is distributed across the social gradient, allowing a visualization of how the risk decreases as education increases. As this meta-analysis only included data from cohort studies, the risk of numerator-denominator bias was eliminated. This is a common limitation of unlinked cross-sectional study approaches due to the non-comparability of educational information given in death certificates and information collected in population censuses (Valkonen, 1993, p. 409). The analyses were conducted as random-effects models to address the possible variation across studies (Borenstein et al., 2009, p. 70). Given the high heterogeneity in the hazard ratio analyses, this have arguably generated more robust overall effect estimates than fixed-effects models would have done.

5.3 Syndemic pandemic

The COVID-19 pandemic occurred against a backdrop of inequalities in social determinants of health as well as economic and social inequalities in existing non-communicable diseases (Bambra et al., 2020, p. 965). This meets the first criteria Singer and colleagues (2017) outlines for a syndemic, that two or more diseases cluster. Furthermore, people with non-communicable diseases often have a higher rate of almost all the known underlying clinical risk factors that increase the severity and mortality of COVID-19 (Bambra et al., 2020, p. 965). Hence, these people are already at a disadvantage to face the pandemic. This corresponds to the second criteria of social and contextual factors creating conditions in which the diseases cluster (Singer et al., 2017, p. 942). Such and other social inequalities exist because people are exposed to social determinants of health to varying degrees. People´s living or working conditions, access to health care or education may vary greatly within the same population. These conditions in turn endure due to the context of where people are born and brought up. As outlined in the theory chapter, social conditions contribute to the formation, clustering and spread of disease, and through increasing susceptibility and reducing immune functions they also contribute to disease progression (Singer et al., 2017, p. 941). As research has proven that some population groups are placed at elevated risk for contracting COVID-19 and experiencing severe illness (in example Seligman et al., 2021; Shadmi et al., 2020), this complies with the third criterion of unfavourable disease interaction increasing the pandemic burden for those affected. When health conditions are further deteriorated by various social and systematic disparities, concerning for example level of education, income, or access to health care, we use the label syndemic. Because the COVID-19 pandemic happened within this context of social inequalities, it has previously been referred to as a syndemic pandemic. With a syndemic approach to the COVID-19 pandemic, one recognizes how social realities shape both individual illness experience and the distribution of disease across populations (Mendenhall, 2016, p. 464).

5.4 Education as a fundamental cause

The statistically significant overall effects from the meta-analyses support the hypothesis of increased COVID-19 mortality among adults in Europe with lower educational attainment. As life expectancy in European counties has continuously increased over time and living conditions are improving in many counties, one would also expect a reduction in social inequality. While this development has led to some risk factors being erased, other risk factors continue to be discovered and people of higher socioeconomic status are more likely to acquire such information (Link & Phelan, 1995, p. 86). This can be considered a dynamic system, where the risk factors are transformable between situations because of underlying factors that allow them to function as elements of risk. These factors are what enables social inequalities to be constantly verified and reproduced. One such factor that ensures and exacerbates inequality, is education. Despite attempts to reduce inequality, such as the United Nations Sustainable Development Goals, educational inequalities persist and has in fact widened in many European countries throughout the years. Because an individual's educational attainment is likely to be stable throughout adult life, one can easily understand that an effect of educational inequality would be an effect of constant nature. In the context of the results obtained in the analyses, and in line with previous research (Rydland et al., 2020), education should therefore be recognized as a fundamental cause as described in the theory by Link and Phelan. This would suggest that education holds the four essential features of a fundamental cause.

First, education is proven to influence health and thereby several disease outcomes (in example Gutzweiler et al., 1989; Guralink et al., 1993). The findings from this study shows an effect of education on COVID-19 mortality. Hence, education fulfils the first feature described. The second feature implies that education impacts disease outcomes through several risk factors. Health risk factors can be of various kinds, such as nutrition, exercise, stress, or economic resources. These are all influenced by health knowledge, working situation, and social support, as Egerter et al. (2009) described as important aspects in the three interconnected pathways linking education to health. This means that there is not a straight line between education and disease outcome, and the effects revealed in the analyses may therefore carry numerous explanations.

Third, recognizing education as a fundamental cause indicates that educational attainment gives access to resources that are beneficial in avoiding risk factors or minimizing the consequence of disease once it has occurred (Link & Phelan, 2013, p. 106). Such resources range from knowledge and work to social network and psychological support. At an individual level, Link and Phelan (2013) describes such resources as "causes of causes" or "risks of risks" that shape health behaviour (p. 107). As educational attainment influences whether people have access to public health information and have the capabilities to apply this information, while also regulating income and affecting whether one can afford to seek health services when necessary, education is thus essential in determining health behaviour and can be understood as a "risk of risks". Egerter and colleagues (2009) further elaborate on how education creates a basis for literacy and health knowledge, which are conditions that allow individuals to seek information and interpret or respond to public health announcements. For this study in particular such announcements concerned infection control measures and efforts to reduce the spread of the COVID-19 virus.

Finally, a cause is only considered fundamental if the association between cause and effect is constant despite a change in intervening mechanisms over time (Link & Phelan, 2013, p. 106). As research conducted decades ago (in example Gutzweiler et al., 1989; Guralink et al., 1993) showed a distinct association between education and health and this present study demonstrates that the same association still exists, the relationship is assumed to be constant. This suggests that educational attainment is an essential element that translates into health inequalities. Therefore, for health disparities to be addressed efforts must seek to understand fundamental social causes and their transformations into patterns of disease and mortality (Link & Phelan, 1995, p. 81). The interrelated pathways suggested by Egerter and colleagues in 2009 is precisely an effort of this fashion.

5.5 Pathways linking educational attainment to COVID-19 mortality

The specific pathways through which educational attainment affects adult COVID-19 mortality in Europe may be dependent on the context in which it occurs. Most likely, which pathway is dominant will also vary between the European countries studied in these analyses. For example, the health knowledge and behaviour pathway may be more dominant in countries where a large part of the population do not undertake education. With this pathway, Egerter et al. (2009) claims that knowledge and literacy can increase people´s cognitive skills and thus enabling them to make informed health decisions and maintaining a healthy lifestyle in line with government recommendations (p. 5). If the general population has low educational attainment, this might assist some to a proactive health behaviour while others fail to continue educating themselves which may lead to lack of health knowledge and bad health outcomes in the event of a public health crisis. In contrast, the work and social pathways may be more relevant to explain inequalities in mortality by education in countries where most of the population is educated and employed. Education increases the opportunity of being employed at all, obtaining a job with healthy working conditions, decent employment benefits and higher wages (Egerter et al., 2009, p. 6), which likely impacts the sense of control and lowers the risk of psychological and financial stress. In countries where society to a large extent revolves around employment and working life, it is thus reasonable to suggest that the latter pathways can better explain the influence in COVID-19 mortality by education.

The societal element of collectivism may influence the extent to which a pathway links education to health. These elements relate to whether collective interests are emphasized in national ideologies and to which extent individuals and communities in a society are connected. The four countries represented in the qualitative synthesis are both alike and different concerning these elements. Sweden is often used as an example of a country that embraces aspects of collectivism, whereas the United Kingdom is generally considered to have a more individualistic tradition. A combination of collectivist and individualistic elements are found in both Spain and Turkey. Despite some minor differences in national ideologies, all four countries included in this study implement social welfare policies to provide support and assistance for their citizens. Compulsory education and free public health care services are two of the features reflecting these policies. This means that in principle all citizens in these countries have the same opportunities for education, health knowledge, and proactive health behaviour with access to health care when they need. However, it is common knowledge that equal opportunities does not indicate equal outcome. The utilization of knowledge and facilities available depends entirely on the individual.

Another element that may influence the extent to which a pathways links education to health is the sense of social cohesion within a country’s population. While Sweden is a country emphasizing high degree of social equality which contributes to social cohesion, the United Kingdom faces challenges of economic inequalities, regional differences, and social stratification, which all can disrupt social harmony. In addition to economic disparities and regional differences, social inequalities and high unemployment rate makes social cohesion a complex topic in Spain. With high unemployment rate, it is reasonable to think that the second pathway described by Egerter and colleagues (2009) concerning employment opportunities and income would act as a threat to poor health outcomes among the unemployed. Being unemployed means that these individuals miss out on income and possible work-related benefits such as health insurance (Egerter et al., 2009, p. 7). Fluctuations in the economy are also more likely to affect those who are unemployed and lower economic security might make it difficult for these individuals to obtain healthcare when needed, and to provide themselves and their family with nutritious foods (Egerter et al., 2009, p. 7). Lack of income may also affect health through psychological stress, enabling a sense of less control. This might also make the influence through the third pathway accelerate in a negative respect. Like in Spain, social cohesion in Turkey is a multifaceted topic. As a diverse country it can be difficult to foster feeling of unity and intergroup dynamics, while the country also faces challenges of unequal distribution of income. As a rich variety of cultural, ethnic, religious, and linguistic backgrounds exists side by side in the Turkish society, it is sensible to assume that the third pathway of social standing and social support is of vital importance for people’s health outcome. This third pathway most likely played a crucial role for people all over the world facing the COVID-19 pandemic. The feeling of social cohesion and community support was essential during the challenging times of the pandemic.

Although this discussion can provide some thoughts and speculations to which pathways seem most influential in the European countries studied, it cannot determine exactly which pathways or mechanisms are most important. Depending on the country situation, the three pathways described by Egerter et al. (2009) will cause educational attainment to influence health to various degrees at different times, in all four countries. More research is needed to establish whether the pathway of health knowledge and behaviour, work, or social standing and support have the biggest impact on COVID-19 mortality in this context.

6.0 Conclusion

The statistically significant findings from the meta-analyses in this master thesis suggests an increased risk of COVID-19 mortality for individuals with low and medium educational attainment, compared to the highest educational groups in the sample. The risk is decidedly highest among those with low educational attainment. Furthermore, the analyses identified a gradient effect of education on COVID-19 mortality. This indicated that for each additional level of education achieved, there is a stepwise decrease in COVID-19 mortality risk. In sum, this implies that the research question of whether educational attainment is associated with COVID-19 mortality for adults in Europe can be confirmed, and the assumption in the hypothesis that lower educational attainment is associated with increased COVID-19 mortality for adults in the same region can be supported. In addition to significant overall effects of the association between educational attainment and COVID-19 mortality, the study has identified education as a fundamental cause determining access to resources that are beneficial in avoiding risk factors or minimizing disease consequences of COVID-19 (Link & Phelan, 2013, p. 106). Together with pathways described by Egerter and colleagues (2009), these theoretical perspectives have created an understanding of possible ways education contributes to increased COVID-19 mortality risk for those with low and medium level of education. However, which mechanisms and pathways are most influential in the relationship between education and COVID-19 mortality is difficult to determine. Taken together, these findings provide support for evidence-based policymaking to reduce inequalities in health across the educational gradient and improve access to education for all. The overall focus should be that all socioeconomic groups would be more equal when facing possible future pandemics.

6.1 Implications for further research

Although this study provides valuable empirical evidence, more research is needed to fully understand the complex relationship between educational attainment and COVID-19 mortality. Socioeconomic causes of difference in mortality have been studied and discussed numerous of times, however, we do not yet entirely understand the trends of differentials. We need to continue to understand medicine as a social science, allowing for sociological theory and methods to be applied, with the intentions of a more holistic understanding of health problems and diseases. Research of a sociological nature is relevant to disentangle how social structures affect health. More sociological research will offer a better understanding of how social conditions such as resources, risk factors, and pathways influence COVID-19 mortality across the educational gradient. It exists a need for more research examining the effect of sex on education-related inequalities in COVID-19 mortality. As gender differences are evident in various health outcomes, this represents an important area for further research. Assuming that the importance of education in health will vary throughout adult life, it would also be interesting to analyse the effect stratified for different age categories. However, this requires a comprehensive evidence base, which is not yet available in this region. To build the limited research base in the European region, more time is needed to accumulate research examining the relationship between education and COVID-19 mortality. This may provide a new framework for future syntheses and meta-analyses on the topic and will enable a more extensive investigation of the association which can allow for further support of policy changes to reduce health inequalities.

Nevertheless, this study is the most comprehensive systematic review and meta-analysis examining the association between educational attainment and adult COVID-19 mortality to this date. It represents an essential step towards identifying and understanding the uneven distribution of pandemic burden. Although this work initially is limited to studying educational inequalities in COVID-mortality in Europe, the scientific contributions from this project will lay grounds for future research on inequalities in all-cause mortality, as well as mortality connected to other specific diseases. Through contributing to methodology development of systematic reviews and meta-analysis in the field of sociology, it has paved the way for further research among social scientists. The study can be used to systematically direct future research and is arguably of high value to guide how future synthesis studies should be conducted. The design should not be limited to health sociology research; however, it can be applied in all cases with an interest to study a much investigated association where consensus is yet to be established.

References

Balduzzi, S., Rücker, G., & Schwarzer, G. (2019). How to perform a meta-analysis with R: A practical tutorial. *Evidence-Based Mental Health, 22*(4), 153-60. https://doi.org/10.1136/ebmental-2019-300117

Bambra, C., Lynch, J., & Smith, K. E. (2021). *The unequal pandemic: COVID-19 and health inequalities*. Policy Press.

Bambra, C., Riordan, R., Ford, J., & Matthews, F. (2020). The COVID-19 pandemic and health inequalities. *Journal of Epidemiology and Community Health, 74*(11), 964-968. https://doi.org/10.1136/jech-2020-214401

Bordens, K. S. & Abbott, B. B. (2018). *Research design and methods: a process approach* (10th edition). McGraw-Hill Education.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. Wiley.

Braveman, P., Egerter, S., & Williams, D. R. (2011). The social determinants of health: Coming of age. *Annual Review of Public Health, 32*(1), 381-389. https://doi.org/10.1146/annurev-publhealth-031210-101218

Brunton, G., Stansfield, C., Caird, J., & Thomas, J. (2017). Finding relevant studies. In D. Gough, S. Oliver, & J. Thomas (Ed.), *An introduction to systematic reviews* (2nd edition, p. 93-122). SAGE.

Cherry, M. G., & Dickson, R. (2017). Defining My Review Question and Identifying Inclusion and Exclusion Criteria. In A. Boland, M. G. Cherry, & R. Dickson (Ed.), *Doing a systematic review: A student´s guide* (2nd edition, p. 43-60). SAGE.

Cooper, H. M., & Rosenthal, R. (1980). Statistical versus traditional procedures for summarizing research findings. *Psychological Bulletin, 87*(3), 442-449. https://doi.org/10.1037/0033-2909.87.3.442

Cumming, G. (2012). Understanding the new statistics: effect sizes, confidence intervals, and meta-analysis. Routledge.

Dahlgren, G., & Whitehead, M. (2021). The Dahlgren-Whitehead model of health determinants: 30 years and still chasing rainbows. *Public Health, 199*, 20-24. https://doi.org/10.1016/j.puhe.2021.08.009

Dickson, R., Cherry, M. G., & Boland, A. (2017). Carrying out a Systematic Review as a Master´s Thesis. In A. Boland, M. G. Cherry, & R. Dickson, *Doing a systematic review: A student´s guide* (2nd edition, p. 1-21). SAGE.

Drefahl, S., Wallace, M., Mussino, E., Aradhya, S., Kolk, M., Brandén, M., Malmberg, B., & Andersson G. (2020). A population-based cohort study of socio-demographic risk factors for COVID-10 deaths in Sweden. *Nature Communications, 11*(1), 5097. https://doi.org/10.1038/s41467-020-18926-3

Egerter, S., Braveman, P., Sadegh-Nobari, T., Grossman-Kahn, R., & Dekker, M. (2009). *Education matters for health* (Issue Brief No. 6). Robert Wood Johnson Foundation.

Elliott, J., Bodinier, B., Whitaker, M., Depierre, C., Vermeulen, R., Tzoulaki, I., Elliott, P., & Chadeau-Hyam, M. (2021). COVID-19 mortality in the UK Biobank cohort: revisiting and evaluating risk factors. *European Journal of Epidemiology, 36*, 299-309. https://doi.org/10.1007/s10654-021-00722-y

FN-sambandet. (2023, 3. februar). *Mindre ulikhet*. https://www.fn.no/om-fn/fns-baerekraftsmaal/mindre-ulikhet

Friedman, J., Balaj, M., Islam, N., Gu, Y., Nahmia, P., Santamaría-Ulloa, C., Rojas, A. G., Rasanathan, K., Hosseinpoor, A. R., Emina, J. B., Eikemo, T. A., & Castillo-Salgado, C. (2022). Inequalities in COVID-19 mortality: defining a global research agenda. *Bulletin of the World Health Organization, 100*(10), 648-650. http://dx.doi.org/10.2471/BLT.22.288211

Gough, D., Oliver S., & Thomas, J. (2017). Introducing systematic reviews. In D. Gough, S. Oliver, & J. Thomas, *An introduction to systematic reviews* (2nd edition). SAGE.

Gough, D., Thomas, J., & Oliver, S. (2012). Clarifying differences between review designs and methods. *Systematic Reviews, 1*(28), 1-9. https://doi.org/10.1186/2046-4053-1-28

Guralink, J. M., Land, K. C., Blazer, D., Fillenbaum, G. G., & Branch, L. G. (1993). Educational status and active life expectancy among older blacks and whites. *New England Journal of Medicine, 329*(2), 110-116. https://doi.org/10.1056/NEJM199307083290208

Gustafsson, P. E., San Sebastian, M., Fonseca-Rodriguez, O., & Connolly, A-M. F. (2022). Inequitable impact of infection: social gradients in severe COVID-19 outcomes among all confirmed SARS-CoV-2 cases during the first pandemic wave in Sweden. *Journal of Epidemiology and Community Health, 76*(3), 261-267. https://doi.org/10.1136/jech-2021-216778

Gutzweiler, F., La Vecchia, C., Levi, F., Negri, E., & Wietlisbach, V. (1989). Education, disease prevalence and health service utilization in the Swiss national health survey "SOMIPOPS". *Preventive medicine, 18*(4), 452-459. https://doi.org/10.1016/0091-7435(89)90005-4

Haddaway, N., Lofti, T., & Mbuagraw, L. (2023). Systemic reviews: A glossary for public health. *Scandinavian Journal of Public Health, 51*(1), 1-10. https://doi.org/10.1177/14034948221074998

Harrer, M., Cuijpers, P., Furukawa, T. A., & Ebert, D. D. (2021). *Doing Meta-Analysis with R: A Hands-On Guide*. Chapman & Hall/CRP Press.

Huck, S. W., & Sandler, H. M. (1979). Rival hypotheses: alternative interpretations of data based conclusions. Harper & Row.

Link, B. G., & Phelan, J. C. (1995). Social conditions as fundamental causes of disease. *Journal of Health and Social behaviour,* 80-94. https://doi.org/10.2307/2626958

Link, B. G., & Phelan, J. C. (2013). Fundamental Case Theory. In W. C. Cockerham (Ed.), *Medical sociology on the move: new directions in theory* (p. 105-125). Springer.

Magnan, S. (2017). Social determinants of health 101 for health care: five plus five. *NAM Perspectives*. https://doi.org/10.31478/201710c

Mendenhall, E. (2016). Beyond comorbidity: a critical perspective of syndemic depression and diabetes in cross-cultural contexts. *Medical anthropology quarterly, 30*(4), 462-478. https://doi.org/10.1111/maq.12215

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *PLoS Medicine, 18*(3), e1003583. https://doi.org/10.1371/journal.pmed.1003583

Pripp, A. H. (2022). Metaanalyse: forskjellige effektstørrelser. *Tidsskrift for den Norske Lægeforening, 142*(16). https://doi.org/10.4045/tidsskr.22.0531

Rosenthal, R. (1991). Meta-analytic procedures for social research (Revised edition). SAGE.

Ross, C. E., & Wu, C. (1995). The Links Between Education and Health. *American Sociological Review, 60*(5), 719-745. https://doi.org/10.2307/2096319

Rostila, M., Cederström, A., Wallace, M., Brandén, M., Malmberg, B., & Andersson, G. (2021). Disparities in coronavirus disease 2019 mortality by country of birth in Stockholm, Sweden: A total-population-based cohort study. *American Journal of Epidemiology, 190*(8), 1510-1518. https://doi.org/10.1093/aje/kwab057

Rydland, H. T., Solheim, E. F., & Eikemo, T. A. (2020). Educational inequalities in high- vs. low-preventable health conditions: Exploring the fundamental cause theory. *Social Science & Medicine, 267*, 113145. https://doi.org/10.1016/j.socscimed.2020.113145

Seligman, B., Ferranna, M., & Bloom, D. E. (2021). Social determinants of mortality from COVID-19: A simulation study using NHANES. *PLoS Medicine, 18*(1), e1003490. https://doi.org/10.1371/journal.pmed.1003490

Shadmi, E., Chen, Y., Dourado, I., Fran-Perach, I., Furler, J., Hangoma, P., Hanvoravongchai, P., Obando, C., Petrosyan, V., Rao, K. D., Ruano, A. L., Shi, L., de Souza, L. E., Spitzer-Shohat, S., Sturgiss, E., Suphanchaimat, R., Uribe, M. V., & Willems, S. (2020). Health equity and COVID-19: global perspectives. *International Journal for Equity in Health, 19*(1), 1-16. https://doi.org/10.1186/s12939-020-01218-z

Singer, M. (2000). A dose of drugs, a touch of violence, a case of AIDS: conceptualizing the SAVA syndemic. *Free inquiry in creative sociology, 28*(1), 13-24.

Singer, M. (2009). Introduction to syndemics: A critical systems approach to public and community health. Jossey-Bass.

Singer, M., Bulled, N., Ostrach, B., & Mendenhall, E. (2017). Syndemics and the biosocial conception of health. *The Lancet, 389*(10072), 941-950. https://doi.org/10.1016/S0140-6736(17)30003-X

Singh-Manoux, A., Adler, N., & Marmot, M. G. (2003). Subjective social status: its determinants and its association with measures of ill-health in the Whitehall II study. *Social Science & Medicine, 56*(6), 1321-1333. https://doi.org/10.1016/S0277-9536(02)00131-4

Skog, O-J. (2004). Å forklare sosiale fenomener: en regresjonsbasert tilnærming (2nd edition). Gyldendal Akademisk.

Sonmez, A., Demirci, I., Haymana, C., Tasci, I., Dagdelen, S., Cakal, E., Atmaca, A., Sahin, M., Celik, O., Demir, T., Ertugrul, D., Unluturk, U., Caglayan, M., & Satman, I. (2021). Clinical characteristics and outcomes of COVID-19 in patients with type 2 diabetes in Turkey: A nationwide study (TurCoviDia). *Journal of Diabetes, 13*(7), 585-595. https://doi.org/10.1111/1753-0407.13171

Soriano, J. B., Peláez, A., Fernández, E., Moreno, L., & Ancochea, J. (2022). The emergence of COVID-19 as a cause of death in 2020 and its effects on mortality by diseases of the respiratory system in Spain: trends and their determinants compared to 2019. *Archivos De Bronconeumología, 58*(51), 13–21. https://doi.org/10.1016/j.arbres.2022.03.001

UN. (2021). Adding fuel to the fire? Inequality and the spread of COVID-19. *Monthly briefing on the economic situation and prospects* (Briefing number 148). https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/Monthly_Briefing_148.pdf

UNESCO Institute of Statistics. (2023). *ISCED Mappings*. http://uis.unesco.org/en/isced-mappings

United Nations Development Programme. (2021). *Human Development Insights*. https://hdr.undp.org/data-center/country-insights#/ranks

Valkonen, T. (1993). Problems in the measurement and international comparison of socio-economic differences in mortality. *Social Science & Medicine, 36*(4), 409-418.

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(3), 1-48. https://doi.org/10.18637/jss.v036.i03

Wallin, A. S., Ohlis, A., Dalman, C., & Ahlen, J. (2022). Risk of severe COVID-19 infection in individuals with severe mental disorders, substance use disorders, and common mental disorders. *General Hospital Psychiatry, 75*, 75-82. https://doi.org/10.1016/j.genhosppsych.2022.02.004

WHO. (2023). *Inequality in COVID-19 mortality between and within countries: Working group 5*. https://www.who.int/data/technical-advisory-group/covid-19--mortality-assessment/working-group-5

Wickham, H., Averick, M., Bryan, J., Chang, W., D´Agostino McGowan, L., Francois, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., (…) Yutani, H. (2019). Welcome to the tidyverse. *Journal of Open Source Software, 4*(43), 1686. https://doi.org/10.21105/joss.01686

Yeap, B. B., Marriott, R., Manning, L., Dwivedi, G., Hankey, G. J., Wu, F. C. W., Nicholson, J. K., & Murray, K. (2022). Higher premorbid serum testosterone predicts COVID-19-related mortality risk in men. *European Journal of Endocrinology, 187*(1), 159-170. https://doi.org/10.1530/EJE-22-0104

Appendix A

Table 1	Comprehensive search	Medium search	Restricted search	Minimal strategy
Socioeconomic Status	"Socioeconomic" OR "socio-economic" OR "social class" OR "social position" OR SES OR SEP OR caste OR "Social status"	ALL	ALL	Socioeconomic OR socio$economic OR SES OR SEP
Education	Educat* OR school* OR liter* OR graduat* OR diploma	ALL	ALL	Educat*
Occupation	Occupation* OR employ* OR unemploy* OR work OR essential OR furlough* OR precar* OR lay-off OR "lay off" OR "laid off" OR union*	ALL	ALL	Occupation* OR employ* OR unemploy*
Income	Income OR wealth OR poverty OR economic OR debt OR "catastrophic spending" OR "catastrophic expenditure" OR affordab* OR bankruptcy	Income OR wealth OR Poverty OR economic OR debt OR bankruptcy	Income OR wealth OR poverty	Income or Poverty
Differences	Inequalit* OR inequit* OR equalit* OR equit* OR stratif*	ALL	ALL	equit* or inequal* or inequit* or dispar* or stratif*
Social Determinants	"Social determinants" OR "Structural determinants"	ALL	NONE	None
Race	Race OR racism OR stigma* OR Black OR "African American" OR Asian OR white OR caucasian OR "American Indian" or native OR "Pacific Islander" OR indigenous	Race OR racism OR stigma* OR indigenous	Race OR racism OR stigma* OR indigenous	Race OR racism OR BAME OR BIPOC
Gender/Sexuality	gender OR sexual* OR gay OR lesbian OR trans* or queer OR LGBT*	ALL	ALL	Gender OR LGBT*
Ethnicity	ethnicity OR ethnic OR Hispanic OR Latin*	ALL	Ethnicity or Ethnic	Ethnicity or Ethnic
Migration Status	*migrant OR *migrant OR refugee OR asylum OR non-native OR "internally displaced"	ALL	*migrant OR *migrant OR refugee OR asylum OR non-native	*migrant OR *migrant OR refugee OR asylum
Religion	religion	ALL	ALL	religion
Vulnerability	Vulnerab* OR insecur* OR Incarc* OR dention* OR native-born OR indigenous OR addict* OR disadvantage* OR marginali?ed OR	ALL	Vulnerab* OR insecur* OR Incarc* OR dention* OR addict* OR disadvantage* OR marginali?ed OR	Vulnerab* OR Incarc* OR marginali?ed

	underserved OR barrier* OR susceptibil* OR segregation OR "underserved" Or risk		underserved OR susceptibil* OR "underserved"	
Food	"food insecurity" OR "food insufficiency" OR "food insecure" OR nutrition* OR *nutrition	"food insecure" OR nutrition* OR *nutrition	"food insecure"	none
Healthcare	Healthcare OR "health care" OR insurance OR "health expenditure" OR "health services" OR telemedicine OR "remote care" OR "unmet need"	Healthcare OR "health care" OR "health services" OR telemedicine OR "remote care"	Healthcare OR "health care" OR "health services"	Healthcare OR "health care"
Housing	Hous* OR homeless* OR overcrowd* OR foreclosure	ALL	ALL	Hous* OR homeless*
Social Protection	"social protection" OR "government expenditure" OR welfare OR "income support" OR "cash transfer" OR "social support" or benefits	"social protection" OR welfare OR "income support" OR "cash transfer" OR benefits	"social protection" OR welfare OR "income support" OR "cash transfer"	none
Demographics	Marital OR married OR single OR widow OR "living alone" OR parent OR lone OR children OR child		None	none
Other	minorit* OR discrimin* OR intersectionality OR internet or "digital divide" OR suffering OR Expos* OR barriers	minorit* OR discrimin* OR intersectionality	minorit* OR discrimin* OR intersectionality	minorit*
COVID-19	Covid-19 OR covid OR coronavirus OR SARS-Cov-2" OR 2019-nCoV	ALL	ALL	ALL
Mortality	Mortality OR death* OR fatalit* OR survival Or "excess mortality"	ALL	ALL	ALL
Place-based	area* OR geo* OR place* OR neighbourhood* OR region* OR count* OR ward* OR cit* OR district* OR municipal* OR province* OR state* OR communit* OR count* OR town* OR district* OR census OR post* OR zip OR spatial OR metropolitan OR depriv* OR environ OR Urban OR Rural OR settlement OR townships OR density	ALL	area* OR geo* OR place* OR neighbourhood* OR region* OR zip OR spatial	Place OR spatial OR area
Qualitative papers	syndemic OR "fundamental cause" OR "commercial determinants" OR "political determinants" OR "institutional theory" OR analytical OR framework OR pathways OR link* OR relationship OR trade OR	ALL	syndemic OR "fundamental cause" OR pathways OR trade OR globali?ation OR neoliberal* OR capital*	Theoretical OR conceptual OR analytical OR framework

	globali?ation OR neoliberal* OR populism OR capital* OR theor* OR model* OR concept*			

Appendix B

```
#set working directory
setwd('/Your/working/directory')

#load packages
library(meta)
library(metafor)
library(dmetar)
library(dplyr)

###########################################################################

#Plot 1: low versus high education OR

#STEP 1: Load in dataset

dataset1 <- read_xlsx("Dataset1.xlsx")

#STEP 2: generate values for plot
m.gen1 <- metagen(TE = dataset1$OR,
                  data = dataset1,
                  studlab = author,
                  sm = "OR",
                  lower = dataset1$Lower,
                  upper = dataset1$Upper,
                  transf = FALSE,
                  backtransf = TRUE,
                  fixed = FALSE,
                  random = TRUE,
                  method.tau = "REML",
                  hakn = FALSE,
                  title = "Low versus high education")

summary(m.gen1)

#STEP 3: create and save forest plot
png(file = "forestplot1.png",#save file with this name to current directory
    width = 3800, height = 2000, res = 400)

plot1 <- forest.meta(m.gen1,
                     prediction = FALSE,
                     test.overall.random = TRUE,
                     print.tau2 = FALSE,
                     print.Q = TRUE, #lists Q value on the plot as X2 value
                     print.pval.Q = TRUE) #lists the pval for the Q values

dev.off() #tells R to save the plot you just created using the file name
created in the png line

###########################################################################
```

```
#Plot 2: medium vs high education

#STEP 1: Load in dataset

dataset2 <- read_xlsx("Dataset2.xlsx")

#STEP 2: generate values for plot
m.gen2 <- metagen(TE = dataset2$OR,
                  data = dataset2,
                  studlab = author,
                  sm = "OR",
                  lower = dataset2$Lower,
                  upper = dataset2$Upper,
                  transf = FALSE,
                  backtransf = TRUE,
                  fixed = FALSE,
                  random = TRUE,
                  method.tau = "REML",
                  hakn = FALSE,
                  title = "Medium vs. high education")

summary(m.gen2) #to view calculated values

#STEP 3: create and save forest plot
png(file = "forestplot2.png",#save file with this name to current directory
    width = 3800, height = 2000, res = 400)

plot2 <- forest.meta(m.gen2,
                     prediction = FALSE,
                     test.overall.random = TRUE,
                     print.tau2 = FALSE,
                     print.Q = TRUE, #lists Q value on the plot as X2 value
                     print.pval.Q = TRUE) #lists the pval for the Q values

dev.off() #tells R to save the plot you just created using the file name
created in the png line

###########################################################################
```

```
#Plot 3: educational gradient plot, OR average: low vs. medium vs. high
#use barplot function

OR <- c(1.13, 1.08, 1)

png(file = "barplot1.png", #save file with this name to current directory
    width = 2000, height = 1800, res = 400)

Plot3<- barplot(OR,
                 xlab = "Education level",
                 ylab = "OR",
                 names.arg = c("Low", "Medium", "High (ref)"),
                 col = "grey",
                 ylim = c(0,1.6),
                 horiz = FALSE)

text(Plot3,OR+0.2,labels=as.character(OR))

dev.off()

############################################################################

#Plot 4: low versus high education HR

#STEP 1: Load in dataset

dataset4 <- read_xlsx("Dataset4.xlsx")

#STEP 2: generate values for plot
m.gen1 <- metagen(TE = dataset4$HR,
                  data = dataset4,
                  studlab = author,
                  sm = "HR",
                  lower = dataset4$Lower,
                  upper = dataset4$Upper,
                  transf = FALSE,
                  backtransf = TRUE,
                  fixed = FALSE,
                  random = TRUE,
                  method.tau = "REML",
                  hakn = FALSE,
                  title = "Low versus high education")

summary(m.gen1)
```

```
#STEP 3: create and save forest plot
png(file = "forestplot4.png",#save file with this name to current directory
    width = 3800, height = 2000, res = 400)

plot4 <- forest.meta(m.gen1,
                     prediction = FALSE,
                     test.overall.random = TRUE,
                     print.tau2 = FALSE,
                     print.Q = TRUE, #lists Q value on the plot as X2 value
                     print.pval.Q = TRUE) #lists the pval for the Q values

dev.off() #tells R to save the plot you just created using the file name
created in the png line

############################################################################

#Plot5: medium education versus high HR

#STEP 1: Load in dataset

dataset5 <- read_xlsx("Dataset5.xlsx")

#STEP 2: generate values for plot
m.gen1 <- metagen(TE = dataset5$HR,
                  data = dataset5,
                  studlab = author,
                  sm = "HR",
                  lower = dataset5$Lower,
                  upper = dataset5$Upper,
                  transf = FALSE,
                  backtransf = TRUE,
                  fixed = FALSE,
                  random = TRUE,
                  method.tau = "REML",
                  hakn = FALSE,
                  title = "Low versus high education")

summary(m.gen1)

#STEP 3: create and save forest plot
png(file = "forestplot5.png",#save file with this name to current directory
    width = 3800, height = 2000, res = 400)

plot5 <- forest.meta(m.gen1,
                     prediction = FALSE,
                     test.overall.random = TRUE,
                     print.tau2 = FALSE,
                     print.Q = TRUE, #lists Q value on the plot as X2 value
                     print.pval.Q = TRUE) #lists the pval for the Q values

dev.off() #tells R to save the plot you just created using the file name
created in the png line
```

```r
###########################################################################

#Plot6: educational gradient plot, HR average: low vs. medium vs. high
#use barplot function

HR <- c(1.38, 1.31, 1)

png(file = "barplot2.png", #save file with this name to current directory
    width = 2000, height = 1800, res = 400)

Plot6<- barplot(HR,
                xlab = "Education level",
                ylab = "HR",
                names.arg = c("Low", "Medium", "High (ref)"),
                col = "grey",
                ylim = c(0,1.95),
                horiz = FALSE)

text(Plot6,HR+0.2,labels=as.character(HR))

dev.off()
```

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