Masteroppgave

NTNU
Norges teknisk-naturvitenskapelige universitet
Fakultet for medisin og helsevitenskap
Institutt for samfunnsmedisin og sykepleie

Mari Bille Johnsrud

Socioeconomic inequalities in prevalence of multimorbidity and complex multimorbidity in a general Norwegian population from 1995 to 2019, the Health Survey in Trøndelag (HUNT2-4)

Masteroppgave i Folkehelse
Veileder: Kristin Hestmann Vinjerui
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Abstract

Introduction: Multimorbidity, defined as having several chronic health conditions, is increasing globally as well as nationally. Prevalence studies on multimorbidity are difficult to compare due to methodically varieties, but general findings support multimorbidity's associations with lower socioeconomic positions, female sex, and higher age. Multimorbidity in relation to socioeconomic inequalities has been investigated more in the later years, but none have done this over time in Norway. The aim of this study is to investigate how multimorbidity varies with socioeconomic positions indicated through education. Complex multimorbidity which has been studied in less degree, but more so in the later years has higher specificity into older age groups compared to multimorbidity.

Method: Repetitive measures through three cross-sectional studies was conducted from questionnaire 1 and measurements in HUNT2, HUNT3 and HUNT4. Sex and age were regarded as confounders to explanatory variable education and outcome variables multimorbidity and complex multimorbidity. 16 conditions were included, disease count was used as measure, and complex multimorbidity was grouped according to chapters of the ICD-10. Logistic regression was used to analyse the data and estimates from the logistic regression were used to derive prevalence differences and ratios in presenting the results.

Results: Multimorbidity and complex multimorbidity was associated with lower socioeconomic position, female sex and older age. Prevalence in both multimorbidity and complex multimorbidity was higher in HUNT2 than HUNT3 and HUNT4. Prevalence ratios and differences were generally higher for primary educational level than secondary educational level compared to tertiary educational level throughout all HUNTs. Overall, educational level prevalence differences and ratios diminished in women at age 70, while still present in men at age 85.

Conclusion: The general trend of multimorbidity's associations to lower socioeconomic position, female sex and older age were shown. Methodically differences internally in the three HUNTs and externally made the prevalence estimates difficult to compare. Interpretation of development over time was also difficult to make due to age standardization was not performed. Inclusion of more conditions and several indicators for socioeconomic positions in addition to implementation of age standardization would have made for a more robust interpretation.

Sammendrag

Bakgrunn: Multimorbiditet, som er definert som å ha flere kroniske helsetilstander, øker globalt og nasjonalt. Studier på forekomst av multimorbiditet er vanskelig å sammenligne pga store variasjoner i metode, men generelt underbygger studier på multimorbiditet dets assosiasjoner til lavere sosioøkonomiske posisjoner, kvinner og høyere alder. Multimorbiditet og sosial ulikhet har blitt studert i økende grad i det senere tiår, men ingen har gjort dette over tid i Norge. Formålet med denne studien er å undersøke hvordan multimorbiditet og avansert multimorbiditet varierer med sosioøkonomiske posisjoner. Avansert multimorbiditet har blitt studert mindre, men i økende grad i det senere tiår og har høyere spesifisitet i høyere aldersgrupper.

Metode: Repeterte målinger gjennom tre tverrsnittstudier ble gjennomført fra spørreskjema 1 og målinger i HUNT2, HUNT3 og HUNT4. Kjønn og alder ble betraktet som konfundere til eksponeringsvariabelen utdanning og utfallvariablene multimorbiditet og avansert multimorbiditet. 16 tilstander ble inkludert, antall tilstander ble brukt som mål og kompleks multimorbiditet ble gruppert i henhold til kapitler i ICD-10. Logistisk regresjon ble brukt til å analysere data og estimatene fra den logistiske regresjonen ble brukt til å uthente forskjeller og forhold i forekomst for presentasjon av resultater.

Resultater: Multimorbiditet og kompleks multimorbiditet ble assosiert med lavere sosioøkonomisk posisjon, kvinner og høyere alder. Forekomst i både multimorbiditet og kompleks multimorbiditet var høyere i HUNT2 enn i HUNT3 og HUNT4. Forekomst i forhold og forskjeller var generelt høyere ved 1.utdannigsnivå enn 2. utdanningsnivå sammenlignet med 3. utdanningsnivå gjennomgående i de tre HUNT-bølgene. Forekomst i forhold og forskjeller i utdanningsnivå ble redusert hos kvinner ved 70-års alder, men til stede hos menn ved 85 års alder.

Konklusjon: Den generelle trenden av multimorbiditets assosiasjoner til lavere sosioøkonomisk posisjoner, kvinner og høyere alder ble vist. Metodiske forskjeller internt i de tre HUNT-bølgene og eksternt gjorde det vanskelig å sammenligne estimatene for forekomst. Tolkning av utvikling over tid lot seg også vanskelig gjøre siden alder standardisering ikke ble utført. Inkludering av flere tilstander samt flere indikatorer for sosioøkonomiske posisjoner i tillegg til å gjennomføre alder standardisering ville kunne bidratt til en sterkere tolkning av resultatene.

Acknowledgements

This master thesis represents the end of not only two years of studies in the master`s program of Public Health at NTNU, but nine years of fulfilling this since the beginning in 2014 on the program of health sciences then. I would like to thank NTNU for having given me the chance to complete this master. Thank you.

These last two years have been compacted with learning and my knowledgebase is at a different place from when I started out.

My personal aim for this project was to learn more about quantitative methods and analyses in general. The topic chosen seemed concrete enough for me to be able to focus more on methods than theme, since I thought I already knew enough about sickness and diseases. In addition to learn about methods and analysis, I have learned that multimorbidity is a whole topic and huge research field and not just more of sickness and disease. It has taken me into side topics and fields of this main theme which has been interesting to explore. The project turned into being a bit bigger than I expected, but then again, hopefully my knowledge will be increased accordingly. It has been learning by doing all the way and I hope I will eventually see the value of every step of the way.

I would like to thank my supervisors Kristin Hestmann Vinjerui and Erik R. Sund for an immense follow up throughout this year from start to end. Thank you both for being generous of your knowledge. Kristin, your direct and concrete guidance and feedback, always being available for questions and your positive backing has been priceless. Thank you.

11. August 2023

Mari Bille Johnsrud

Table of Contents

1. Introduction

1.1 Multimorbidity and complex multimorbidity definitions and measures

Multimorbidity, from its Latin origin meaning “several illnesses” (1,2), is a heterogenous health concept described with several terms (3,4). The main difference from comorbidity is that multimorbidity is not defined by an index condition (3,5). Multimorbidity is most commonly defined as having 2 or more chronic conditions (4,6,7). Complex multimorbidity has been defined as having 3 or more chronic conditions in which 3 or more organ systems is affiliated within one person without defining an index chronic condition (8). Only in the recent years, studies have been more specific in the use of complex multimorbidity as measure (9–11) after suggesting the use of the more specific definition >=3 diseases by Fortin et al (6) in addition to the defined >=2 diseases (4,6,7). Harrison et al suggests complex multimorbidity as measure is more useful to better identify persons with higher needs as it lowers the prevalence estimates and shows greater differentiation among elderly and will reflect the overall severity (8).

With regards to the requirement of multimorbidity encompassing *chronic* conditions, criteria for chronicity of conditions has been proposed to be dependent on duration (4,6,12), requirements for medical care (4,6,12–14), have severe effects for the individual and high prevalence (4,6,13).

Prevalence in multimorbidity and complex multimorbidity studies have been difficult to compare due to methodical differences (6,15–18), even though the methodology is transparent and detailed (5,15,19,20). The difficulty in comparability has been addressed several times, but there is still a lack of standard definition which challenge comparability of studies on multimorbidity (6,7,15–18,21). Comparability is shown to increase when multimorbidity is operationalised as multiple organ systems affected also known as complex multimorbidity (8).

1.2 Multimorbidity prevalence and associations

For people with chronic diseases, multimorbidity is the norm (19). At a threshold of 2 or more conditions, one in three people is identified as having multimorbidity globally (22), while 42% of the Norwegian population has multimorbidity (23). 54% had complex multimorbidity in Norway (11). Generally, studies on prevalence in multimorbidity and complex multimorbidity over time shows an increase (10,24–26). In comparison to single studies a wide range in prevalence of multimorbidity is shown, from 3.5% to 98.5% (6,18,22). Studies on complex multimorbidity has shown significantly high prevalence (9,11).

Multimorbidity is associated with lower socioeconomic position, increased age and female sex with a threshold of 2 chronic conditions or more (18,19,24,27,28). Complex multimorbidity shows increased specificity into older age groups (8), reflects stronger inequality than regular multimorbidity (10) and prevalence has shown to be common from early adulthood (10,11,29). Trends of rapidly growing population of older adults, increased

life expectancy and disease dynamics has been pointed out to foretell rises in prevalence of chronic conditions and multimorbidity (13).

Prevalence in multimorbidity varies in studies because of its highly dependency on definition and measures. Prevalence is determined by the chosen threshold in numbers of conditions to classify as multimorbid, the total number of conditions to count from, and the differentiation of the conditions included (6,8,30), in the way that prevalence is higher with lower threshold and with more conditions included (6,8,20). It`s common to differentiate conditions in single units rather than grouped (4) and the prevalence estimates have shown to be comparable regardless of level of differentiation of conditions when the threshold is 2 conditions or more (8). At a threshold of 3 or more, equal distinction in conditions is required for prevalence comparability (8). Valid measurements for prevalence of multimorbidity demands a minimum of 12 health conditions included (6,8). It is suggested though to include all chronic conditions to obtain the best possible estimates on prevalence since at a threshold of 3 or more conditions, the prevalence proportions detected has shown insufficient (6,8). It is also suggested to investigate the validity of each included condition (5).

In the later years the knowledge base around multimorbidity has grown fast and so has the studies on prevalence in multimorbidity. An international publications library is continuously updated through University of Glasgow (31).

1.3 Allostatic overload and multimorbidity

Although knowledge on aetiology of multimorbidity is limited (32), Tomasdottir found that development of multimorbidity was associated with `existential unease' and people's vulnerability to disease increases when connected to what is known about allostatic load (33). Allostasis means stability through change and involves the interaction between neural, endocrine, and immunologic processes to enable the body's adaptation to life's challenges and strain. These processes are foundational prerequisites for the body to be able to maintain a well-functioning inner environment both biochemically and physiologically, also known as homeostasis (34,35). Allostatic load is part of life in the way that positive stress and normal aging is not harmful when given the opportunity and time to restore. Allostatic overload on the other hand is when intolerable levels of stress over long term overtax the physiological adaptation mechanisms and develop disease (34,35). Examples of such situations of overload is adverse childhood experiences, to feel threatened, to experience helplessness and to be in constant alarm condition or on guard (34,36,37). The model on allostasis has in the later years been used in research on social inequalities in health (34,38,39) and give new perspectives on multimorbidity and the social gradient in disease (34,37). In compliance with epidemiological studies, a direct reasoning can be drawn from social deprivation, health damaging stress, allostatic overload and physiological dysregulation to chronic disease and multimorbidity (19,40).

1.4 Social inequalities in health

Social inequalities in health can be defined as "any type of persistent and important differences in aggregated health between social positions in the same social structure(s)" (41) (p.8).

The importance of equal opportunities and resources for everyone to better each individual potential for health has been addressed and emphasized by The World Health Organization (42,43) and the Norwegian government (44). A main goal for achieving this is by reducing social inequalities among groups and better the socioeconomic position (43,44).

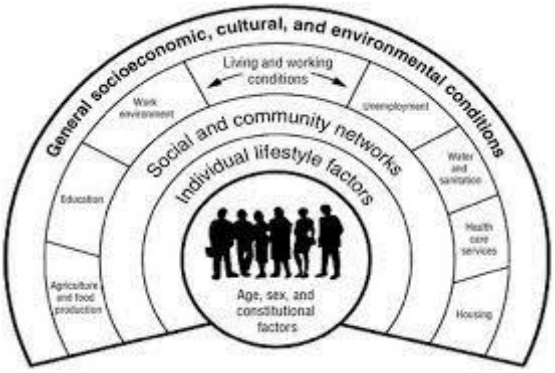


Figure 1. The Dahlgren-Whitehead model of health determinants (45).

The concept of determinants of health was visualized through WHO in 1991 and shows how the determinants of health interact with one another (45). The model proposes that age, sex, and biology are unchangeable, but lifestyle factors, social and community, living and working conditions and cultural and environmental conditions can be modified through interaction in between levels of the model (45) (fig. 1). The structural drivers of health inequalities between social groups was further explained through Marmots report in 2008 (43). Social inequalities in health is known and forms a gradient and will affect the chances of poor or good health depending on the different steps of the status ladder most often shown as education, income and occupation (43,46).

Education is considered a stabile measure for social inequality and is used to capture knowledge related assets of a person when used as socioeconomic position in a study (47). It is easy to measure with self-report questionnaires as it is maintained throughout the life course, usually from early adulthood regardless of work and other circumstances (47,48). Education affect cognitive functioning and reflects health literacy to indirectly can effect health (47,49). Education contributes to better a financial situation, living conditions and coping strategies. Education reduces the risk of unemployment and gives a foundation for social mobility which again enhances the health condition. Students who do not complete secondary school are at higher risk for developing worse health in adulthood (44).

The welfare state operates as a basis in the Norwegian society for social equalization and specifically social equalization in health. Through financial security with the National Insurance Scheme, the welfare model also includes public healthcare, education and other services financed through taxation (50). The Norwegian and Nordic welfare model has developed over centuries but increased after world war II and with further expansions in the

60ies and 70ies (51,52). The increase in wealth in Norway over the decades has contributed to an increase of welfare of Norway as a whole (53,54). Even though large efforts has been made to limit social inequalities in Norway through this system, socioeconomic inequalities still exist in Norway, is increasing and been named *the Nordic paradox* (44,55).

1.5 Social inequalities in multimorbidity

Chronic diseases have accumulated through the 20th century and WHO has considered it to be "the health care challenge of the 21th century" (12). There has been a shift from acute infectious diseases being the more dominant in the western societies to chronic conditions which has increased over the later years (24,25,56,57) and the rising burden of these diseases is claimed to impose new challenges to health systems (57).

Multimorbidity has large negative consequences for the individual as for the health care systems and society. Multimorbidity is associated with high resource use of health care and health care systems (19,58–61).

Social inequalities in multimorbidity has been increasingly studied in the last decades and studies generally report multimorbidity to be more common with lower socioeconomic position (9–11,18,19,62,63). Multimorbidity prevalence and complexity rise with fewer social resources (19,39) and the onset of multimorbidity is shown to occur 10-15 years earlier for people of lower socioeconomic position (19). As social inequalities in prevalence of multimorbidity increase, it is most prominent for complex multimorbidity shown in Great Britain (10).

1.6 Purpose, aim and research question

This study adds to former work on multimorbidity using data from The Trøndelag Health Study (HUNT). Thomasdottir operationalized multimorbidity as two or more conditions in HUNT3, investigating relations to childhood conditions (37) and patterns (23) in addition to prevalence. Vinjerui continued to study the HUNT3-population and explored social differences in prevalence of several measures of multimorbidity and complex multimorbidity, where she increased the number of conditions included, compared to Thomasdottir.

This master thesis investigates prevalence in normal multimorbidity and complex multimorbidity, from in large parts identical conditions, and its connection to social inequalities over three time periods, which has not been done in Norway yet. This study will increase knowledge on historical development in prevalence and social differences in multimorbidity and complex multimorbidity in Norway.

How does prevalence of multimorbidity and complex multimorbidity vary with educational level, age, and sex, from 1995-2019 in a general Norwegian population?

2. Methods

2.1 The Trøndelag Health Study (HUNT)

The Trøndelag Health Study (HUNT) is a Norwegian population-based cross-sectional health survey where all adults 20 years and older living in Northern Trøndelag County has been invited to participate. The Survey has been conducted four times: HUNT1 (1984-86), HUNT2 (1995-97), HUNT3 (2006-08) and HUNT4 (2017-19) and include health information and biological material from the inhabitants (64–66).

As a basis for public health work, HUNT has the aim to get an overview over health- and living conditions in Northern Trøndelag. Through the data and material obtained, there are possibilities to study the connections between genetic variations, lifestyles, and environmental impact as well as health and social conditions in the population and can give new knowledge on public health, health and disease. About 250 000 participants have approved the use of deidentified health information for research projects since the beginning in 1984 (65–67).

Ongoing research projects can be seen on HUNTs websites (68–70).

2.2 Study design

The design of this study is cross-sectional design, in which data is processed and analysed from three different time periods: HUNT2 (1995-97), HUNT3 (2006-08) and HUNT4 (2017-19). The three cross-sectional studies are comparable since they consist of nearly identical conditions and are defined in the same way. A cross-sectional study design is suitable to describe prevalence since information obtained is covered through a certain timeframe (71,72).

A cross-sectional study means that the method can be standardized and explore many variables in the same study (72) which gives great opportunities to map a greater selection and also study contexts in between variables. The study design is assumed to have relational factors between outcome and exposure, but cannot conclude on what the causes and effects are (72).

Comparative cross-sectional research in form of changes across time in prevalence and associations, present challenges, such as bias and interpretation of results (73). This study though has tried to follow the general recommendations for such studies (73).

2.3 Study population

This study uses data mainly collected through the main questionnaire (questionnaire 1) and measurements in HUNT2, HUNT3 and HUNT4 (74) (additional appendix). The main questionnaire was received by the participant with the invitation letter and handed in when attending the screening station where clinical measurements were taken. Further data

collection procedures have been described in cohort profiles (64–66). Questionnaire 1 is a self-report questionnaire and this give reliable estimates of multimorbidity in studies of large samples (6).

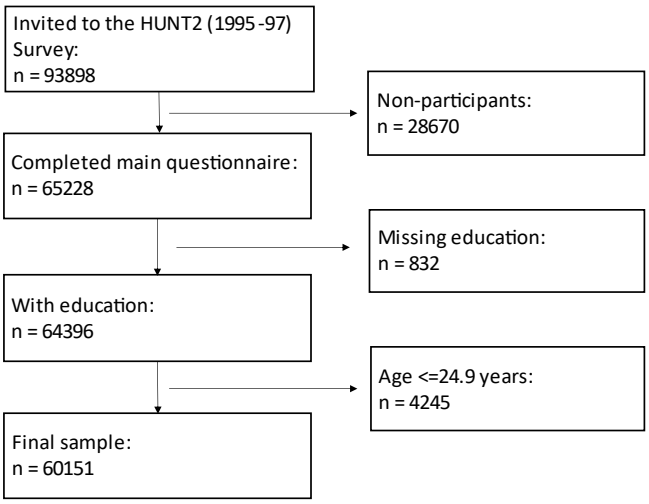
To ensure the participants education level was attained, the analysis of the data was limited to participants 25 years and older (fig. 2).

A total of 65228 individuals (69% of 93898 invited) in HUNT2 completed the main questionnaire, required to consider a person an attendant of the HUNT2 Survey. 832 respondents were excluded due to missing educational data. An additional 4245 participants younger than 25 years were excluded. Finally, 60151 of 65228 (92%) respondents were eligible for data analysis in HUNT2.

A total of 50800 individuals (54% of 93860 invited) in HUNT3 completed the main questionnaire. 4609 respondents were excluded due to missing educational data. An additional 1435 participants younger than 25 years were excluded. Finally, 44756 of 50800 (88%) respondents were eligible for data analysis in HUNT3.

A total of 56041 individuals (54% of 103798 invited) in HUNT4 completed the main questionnaire. 254 respondents were excluded due to missing educational data. An additional 3324 participants younger than 25 years were excluded. Finally, 52463 of 56041 (94%) respondents were eligible for data analysis in HUNT4.

Sampling for each HUNT2, HUNT3 and HUNT4 is described in figure 2.



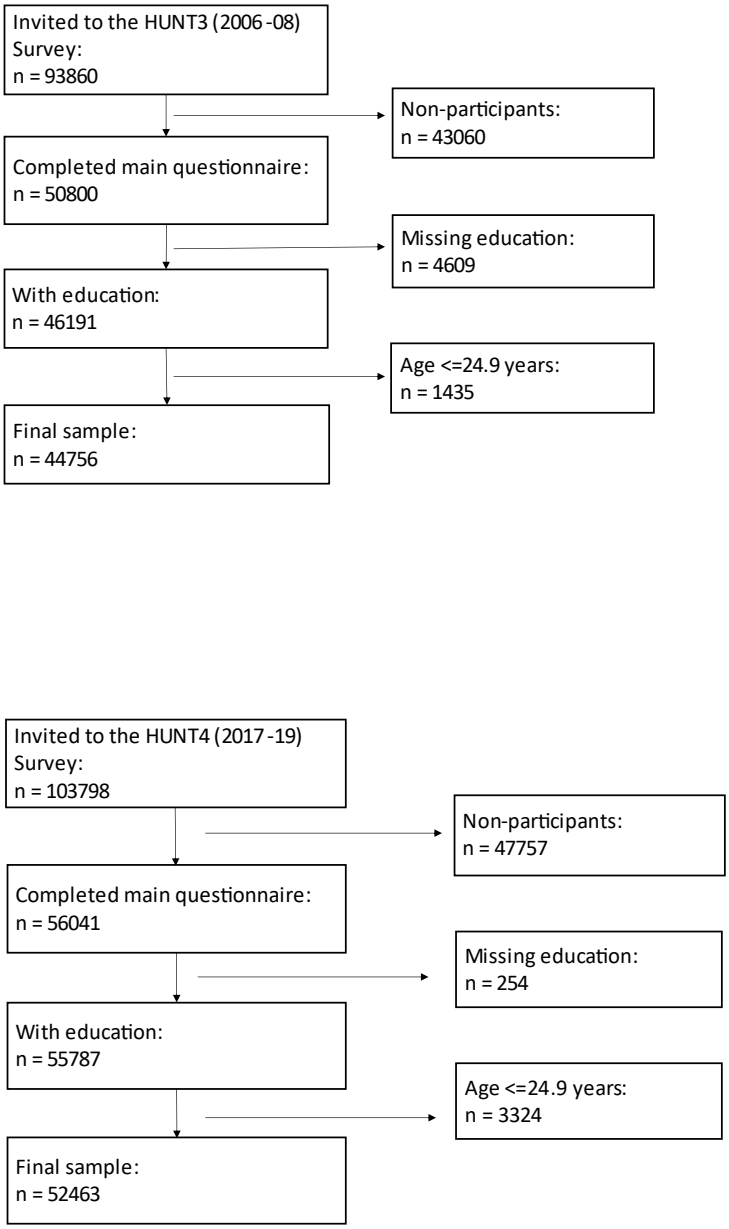


Figure 2. Flowchart for sample selection HUNT2, HUNT3 and HUNT4; inclusion and exclusion criteria and missing data.

2.4 Study variables

2.4.1 Explanatory variable socioeconomic position

Education was used as an indicator for socioeconomic position and was the main explanatory variable in this study.

Educational information is not attained in the HUNT3 Survey. Therefore, HUNT1 and HUNT4Emig Surveys in addition to educational information in HUNT2 and HUNT4 was used

to cover educational data for participants in HUNT3 if available (appendix A). Missing data on educational level was extracted (appendix A and fig. 2). If the respondents had participated in several surveys in the HUNT Study, any missing data on educational level were imputed if available. The remaining missing regarding education were handled through multiple imputation in all three surveys (HUNT2, HUNT3, and HUNT4) (appendix A) (75).

The original set of variables on education were converted into five levels based on educational classifications of ISCED11 and NUS2000 (76) and correspondence/guidance with SSB (e-mail 17.-21.11.2022 Maj-Lisa Lervåg, adviser, section for educational and cultural statistics, department for person- and social statistics, SSB). To better the communication of the results the five levels were further collapsed into three levels: primary (primary and lower secondary school), secondary (upper secondary and post-secondary school), and tertiary (first and second stage of tertiary education). Further details in the division of levels, see (appendix B and additional appendix).

It is shown that Northern Trøndelag county has to some extent lower education and income levels compared to the Norwegian population on average (77,78).

2.4.2 Confounding variables

Sex and age were regarded as confounders and are derived from HUNT Databank. Sex is a categorical dichotomous variable with values «women» and «men» and derived from the personal identification number. Age at participation, a continuous variable rounded off to 1 decimal, was used in the analysis. All participants over 100 years were given the value 100 years to uphold privacy (79–82). Birthdate for participants was from 1882 to 2000. In the descriptive analyses, age was categorized in four age groups; 25-44, 45-64, 65-74 and 75-100 years (11,83).

2.4.3 Outcome variables multimorbidity and complex multimorbidity

Multimorbidity and complex multimorbidity were the outcome variables in this study.

All conditions possible to generate from the HUNT2, HUNT3 and HUNT4 Surveys were included to meet recommendations on deriving the best estimate of prevalence of multimorbidity (8), within the scope of a master thesis. 16 single-entities conditions from questionnaire 1 and measurements were coinciding in HUNT2, HUNT3 and HUNT4 (appendix C). Of these, 9 conditions were dichotomous self-reported variables, and 7 conditions were constructed into dichotomous variables. They were further combined and made into one dichotomous multimorbidity and one dichotomous complex multimorbidity variable for each of the HUNT2, HUNT3 and HUNT4 Surveys (six variables in total) before analysis. Multimorbidity was measured as the occurrence of 2 or more single conditions. Complex multimorbidity was grouped according to the International Classification of Diseases, Tenth Revision (ICD-10), in eight organ-specific chapters and one chapter on symptoms, signs and abnormal clinical and laboratory findings, nine chapters in total (box 1) (84). Chapters were counted once if affected by at least one chronic condition, and a summary score of the chapter variables was generated and thus complex multimorbidity was defined as having conditions in at least 3 of 9 chapters (box 1).

Prevalence on single conditions was derived (appendix D).

ICD-10 chapter
Conditions
II Neoplasm
Cancer
IV Endocrine/nutritional/metabolic
Obesity
Hypercholesterolemia
Diabetes
V Mental/behavioural
Mental health/CONOR MHI-average
VII Eye/Adnexa
Impaired vision
VIII Ear/mastoid
Impaired hearing
IX Circulatory system
Hypertension
Angina pectoris
Myocardial infarction
Stroke or brain haemorrhage*
X Respiratory system
Asthma
XIII Musculoskeletal/connective tissue
Rheumatoid arthritis
Osteoarthritis
Ankylosing spondylitis (Bechterews)
XVIII Symptoms, signs/abnormal clinical/laboratory findings
Chronic widespread pain/chronic musculoskeletal pain
*Exception to single entity

Box 1. Conditions grouped by ICD-10 chapter.

Chronicity of conditions was defined as long-lasting (at least 3 months) or with severe effects or requirements to the health care systems and management (4,6,12,14). Some of the raw data varies in specifying factors for determining chronicity. When in absence of this information, chronicity was determined following the definitions in Vinjeruis doctoral thesis (63).

Disease count is the dominant multimorbidity measure, most multimorbidity research is conducted in the general population and self-report is typically used, which were all used in this study and considered valid (4,6,7,30). It has been suggested to use previously published sets of condition-lists to achieve the most stabile estimates of multimorbidity estimates (5,21,85).

Getz has problematized that a lower limit value for high blood pressure and high cholesterol can put more people in category as sick than needed (86). According to definitions on chronicity, the limit values used in this study are considered to be over the threshold of requirement of medical care and with severe effects on the individual (12) (appendix C).

Information on missing data was collected from the HUNT Databank (82). Some topics are covered by 1 question, whereas others include 1 index question and further questions in a block (additional appendix). In cases where data was missing in any of the questions in a block, this was corrected based on reply to index question and if any other alternatives were crossed off, missing data was regarded as “no”.

Information on missing data was extracted for conditions with question asked “have you had or have you ever had…” named “disease ever” conditions and included 9 conditions in HUNT2 and HUNT3 and 8 conditions in HUNT4. Osteoarthritis is taken out of the missing extraction for HUNT4 because this variable deviated from the variable used in HUNT2 and HUNT3 and was not a “disease ever” question (appendix C). This is regarded as valid to do, since this stage of extracting missing is done considering that participants get tired of filling in many questions after one another which is what is explored (87,88). Were data was missing in any of the questions of “disease ever”, this was corrected if any other questions were crossed off. Missing data was then regarded as “no”.

The row total command in Stata manages missing data as 0 or “no” and ignores missing values. Those with completely missing data when constructing the multimorbidity and complex multimorbidity variables have therefore been excluded. This applies to one person in HUNT3 and HUNT4.

For further details on the original variables see HUNT Databank (82), additional appendix with questionnaire 1 for HUNT2, HUNT3 and HUNT4 and appendix C. A version of the questionnaire 1 in English is available for HUNT2 and HUNT3, but not for HUNT4 since an approved scientific translation of the HUNT4 questionnaire 1 has not been put into process yet in English (Vegard Marchhäuser, personal communication, 21.04.2023)(89) and therefore the additional appendix consists of the Norwegian versions.

2.5 Statistical analysis

2.5.1 Descriptive statistics

Descriptive statistics and cross tables were used to present the study population in table 1 and outcome distribution in table 2 of the samples in HUNT2, HUNT3 and HUNT4. Table 1 present the sociodemographic characteristics sex, age, and educational level. Table 2 present the sociodemographic distribution of educational level and age stratified by sex for multimorbidity and complex multimorbidity separately.

2.5.2 Logistic regression and designing the models

Binary logistic regression was used to examine associations between educational level, the main predictor of interest, and the two outcomes multimorbidity and complex multimorbidity (90). The hypothesis that lower educational level associate with higher prevalence of multimorbidity or complex multimorbidity is based on what we know of social inequalities in health (43,45,46,91) and multimorbidity (10,11,19). We assume that educational level was completed before multimorbidity and complex multimorbidity arose. However, in this study the outcomes and exposure were measured in the same timeframes.

Regression is a method were you study the relation between statistical variables with a purpose to explain the variation in one outcome variable with the use of other explanatory variables (92,93). Through logistic regression we want to be able to say something about the probability for an outcome with a predefined set of combinations of risk factors or explanatory variables, exemplified by how big part of the population will have the outcome if the predefined set of risk factors or explanatory variables are present (72).

We chose regression models based on an idea of causal effect or relationship, as suggested by directed acyclic graphs. Directed acyclic graphs are visual representations of causal assumptions by making underlying relations explicit and in that way can identify confounding (94). DAGs are increasingly and preferably used in modern epidemiology to identify sources of confounding (94), as exemplified in figure 3, age as a confounder when wanting to assess the causal relationship between the exposure education and the outcome multimorbidity.

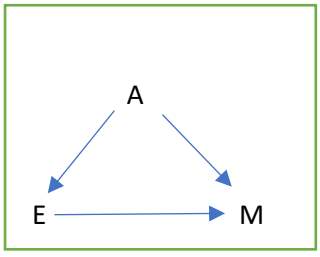


Figure 3. Age (A) as a confounder to the relation between education (E) and outcome multimorbidity (M).

Confounding is a central element in epidemiological observational study design and it can simply be defined as confusion of effects which implies that the effect of the exposure is mixed with the effect of other variables that can lead to bias (71). Confounding variables, relate to both the exposure and the outcome, but must not be an effect of the exposure (71) (fig. 3). Former studies indicate that sex and age impact both educational level obtained and

health outcomes, such as multimorbidity and complex multimorbidity. We thus regard age and sex as confounders (71). We further assume that there is an interaction between education and age since the Norwegian population is getting older, more of the population inhabit education and a greater proportion has higher education now than 40 years ago (95–98). In addition, we expected non-linear trends to occur in the data for age, thus including age squared.

It is tradition in social epidemiology to present sex separately and our basic model was educational level, stratified on sex. For each HUNT-wave and outcome, we used likelihood ratio tests to evaluate competing statistical models' fit to the observations in the sample (93). Likelihood ratio test is a test of two models which is nested in each other to give the best/sufficient fit of the model. For example, the model including education, age, and age squared, nests the model consisting of education and age only. "Fit" means how well the model is customized the actual observed data. It is important to not customize too much for the model to still be applicable and possible to be generalized (93).

The final models for multimorbidity included age squared in HUNT2, but not in HUNT3 and HUNT4. This suggests multimorbidity`s relation to age and education varies more in HUNT2 but is more constant in HUNT3 and HUNT4. For complex multimorbidity age squared is included in all HUNT-waves, except for men in HUNT3.

2.5.3 Presentation of results

In epidemiology, a confidence interval is used to present uncertainties connected to the point estimate. The confidence interval gives an indication of the degree of random errors in the estimate (71). A small confidence interval can decipher that the estimates are certain, and a larger confidence interval can decipher that the estimates are more uncertain (72,99). The confidence interval gives a clearer picture of the precision around the effect measure.

Results from a logistic regression can be presented as coefficients or odds ratios (OR). Odds ratio is the relation between two odds where one odds is the probability that an outcome will occur in relation to the probability that it will not occur. Odds ratio is being used to express how strong the connection between two occurrences is. The stronger the relation between the two occurrences is, the greater the differences between the two odds and the higher is OR (100). Odds ratio is challenging to interpret and is suggested used when the prevalence is rare in a population, typically less than 10 % (101). Since multimorbidity and complex multimorbidity are more common, OR is not presented in this study, but we present odds ratio converted into prevalence differences (PD) and prevalence ratios (PR). Adjusted risk ratio in Stata reports the point estimates, standard errors and 95% confidence intervals and can compute these for specific values of the variable of interest (102). Relative risk calculate the relationship between the occurrences, or differences (72) and gives an impression of to what extend disease/occurrence of disease among the exposed population is a consequence of the exposure (71). The measure is being expressed in a scale from 1 to infinity and is being converted to a proportion. The predicted difference is shown in percentage point or absolute terms (102).

Estimates from the logistic regression models were used to derive prevalence difference, the difference in mean predicted probability, and prevalence ratios, the ratio between the mean predicted probabilities, between educational levels while holding other covariates constant (102). The tertiary educational level was chosen as the reference group. Prevalence differences and prevalence ratios were calculated for age groups 35, 55, 70 and 85 years which respectively represent adult, middle aged, aged and oldest old (83) and is the middle age for each age group categorized for the descriptive analysis. Results are presented in table 3, were age 55 are being described in detail while the other ages are being presented in supplementary appendix (appendix D). Line chart are being used to visualize the results for age 55 years. Interpretation of confidence intervals is straight forward. For PR, a confidence interval that does not include 1 is considered statistically significant. For PD, a confidence interval that does not include 0 is considered statistically significant.

StataIC 17.0 was used to analyse the data (103).

2.6 Research ethics and risk evaluation

This study is approved by the Regional Committees for Medical and Health Research Ethics mid-Norway (Ref. 535577) (additional appendix). A change notification was sent two times to prolong the project period and was approved to be extended to 15.01.2024.

An application to extract data from HUNT was sent to HUNT research centre and an agreement of the use of research material from The Trøndelag Health Study (HUNT) was being signed by three parties, the 31.10.2022 (additional appendix). The datafile from HUNT research centre was sent to the project leader 07.11.2011.

All data was deidentified before extradition for research and the received data was saved on NICE-1 protected storage area which demands log in through VPN and two-factor authentication (104,105). HUNT research centre is the only one that has the coupling key between personal data and project specific ID. HUNT research centre has approved security procedures for storage and handling of HUNT-data through concession from the Norwegian Data Protection Authority. The project leader will delete the data after the project period is over. NICE-1 can manage data that needs increased security (104–106).

2.6.1 User participation

Participation in HUNT is voluntary, and a consent is needed for participance which can be withdrawn at any time (107).

Populations of lower socioeconomical positions are vulnerable groups. Concerning this study where social inequalities in health is being explored, close attention to avoid stigmatisation is needed when presenting and communicating the results.

Regional Committees for Medical and Health Research Ethics has evaluated the utility of the HUNT Studies larger than the disadvantage for the individual participant (65).

3. Results

3.1 Descriptive statistics

Table 1 describes the sociodemographic characteristics of each HUNT wave. With regards to education, the educational level shifts in the study population between HUNT2 and HUNT4, as reported in table 1 and visualized in figure 4. In total numbers, roughly equally many had completed primary and secondary education, constituting 40% each (prim n =24661, sec n=24157), while 19% (n=11333) had completed tertiary education in HUNT2. While in HUNT4, as few as 12% (n=6533) had only completed primary education and 40% (n=20868) had completed tertiary education. In HUNT3, 23% (n=10461) had completed primary education, while 31% (n=13769) had completed tertiary education.

With regards to sex and age, women constituted the major part of the eligible sample in each HUNT-wave. 53% (n=31870) were women in HUNT2, 55% (n=24555) in HUNT3 and 54% (n=28559) in HUNT4. The study population increased in total mean age, and in each educational group, from HUNT2 to HUNT4. In each HUNT, mean age is lower for each increase in educational level. Appendix E shows age distribution through age groups by educational level which also shows the shift in educational level by age and time.

Table 1. Sex and mean age distribution by educational level in HUNT2, HUNT3 and HUNT4[a].

		Educational level			
		Tertiary	Secondary	Primary	Total
		Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)
HUNT2 (1995-1997)					
Total		11333 (100)	24157 (100)	24661 (100)	60151 (100)
Sex					
	Women	5870 (52)	11469 (48)	14531 (59)	31870 (53)
	Men	5463 (48)	12688 (53)	10130 (41)	28281 (47)
Age, years					
	Mean (SD)	45 (13)	46 (14)	62 (14)	52 (16)
HUNT3 (2006-2008)					
Total		13769 (100)	20526 (100)	10461 (100)	44756 (100)
Sex					
	Women	7819 (57)	10283 (50)	6453 (62)	24555 (55)
	Men	5950 (43)	10243 (50)	4008 (38)	20201 (45)
Age, years					
	Mean (SD)	49 (13)	54 (13)	67 (12)	56 (14)
HUNT4 (2017-2019)					
Total		20868 (100)	25062 (100)	6533 (100)	52463 (100)
Sex					
	Women	12317 (59)	12223 (49)	4019 (62)	28559 (54)
	Men	8551 (41)	12839 (51)	2514 (39)	23904 (46)
Age, years					
	Mean (SD)	52 (15)	57 (15)	70 (15)	56 (16)

Freq., Frequency
[a]Decimals are rounded up from 0.5 and rounded down from 0.4. Therefore, the percentage sums are uneven some places.

Figure 4a)

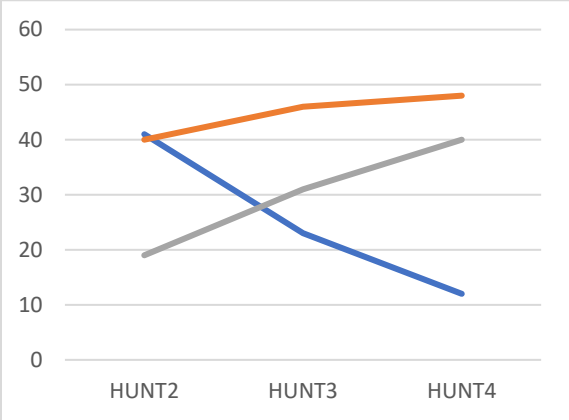


Figure 4b)

[a]Primary educational level, secondary educational level, tertiary educational level.

Figure 4. Educational level by percent (a) and absolute numbers (b) for HUNT2, HUNT3 and HUNT4[a].

The development in educational level from HUNT2 to HUNT4 shows an increase in tertiary educational level and decrease in primary educational level both in percent and absolute numbers (fig. 4).

Table 2a and 2b shows the sociodemographic distribution of the outcomes, multimorbidity and complex multimorbidity.

In total, 40% (n=24101 of 60151) met the criteria for having multimorbidity in HUNT2, 23% (n=10154 of 44756) in HUNT3 and 29% (n=15390 of 52463) in HUNT4. Of women, 43% (n=13683) met the criteria for having multimorbidity in HUNT2, 24% (n=5970) in HUNT3 and 31% (n=8842) in HUNT4. The proportions increased from tertiary to primary educational level from 22% (n=1274) to 61% (n=8883) in HUNT2, 13% (n=1016) to 41% (n=2659) in HUNT3 and 22% (n=2751) to 47% (n=1879) in HUNT4. The proportions increased from age group 25-44 years to age group 75-100 years from 18% (n=2196) to 81% (n=2830) in HUNT2, 7% (n=476) to 54% (n=1486) in HUNT3 and 16% (n=1264) to 51% (n=1932) in HUNT4.

Of men, 37% (n=10418) met the criteria for having multimorbidity in HUNT2, 21% (n=4184) in HUNT3 and 27% (n=6548). The proportions increased from tertiary to primary educational level from 23% (n=1249) to 52% (n=5287) in HUNT2, 14% (n=817) to 35% (n=1413) in HUNT3 and 22% (n=1899) to 43% (n=1076) in HUNT4. The proportions increased from age group 25-44 years to age group 75-100 years from 17% (n=1814) to 68% (n=1724) in HUNT2, 6% (n=310) to 48% (n=992) in HUNT3, 13% (n=734) to 49% (n=1485) in HUNT4.

Table 2a). Sociodemographic distribution of multimorbidity in HUNT2, HUNT3 and HUNT4.

		Multimorbidity					
		Women			Men		
		No, n (%)	Yes, n (%)	Total, n (%)	No, n (%)	Yes, n (%)	Total, n (%)
HUNT2 (1995-97)							
Total		18187 (57)	13683 (43)	31870 (100)	17863 (63)	10418 (37)	28281 (100)
Educational level							
	Tertiary	4596 (78)	1274 (22)	5870 (100)	4214 (77)	1249 (23)	5463 (100)
	Secondary	7943 (69)	3526 (31)	11469 (100)	8806 (69)	3882 (31)	12688 (100)
	Primary	5648 (39)	8883 (61)	14531 (100)	4843 (48)	5287 (52)	10130 (100)
Age, years							
	25-44	10064 (82)	2196 (18)	12260 (100)	8956 (83)	1814 (17)	10770 (100)
	45-64	6220 (54)	5229 (46)	11449 (100)	6487 (61)	4219 (39)	10706 (100)
	65-74	1233 (26)	3428 (74)	4661 (100)	1601 (38)	2661 (62)	4262 (100)
	75-100	670 (19)	2830 (81)	3500 (100)	819 (32)	1724 (68)	2543 (100)
	Mean (SD)	45 (14)	61 (15)	52 (16)	47 (14)	60 (15)	52 (16)
HUNT3 (2006-08)							
Total		18585 (76)	5970 (24)	24555 (100)	16017 (79)	4184 (21)	20201 (100)
Educational level							
	Tertiary	6803 (87)	1016 (13)	7819 (100)	5133 (86)	817 (14)	5950 (100)
	Secondary	7988 (78)	2295 (22)	10283 (100)	8289 (81)	1954 (19)	10243 (100)
	Primary	3794 (59)	2659 (41)	6453 (100)	2595 (65)	1413 (35)	4008 (100)
Age, years							
	25-44	6214 (93)	476 (7)	6690 (100)	4491(94)	310 (6)	4801 (100)
	45-64	8870 (78)	2519 (22)	11389 (100)	8260 (83)	1716 (17)	9976 (100)
	65-74	2247 (60)	1489 (40)	3736 (100)	2202 (65)	1166 (35)	3368 (100)
	75-100	1254 (46)	1486 (54)	2740 (100)	1064 (52)	992 (48)	2056 (100)
	Mean (SD)	52 (14)	65 (13)	55 (15)	54 (13)	65 (13)	56 (14)
HUNT4 (2017-19)							
Total		19717 (69)	8842 (31)	28559 (100)	17356 (73)	6548 (27)	23904 (100)
Educational level							
	Tertiary	9566 (78)	2751 (22)	12317 (100)	6652 (78)	1899 (22)	8551 (100)
	Secondary	8011 (66)	4212 (34)	12223 (100)	9266 (72)	3573 (28)	12839 (100)
	Primary	2140 (53)	1879 (47)	4019 (100)	1438 (57)	1076 (43)	2514 (100)
Age, years							
	25-44	6528 (84)	1264 (16)	7792 (100)	5106 (87)	734 (13)	5840 (100)
	45-64	8144 (71)	3402 (29)	11546 (100)	7458 (76)	2374 (24)	9832 (100)
	65-74	3195 (59)	2244 (41)	5439 (100)	3249 (62)	1955 (38)	5204 (100)
	75-100	1850 (49)	1932 (51)	3782 (100)	1543 (51)	1485 (49)	3028 (100)
	Mean (SD)	53 (16)	62 (16)	56 (16)	54 (15)	64 (14)	57 (16)

In total, 17% (n=10197 of 60151) met the criteria for having complex multimorbidity in HUNT2, 6% (n=2697 of 44756) in HUNT3 and 8% (n=4176 of 52463) in HUNT4, table 2b.

Of women, 20% (n=6326) met the criteria for having complex multimorbidity in HUNT2, 7% (n=1697) in HUNT3 and 9% (n=2448) in HUNT4. The proportions increased from tertiary to primary educational level from 6% (n=373) to 32% (n=4699) in HUNT2, 3% (n=207) to 14% (n=903) in HUNT3 and 5% (n=653) to 16% (n=649) in HUNT4. The proportions increased from age group 25-44 years to age group 75-100 years from 4% (n=465) to 52% (n=1833) in HUNT2, 1% (n=72) to 20% (n=553) in HUNT3 and 3% (n=256) to 20% (n=752) in HUNT4.

Of men, 14% (n=3871) met the criteria for having complex multimorbidity in HUNT2, 5% (n=1000) in HUNT3 and 7% (n=1728) in HUNT4. The proportions increased from tertiary to primary educational level from 6% (n=345) to 22% (n=2268) in HUNT2, 3% (n=167) to 10% (n=411) in HUNT3 and 5% (n=456) to 13% (n=329) in HUNT4. The proportions increased from age group 25-44 years to age group 75-100 years from 3% (n=374) to 34% (n=874) in HUNT2, 1% (n=40) to 15% (n=314) in HUNT3 and 3% (n=150) to 17% (n=508) in HUNT4.

Table 2b). Sociodemographic distribution of complex multimorbidity in HUNT2, HUNT3 and HUNT4.

		Complex multimorbidity					
		Women			**Men**		
		No, n (%)	**Yes, n (%)**	**Total, n (%)**	**No, n (%)**	**Yes, n (%)**	**Total, n (%)**
HUNT2							
Total		25544 (80)	6326 (20)	31870 (100)	24410 (86)	3871 (14)	28281 (100)
Educational level							
	Tertiary	5497 (94)	373 (6)	5870 (100)	5118 (94)	345 (6)	5463 (100)
	Secondary	10215 (89)	1254 (11)	11469 (100)	11430 (90)	1258 (10)	12688 (100)
	Primary	9832 (68)	4699 (32)	14531 (100)	7862 (78)	2268 (22)	10130 (100)
Age, years							
	25-44	11795 (96)	465 (4)	12260 (100)	10396 (97)	374 (3)	10770 (100)
	45-64	9322 (81)	2127 (19)	11449 (100)	9259 (86)	1447 (14)	10706 (100)
	65-74	2760 (59)	1901 (41)	4661 (100)	3086 (72)	1176 (28)	4262 (100)
	75-100	1667 (48)	1833 (52)	3500 (100)	1669 (66)	874 (34)	2543 (100)
	Mean (SD)	49 (15)	66 (13)	52 (16)	50 (15)	64 (13)	52 (16)
HUNT3							
Total		22858 (93)	1697 (7)	24555 (100)	19201 (95)	1000 (5)	20201 (100)
Educational level							
	Tertiary	7612 (97)	207 (3)	7819 (100)	5783 (97)	167 (3)	5950 (100)
	Secondary	9696 (94)	587 (6)	10283 (100)	9821 (96)	422 (4)	10243 (100)
	Primary	5550 (86)	903 (14)	6453 (100)	3597 (90)	411 (10)	4008 (100)
Age, years							
	25-44	6618 (99)	72 (1)	6690 (100)	4761 (99)	40 (1)	4801 (100)
	45-64	10784 (95)	605 (5)	11389 (100)	9614 (96)	362 (4)	9976 (100)
	65-74	3269 (88)	467 (12)	3736 (100)	3084 (92)	284 (8)	3368 (100)
	75-100	2187 (80)	553 (20)	2740 (100)	1742 (85)	314 (15)	2056 (100)
	Mean (SD)	54 (15)	68 (12)	55 (15)	55 (14)	68 (12)	56 (14)
HUNT4							

Total		26111 (91)	2448 (9)	28559 (100)	22176 (93)	1728 (7)	23904 (100)
Educational level							
	Tertiary	11664 (95)	653 (5)	12317 (100)	8095 (95)	456 (5)	8551 (100)
	Secondary	11077 (91)	1146 (9)	12223 (100)	11896 (93)	943 (7)	12839 (100)
	Primary	3370 (84)	649 (16)	4019 (100)	2185 (87)	329 (13)	2514 (100)
Age, years							
	25-44	7536 (97)	256 (3)	7792 (100)	5690 (97)	150 (3)	5840 (100)
	45-64	10736 (93)	810 (7)	11546 (100)	9290 (94)	542 (6)	9832 (100)
	65-74	4809 (88)	630 (12)	5439 (100)	4676 (90)	528 (10)	5204 (100)
	75-100	3030 (80)	752 (20)	3782 (100)	2520 (83)	508 (17)	3028 (100)
	Mean (SD)	55 (16)	66 (16)	56 (16)	56 (16)	67 (14)	57 (16)

Prevalence for single conditions were derived and shown for HUNT2, HUNT3 and HUNT4 (appendix D). Musculoskeletal pain deviated the most between the HUNTs with 52% having this condition in HUNT2 (n=31197), 1 % in HUNT3 (n=500) and 1 % in HUNT4 (n=680). High blood pressure with 18% (n=10847) in HUNT2, 8% (n=3697) in HUNT3 and 7% (n=3724) in HUNT4, and high cholesterol with 20% (n=12282) in HUNT2, 10% (n=4555) in HUNT3 and 7% (n=3614) in HUNT4, deviated also along with osteoarthritis with 10% (n=6221) in HUNT2, 16% (n=6949) in HUNT3 and 33% (n=17087) in HUNT4 (appendix D).

3.2 Absolute and relative socioeconomic inequalities in multimorbidity and complex multimorbidity

Table 3 shows prevalence differences (PD) and prevalence ratios (PR) between educational levels presented at age 55 years, in women and men in HUNT2, HUNT3 and HUNT4. The table is presented as two separate tables, for multimorbidity (table 3a) and complex multimorbidity (table 3b) respectively, and contain results for HUNT2, HUNT3 and HUNT4 together. Line graphs in figures 5 and 6 visualize the trends in absolute and relative differences in prevalence of multimorbidity and complex multimorbidity for educational level in HUNT2, HUNT3 and HUNT4. Age 55 years represents the middle aged, while appendix F presents the prevalence differences and ratios for young adults, age 35, older adults, 70 years, and the eldest, 85 years (83).

3.2.1 Multimorbidity

Both prevalence differences (PD) and prevalence ratios (PR) for multimorbidity at age 55, increased by lower educational level, compared with the tertiary educational level (table 3a).

Prevalence differences between those having tertiary and primary educational levels for age 55 was 19 (17 to 21) percentage points (pp) in women and 18 (16 to 20) pp in men in HUNT2. In HUNT3 it was 11 (9 to 13) pp both in women and men and in HUNT4 it was 14 (11 to 16) pp both in women and men.

Compared with the tertiary educational level, prevalence ratios for people having primary educational level were at 55 years, 1.56 (1.46 to 1.66) in women and 1.59 (1.48 to 1.70) in men in HUNT2. This means 56% for women and 59% for men had higher chance of having

multimorbidity if you had primary educational level compared to tertiary educational level in HUNT2. Prevalence ratios were 1.70 (1.56 to 1.85) in women and 1.83 (1.65 to 2.04) in men in HUNT3, meaning 70% for women and 83% for men had higher chance of having multimorbidity in HUNT3 if you had primary educational level compared to tertiary educational level. Prevalence ratios were 1.57 (1.46 to 1.68) in women and 1.67 (1.53 to 1.83) in men in HUNT4. This means 57% for women and 67% for men had higher chance of having multimorbidity in HUNT4 if you had primary educational level compared to tertiary educational level.

The differences vary in size, but the pattern of prevalence differences and prevalence ratios between primary and secondary educational level compared to tertiary educational level remained at age 35, 70 and 85 in all HUNTs, except in HUNT3 at age 85 were prevalence differences and prevalence ratios was higher at secondary level than primary level for women (0.98/0.94; -0.01/-0.04), and men (1.14/1.11; 0.07/0.06) (appendix F).

The most extreme values were in HUNT2, 19 pp for women and 18 pp for men at age 55 (PD) and 1.75 for women and 1.65 for men at age 35 (PR). In HUNT3, 11 pp for women and men at age 55 (PD) and 3.09 for women and 2.74 for men at age 35 (PR). In HUNT4, 17 pp for women at age 35 and 14 pp for men at age 55 (PD) and 2.42 for women and 2.53 for men at age 35 (PR) (appendix F).

The least differences were in HUNT2, -4 pp for women and 5 pp for men at age 85 (PD) and 0.96 for women and 1.08 for men at age 85 (PR). In HUNT3 they were -4 pp for women at age 85 and 1 pp for men at age 35 (PD) and 0.94 for women and 1.11 for men at age 85 (PR), and in HUNT4 they were -1 for women and -0 for men (PD) and 0.98 for women and 1.00 for men at age 85 (PR) (appendix F).

Educational level prevalence differences and ratios diminished in women by age 70 years, while still present in men at age 85 years in all HUNTs (appendix F).

Table 3a). Prevalence ratios (PRs) and prevalence differences (PDs) with 95% CIs in multimorbidity between educational levels, stratified by sex, age 55 for HUNT2, HUNT3 and HUNT4.

			Women		Men	
Age, years	HUNT	Educational level	PR (95%CI)	PD (95%CI)	PR (95%CI)	PD (95%CI)
55[1]	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.33 (1.24 to 1.42)	0.11 (0.09 to 0.14)	1.34 (1.25 to 1.44)	0.11 (0.08 to 0.13)
		Primary	1.56 (1.46 to 1.66)	0.19 (0.17 to 0.21)	1.59 (1.48 to 1.70)	0.18 (0.16 to 0.20)
55[2]	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.35 (1.26 to 1.44)	0.06 (0.04 to 0.07)	1.28 (1.18 to 1.39)	0.04 (0.02 to 0.05)
		Primary	1.70 (1.56 to 1.85)	0.11 (0.09 to 0.13)	1.83 (1.65 to 2.04)	0.11 (0.09 to 0.13)
55[2]	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.32 (1.27 to 1.38)	0.08 (0.07 to 0.09)	1.27 (1.20 to 1.34)	0.05 (0.04 to 0.07)
		Primary	1.57 (1.46 to 1.68)	0.14 (0.11 to 0.16)	1.67 (1.53 to 1.83)	0.14 (0.11 to 0.16)

[1]Model women and men, included education, continuous age, age squared and an interaction term for age and education.

[2]Model women and men, included education, continuous age, and an interaction term for age and education

Figure 5a) PD in women, p.p.

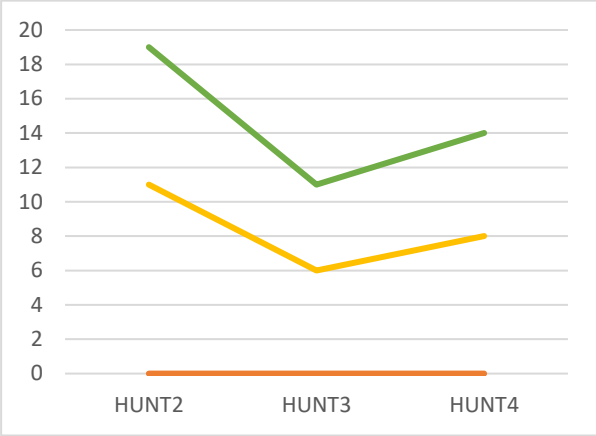


Figure 5b) PR in women, %

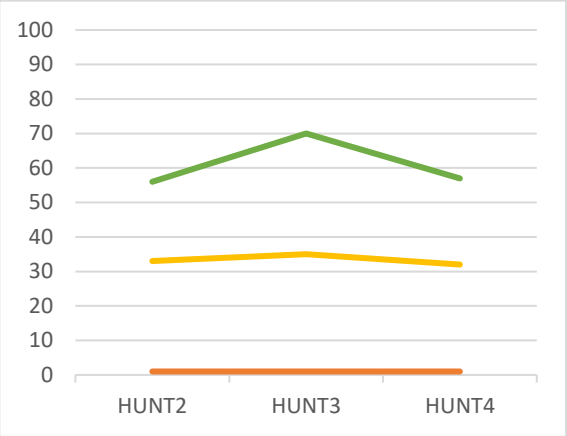


Figure 5c) PD in men

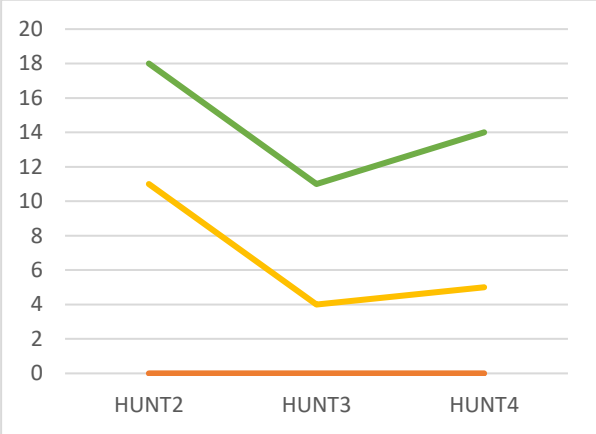


Figure 5d) PR in men

[a] Tertiary education (ref.), Secondary education, Primary education.

Figure 5. Trends in absolute differences (PD, percentage points) and relative differences (PR, percent), multimorbidity at 55 years by educational level in HUNT2, HUNT3 and HUNT4 in women (a and b) and men (c and d)[a].

Prevalence differences (PD) and prevalence ratios (PR) increase by educational level in all HUNTs for both women and men. Prevalence differences decreases in HUNT3 from HUNT2 but increases from HUNT3 to HUNT4 in both sexes. Prevalence ratios increases from HUNT2 to HUNT3 before decreasing in HUNT4 for primary educational level in both sexes. For secondary educational level prevalence ratios are more even throughout the HUNTs with a slight increase in HUNT3 for women, and slight decrease from HUNT2 to HUNT4 for men.

3.2.2 Complex multimorbidity

Both prevalence differences (PD) and prevalence ratios (PR) for complex multimorbidity at age 55, increased by lower educational level, compared with the tertiary educational level (table 3b).

Prevalence differences between tertiary and primary educational levels at age 55 was 12 (10 to 13) pp in women and 8 (7 to 10) pp in men in HUNT2. In HUNT3 it was 5 (3 to 6) pp in

women and 3 (2 to 5) pp in men. In HUNT4 it was 5 (3 to 6) pp in women and 4 (3 to 6) pp in men.

Compared with the tertiary educational level, prevalence ratios for the primary educational level were at 55 years, 2.06 (1.80 to 2.36) in women and 1.91 (1.66 to 2.20) in men in HUNT2. This means it was 106% higher chance for women and 91% for men of having complex multimorbidity if you had primary educational level compared with tertiary educational level in HUNT2. Prevalence ratios were 2.51 (2.01 to 3.12) in women and 2.48 (1.93 to 3.19) in men in HUNT3, meaning it was 151% higher chance for women and 148% for men of having complex multimorbidity if you had primary educational level compared with tertiary educational level in HUNT3. In HUNT4, prevalence ratios were 1.95 (1.64 to 2.31) in women and 1.97 (1.58 to 2.44) in men, meaning it was 95% higher chance for women and 97% for men of having complex multimorbidity with primary educational level compared with tertiary educational level.

The size of prevalence differences and ratios varied, but a similar pattern remained, between primary and secondary educational level compared to tertiary educational level for women and men for ages 35, 70 and 85 in all HUNTs, except for men in HUNT4 at age 85 were prevalence differences and prevalence ratios was higher at secondary level than primary level (0.05/0.04;1.33/1.28) (appendix F).

The most extreme values were in HUNT2, 12 pp for women at age 55 and 12 pp for men at age 70 (PD) and 2.79 for women and 2.16 for men at age 35 (PR). In HUNT3, 5 pp for women at age 55 and 5 pp for men at age 70 (PD) and 23.09 for women and 4.08 for men at age 35 (PR). In HUNT4, 8 pp for women and 6 pp for men at age 35 (PD) and 4.59 for women and 5.42 for men at age 35 (PR) (appendix F).

The least differences were in HUNT2, -1 pp for women at age 85 and 1 pp for men at age 35 (PD) and 0.98 for women and 1.25 for men at age 85 (PR). In HUNT3, 0 pp for women at age 70 and 0 pp for men at age 35 (PD) and 1.01 for women at age 70 and 1.17 for men at age 85 (PR). In HUNT4, -3 for women at age 85 and 1 for men at age 55 (PD) and 0.88 for women at age 85 and 1.15 for men at age 70 (PR) (appendix F).

Educational level prevalence differences and ratios were diminishing in women at 70 years, except in HUNT3 were prevalence differences and prevalence ratios persisted at 85 years. For men, prevalence differences and prevalence ratios were still present at age 85 years in all HUNTs (appendix F).

Table 3b). Prevalence ratios (PRs) and prevalence differences (PDs) with 95% CIs in complex multimorbidity between educational levels, stratified by sex, age 55 for HUNT2, HUNT3 and HUNT4.

			Women		Men	
Age, years	HUNT	Educational level	PR (95%CI)	PD (95%CI)	PR (95%CI)	PD (95%CI)
55[1]	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.59 (1.37 to 1.84)	0.06 (0.05 to 0.08)	1.50 (1.29 to 1.73)	0.05 (0.03 to 0.06)
		Primary	2.06 (1.80 to 2.36)	0.12 (0.10 to 0.13)	1.91 (1.66 to 2.20)	0.08 (0.07 to 0.10)
55[2]	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.69 (1.38 to 2.07)	0.02 (0.01 to 0.03)	1.28 (1.03 to 1.59)	0.01 (0.00 to 0.01)
		Primary	2.51 (2.01 to 3.12)	0.05 (0.03 to 0.06)	2.48 (1.93 to 3.19)	0.03 (0.02 to 0.05)
55[1]	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.49 (1.32 to 1.70)	0.03 (0.02 to 0.03)	1.26 (1.08 to 1.47)	0.01 (0.00 to 0.02)
		Primary	1.95 (1.64 to 2.31)	0.05 (0.03 to 0.06)	1.97 (1.58 to 2.44)	0.04 (0.03 to 0.06)

[1]Model women and men, included education, continuous age, age squared and an interaction term for age and education.

[2]Model women, included education, continuous age, age squared and an interaction term for age and education.

Model men, included education, continuous age, and an interaction term for age and education.

Figure 6a) PD in women, p.p.

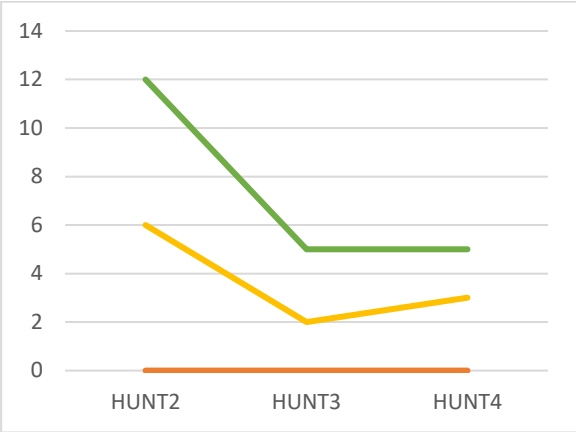


Figure 6b) PR in women, %

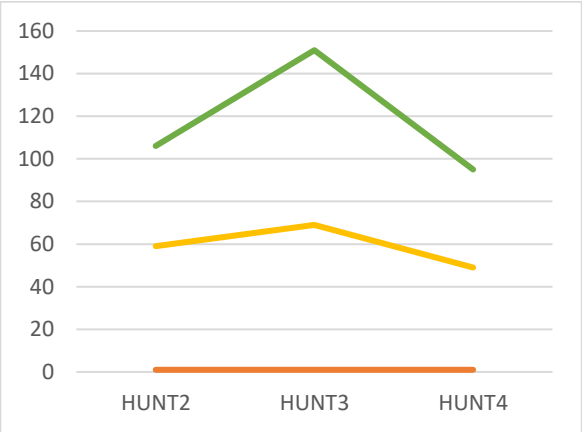


Figure 6c) PD in men

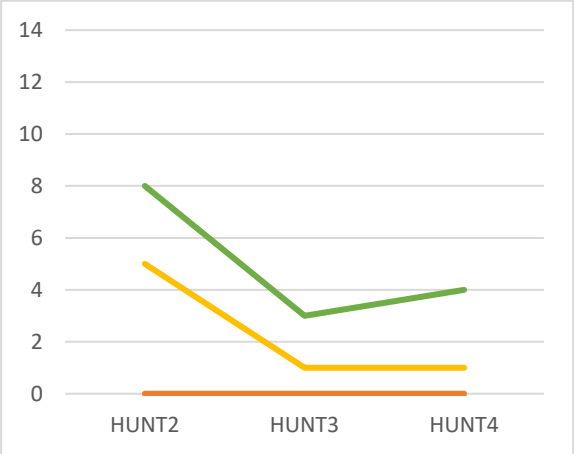


Figure 6d) PR in men

[a] Tertiary (ref.), Secondary educational, Primary educational

Figure 6. Trends in absolute differences (PD, percentage points) and relative differences (PR, percent), complex multimorbidity at 55 years by educational level in HUNT2, HUNT3 and HUNT4 in women (a and b) and men (c and d)[a].

Prevalence differences (PD) and prevalence ratios (PR) increase by educational level in all HUNTs in both sexes. Prevalence differences decrease from HUNT2 to HUNT3 in both educational levels compared to tertiary educational level in both sexes. For women, prevalence differences increase from HUNT3 to HUNT4 in secondary educational level while stabile in primary educational level. For men, prevalence differences increase from HUNT3 to HUNT4 in primary educational level, while stabile in secondary level. Prevalence ratios increase from HUNT2 to HUNT3 and decrease to HUNT4 in both sexes for primary educational level. For women, prevalence ratios increase from HUNT2 to HUNT3 and decrease to HUNT4 in secondary educational level. For men, prevalence ratios decrease from HUNT2 through to HUNT4 in secondary educational level.

4. Discussion

4.1 Main findings

Multimorbidity was more common than complex multimorbidity but varied over the three HUNT surveys. In all HUNTs, prevalence of multimorbidity and complex multimorbidity increased with lower educational level, was higher in women and increased with age and present from early adulthood.

Prevalence differences (PD) and prevalence ratios (PR) for multimorbidity and complex multimorbidity, overall increased by lower educational level in both sexes and at all ages, compared with the tertiary educational level only to diminish in women by approximately age 70 years, while still present in men at age 85 years.

4.2 Methodological considerations

The design of this study is suitable for describing prevalence and explore contextual factors between outcome and exposure, but detection of actual cause and effect is less likely (72). Educational level and multimorbidity and complex multimorbidity are assessed simultaneously over three timeframes and the association of temporality between the two cannot be determined. The prevalences are estimates of a true frequency, and the socioeconomic gradients are descriptive. Prevalence differences and ratios are both recommended to use and are presented as results (73). Age standardization is normally done when we compare total prevalence in populations with different age composition. As this study is three cross-sectional studies supposedly compared with each other, it would have been naturally to age standardize for each of the three. This has not been done, therefore a direct comparison in between the HUNTs and discussion around trends over time has been difficult to conclude on. Elements concerning accuracy and generalizability of the estimates in this study are discussed below.

4.2.1 Validity, participation and bias

Validity indicates whether a measure truly measure what it is meant to measure. If a study has internal validity, it means that this study's findings are valid, meaning one has measured what is intended to measure in this concrete study. Internal validity can be distorted by systematic errors such as confounding (confusing of associations), bias in participant selection, or mismeasurement of study variables.

In this thesis, age and sex are confounders to the study and managed accordingly. They are tested for when designing the final models before analysing (section 2.4.2/2.5). Stratification limits the bias of confounders (71).

All adults in Nord-Trøndelag County have been invited to participate in the HUNT Surveys. Participation depends on the possibility to attend a screening station to be accounted as a participant (64–66). It can therefore be expected a somewhat healthy participant bias, which can affect the data and results. The direction of bias is likely to cause an underestimation of socioeconomic inequalities in multimorbidity and complex multimorbidity. Non-participants

of the HUNT3 Survey had lower socioeconomic status and have shown higher prevalence of several chronic illnesses (108). Other studies has shown underreporting of chronic conditions by lower socioeconomic groups when comparing self-report and administrative data (109,110). Underreporting by lower socioeconomic groups may occur in this study which will underestimate the associations with socioeconomic position. Underreporting of chronic conditions may also have led to relatively low estimates in some of the prevalence estimates of multimorbidity and complex multimorbidity. The relatively low number of conditions used excludes other chronic conditions participants may have had and thus underestimation of multimorbidity and complex multimorbidity can also occur.

Participation was lower among men in all three HUNTs of this study. In the HUNT Surveys, HUNT2 had gradually lower participation rate in younger and older age groups than 60-69 years (64). HUNT3 had lower participation rate in the age groups older than 80 years, younger than 40 years and lower socioeconomic groups (65). Participation in HUNT4 was highest in the age group 40-79 years (66). It can be expected conservative outcome estimates in men, lower and higher age ranges, and lower socioeconomic groups.

Bias in outcome estimates can occur if information and the collected measures about and from study participants, on confounders, exposure, or outcome are incorrect. HUNT has gone through all data collected and checked for outliers. The registry data is not assumed to have reading errors since they have been often checked against the other HUNT Surveys (appendix C) (67,82). Multiple imputation done for educational data is expected to reduce bias in estimates (92).

When allocating individuals in socioeconomic positions and identifying individuals as cases of the dichotomous multimorbidity measures, differential misclassification can occur. Participants younger than 25 years were excluded from this study to best possible include all participants with highest educational level obtain. Younger participants may have been misclassified with lower socioeconomic position assuming that the highest level of education may not yet been obtained. This concerning Norwegian students which are among the oldest in Europe and 1 in 5 postpone further education after completing upper secondary school (111).

Education is this studies indicator for socioeconomic position and is considered valid as it is a stabile socioeconomic marker used in epidemiological studies on social inequalities (47,112). The original educational levels division to five levels and further collapsing in to three levels (section 2.4.1, appendix B) has been done in previous studies on socioeconomic positions (11,62,113), but still some dilution of outcome estimates can be expected.

This study, as most multimorbidity studies, is conducted in the general population (7), based on the most common data source, self-report, which is susceptible to report bias (4,6). When larger samples is used such as in this study, multimorbidity measures based on disease count is considered valid (6,15). Disease count reproduce anticipated associations with sociodemographic characteristics and health outcomes (30).

4.3.2.1 Differences in conditions and variables

There were differences in prevalence of single conditions between the HUNTs (appendix D). Prevalence of musculoskeletal pain was substantially higher in HUNT2 than HUNT3 and HUNT4. High blood pressure and high cholesterol had also higher prevalence in HUNT2 than HUNT3 and HUNT4. The instrument used for measuring blood pressure was different in between HUNT2, and HUNT3 and HUNT4 (appendix C) (82). The substitute variable of osteoarthritis in HUNT4 had higher prevalence than osteoarthritis in HUNT2 and HUNT3. These differences correlate to the total prevalence estimates of multimorbidity and complex multimorbidity of the three HUNTs. It is suggested to investigate the validity of each included condition (5). Validity studies on most conditions are available in appendix C.

The wording of the same condition varied in between HUNT2, HUNT3 and HUNT4 for some of the variables; musculoskeletal pain, rheumatoid arthritis, osteoarthritis, spondyloarthritis and impaired vision and hearing (appendix C). The order and setup of questions in questionnaire 1 deviate somewhat in between HUNT2, HUNT3 and HUNT4 (additional appendix and appendix C). These variations may affect answer reliability, in which underestimation can occur (87,88). The procedure of checking for missing data of "disease ever"-conditions confirm this (section 2.4.3).

When self-reported questions are used with graded answer alternatives, it is chosen to use a degree of severity when converting into dichotomized variables, this to assume chronicity. This includes the variables impaired vision and hearing for HUNT2, HUNT3 and HUNT4 and musculoskeletal pain in HUNT3 and HUNT 4 (appendix C). A lack of accuracy in the degree of chronicity of the conditions included, may occur.

The setting of limit values for the variables on measurements obesity (63,114,115), hypercholesterolemia (86,116) and hypertension (86,116) was in according to national and international recommendations and guidelines and are also in accordance to criteria for chronic conditions (12,14,114–116). It has been problematized that the limit values for high cholesterol at 5 mmol/l and high blood pressure at 140/90 mmHg based on European guidelines has placed a large part of the population in category for being sick than needed (86,117), and therefor set a higher limit value for these conditions.

BMI >=35 defines morbid obesity grade 2 and is the BMI level for when treatment is being initiated when used BMI as measurement only (114,115). There is little data that support specific targets for when to start with weight reducing interventions. Medical approaches for when start with weight reducing intervention is often based on consensus from experts and clinical experiences (114). The BMI limit value set in this thesis follows Vinjeruis limit values for obesity used in her doctoral thesis (63). The limit value is also in accordance to the criteria for a chronic condition where it is of severe effects for the individual and require medical treatment (12,14). It's generally recommended that BMI in connection to waist circumference is used to better establish level of obesity (114,115). Waist circumference however is not used as a measure for obesity in this study due to the scope of master thesis. Also, the measurements of waist circumference have shown large interrater observations. Comparison of measurements in HUNT2 and HUNT3 has shown large changes in waist circumference without it corresponds with changes in weight (118,119). The extremely low

values of BMI in the dataset were initiated to obtain information about but was instructed to evaluate if weather to keep the values or treat them as extreme values (personal communication, Jørn Søberg Fenstad, 18.11.2022). It was considered to keep and include the values since the information on why the values are low were not sufficient.

The Norwegian directorate of health defines high blood pressure between 120/70 mmHg (sleeping) and 140/90 mmHg (office blood pressure). 160/100 mmHg is assumed to be severe heightened blood pressure whereas persistent severely high blood pressure (180/110 mm Hg) suspect secondary hypertension which is caused by another disease (116). The limit value for high blood pressure in this study was set in accordance to the Norwegian guidelines of prevention of cardiovascular disease and on the indication for starting with treatment which was 160/100 mmHg systolic and diastolic (116). Information on systolic blood pressure is needed to evaluate risk for high blood pressure. Diastolic blood pressure is included when this is mentioned as an indicator for high blood pressure (116), but is needed to be confirmed by repetitive measurements for when this single factor should be available (116). Because of average measurements between 2. and 3. measurement for each diastolic and systolic measurement in the HUNT Surveys was available, both was included for measurement of high blood pressure and will strengthen the estimates of this condition included.

A minimum of twelve conditions is required to produce valid prevalence estimates of multimorbidity (6,8). It is suggested to include all possible conditions as one prerequisite to determine prevalence is by the total number of conditions included in a study. Inclusion of several conditions could have contributed to more accurate estimates in this study (6,8). Several conditions were relevant to include but was not satisfactory alike in between the three HUNTs. COPD was excluded and confirmed by Arnulf Langhammer (personal communication, Arnulf Langhammer, 25.10.2022). The variable on hypertension medication use was decided to exclude when both mean 2. and 3. Systolic and diastolic blood pressure was included. Waist circumferences were taken out of the obesity measurement (appendix C). HUNT4 did not obtain the same variable on osteoarthritis, and a substitute variable was used instead (appendix C). Despite only 16 conditions were included in this study, the results still projects the norm in prevalence studies of multimorbidity that variations in measure and methods influence prevalence (7,15–17).

The differences in variables on conditions across the HUNTs in this study also projects this norm and makes this study also difficult to internally compare (6,8,18). For comparability in prevalence studies of multimorbidity, suggestions has been made to use previously published set of conditions if they are similar in setting and outcome (5,21,85). The set of conditions in this study uses to some extend the same as Tomasdottir (40) and Vinjeruis (63) set of conditions.

4.2.2 Random error and precision

Random error is what remains after eliminating systematic error and is variability in the data which cannot readily be explained (120). Random error decreases with larger samples but leads to imprecision of the estimate which can be shown as confidence intervals and affects the reliability and reproducibility of the measure. This master thesis contains of larger

samples. Stratification of sex, age and socioeconomic position reduce the sample size and may increase imprecision of estimates but still in the stratified subgroups the samples were in hundreds and thousands in which high precision can be assumed. An example of random error can be seen in appendix F (table 3b) at 35 years for women in HUNT3 where prevalence ratio is 23.09 for primary educational level. The confidence interval ranges from 9.8 to 54.43 thus indication very low precision.

Prevalence differences shown with confidence interval below 0 and prevalence ratios shown with confidence intervals below 1 are not statistically significant for the reference group.

4.2.3 Generalizability

Generalizability concerns weather the results can translate to populations other than who has been studied (72). The HUNT Study lacks major cities included and has slightly lower education level and median income than the Norwegian mean (77). This could influence the social gradient in the HUNT study to be smaller than in Norway as a whole (23). Participants in HUNT3 had higher socioeconomic position than the nonparticipants (108). Despite the mentioned biases, the HUNT Study is representative for Norway in general (64). The surveys health trends follows those of western high income countries (121–123), and socioeconomic differences in health has been comparable with those of other Northern European countries (77).

In this study age standardization has not been done. This would have given a more robust comparison and interpretation of trend in prevalence across the three HUNTs and helped improve generalizability as it has better remained representative of national patterns (10).

4.3 Discussion of findings

This study is based on data collected before the covid-19 pandemic and financial instabilities which can be assumed to influence the trends and patterns of population health and public health in the years after 2019 substantially. Therefore, the results of this study may differ from what the situation is today. Although the long term consequences of the pandemic is largely still unknown (44), social inequalities in health existed before the pandemic, became clearer during the pandemic and is an increasing problem post-pandemic (44,95).

4.3.1 Comparison with existing literature

Prevalence in multimorbidity studies varies largely due to differences in definitions and methodology used (6,18), but the methodology is transparent and detailed in aiding comparability (5,15,19,20). Specification in measurements of multimorbidity have been strengthened recently (8,10,11), but studies are still difficult to compare (6,18,20). Findings in this study can be comparable to the main associations with multimorbidity and complex multimorbidity, such as lower socioeconomic position, female sex and older age (10,11,18,19,24,27). An increase in educational level in the population, more people with education and increased life expectancy are reflected through the results (95–98,124).

Compared to prevalence of complex multimorbidity in HUNT3 in Vinjeruis doctoral thesis (11,63), the prevalence in this study were lower both for socioeconomic position and age.

Her findings showed 54% prevalence of complex multimorbidity, while in this study only 17% for HUNT2, 6% for HUNT3 and 8% for HUNT4 were identified with complex multimorbidity. The difference in number of conditions and chapters included between the two studies were severe and deviated from 51 conditions and 14 chapters vs 16 conditions and 9 chapters and can explain why the prevalences deviated in such degree. Vinjeruis findings of multimorbidity`s associations with lower socioeconomic position, female sex and older age are comparable to findings of this study. The findings of multimorbidity and complex multimorbidity was shown to be present from early adulthood also associate with this study (11,62).

Tomasdottir found in her study that 42% had multimorbidity based on the HUNT3 population from a selection of 21 conditions. Her study showed that multimorbidity was common in all adult age groups and more common in women. The numbers of conditions in her study were closer to the numbers in this study, but the prevalence estimates still deviated from this study where prevalence estimates were 40% in HUNT2, 23% in HUNT3 and 29% in HUNT4. Tomasdottir performed age standardization in her study which one can assume has made for more accurate results than in this study (23).

Singer et al found the prevalence in multimorbidity in England maintained high (50%) in the older population investigated in the time period 2002 to 2015. In 2015 this prevalence estimate maintained high but also in a younger age group. Complex multimorbidity showed to increase faster in the time period, from 12% to 21% and by this could foretell rises in multimorbidity and complex multimorbidity in the increasing aging population (10). In this study, development across time is difficult to interpret since age standardization has not been done.

The proportions increased by age in both multimorbidity and complex multimorbidity in all HUNTs but the proportions were lower for complex multimorbidity than multimorbidity which shows the known increase in prevalence of multimorbidity/complex multimorbidity with age (11,18,19,24).

Complex multimorbidity has been shown to capture greater socioeconomic inequalities into older age groups compared with normal multimorbidity (10). In this study, the socioeconomic distribution varied by age and sex for both multimorbidity and complex multimorbidity, and there were differences in magnitude of socioeconomic gradients from HUNT2 to HUNT4. There was a higher proportion of individuals with multimorbidity and complex multimorbidity with primary educational level throughout all HUNTs. This shows Multimorbidity`s association to educational level (18,27).

A substantial shift in educational level between the HUNTs was seen in this study, were tertiary educational level increased from HUNT2 to HUNT4, and primary educational level decreased. These findings reflects a Norwegian societal change of development in educational level that has happened across the time period that of this study (96,124).

Life expectancy increases globally (56) and in Norway life expectancy is among the highest in the world (95,97,98), although it has decreased since the covid-19 pandemic (125). The

increase in age (appendix E) and mean age (table 1) of this study correlates with known increased life expectancy in the population (95,97,98).

4.3.2 Mechanisms to explain findings

In interpretation of prevalence difference and prevalence ratios from table 3, where both is a measure of inequality, prevalence differences are more suitable and emphasized when looking at change over time. This is because prevalence ratios are sensitive to change in total prevalence where it increases as prevalence decreases (and vice versa). This can be seen in figure 5. and 6 where prevalence ratios increase in HUNT3 where the prevalence is lower than HUNT2 and HUNT4. Prevalence ratios are based on ratios while prevalence difference are based on differences.

The associations of lower socioeconomic position to poorer health are well established. The unequal distribution of resources is known to be socially determined by fundamental causes that impact conditions of everyday life which results in health inequalities (43). Social health inequalities still exists in Norway despite offering universal healthcare and financial security through the welfare system (91).

The population's general state of health is influenced by the macro condition in community life such as the populations standard of living, how income and fortune is distributed, weather the political system is democratic and gives high level of legal certainty (54). The substantial change in life expectancy and educational level over the recent decades seen both in this study and the general Norwegian population (95,98,124) is assumably influenced by the financial and social changes seen in the same time frame (54), in addition to what we know about social inequality in health and the social gradient (43,45).

As the patterns of prevalence differences and prevalence ratios between educational levels generally persist throughout the HUNTs in most of the age groups for both multimorbidity and complex multimorbidity, there is an exception for women in HUNT3 with multimorbidity and for men in HUNT4 with complex multimorbidity at age 85 where prevalence differences and prevalence ratios are higher for secondary educational level than primary educational level compared with tertiary educational level. Smaller groups give wider confidence intervals which gives more uncertain results and can explain these findings in addition to a healthy elderly/survival bias.

There is a distinct difference in prevalence for multimorbidity and complex multimorbidity in HUNT2, HUNT3 and HUNT4. The composition in population changes over the three HUNTs, as well as a shift in age and educational level which may explain some of these differences. There are though distinct differences in the prevalence of single conditions in some of the variables used (appendix D) which assumably have influenced the final prevalence estimates. Musculoskeletal pain had distinctively higher prevalence in HUNT2 than HUNT3 and HUNT4. High blood pressure and high cholesterol had also higher prevalence in HUNT2 although not as much as musculoskeletal pain. The substitute variable of osteoarthritis in HUNT4 had higher prevalence than for the one used HUNT2 and HUNT3 (appendix C and D).

Mean age was higher for those with multimorbidity and complex multimorbidity in all HUNTs compared to those without multimorbidity and complex multimorbidity, but even

higher for those with complex multimorbidity. This shows that complex multimorbidity has higher specificity in older age groups (6,8,11,18,19,23,24).

The results for the elderly group aged 85 years requires some additional comments. It is likely that the estimates for the reported inequalities is affected by observing a special group of people. The sickest individuals have already died at this age and only the healthiest are left in the sample. Hence, the estimates are likely affected by survivorship bias (or survival bias) which is a form of selection bias.

4.3.3 Strengths and limitations

Strengths of this study is the estimation of prevalence of basic multimorbidity and complex multimorbidity from a general population survey, the most common study design in multimorbidity studies (7). Self-report is considered a valid approach when studying large samples (6). Absolute and relative differences in compliance with recommendations on measurements of socioeconomic inequalities in health was presented (46,73). Results are stratified by age and sex which is established as a minimum of requirements for proper reporting of multimorbidity (18). The conduction of comparable data from three different time periods is a strength. The use of education as an indicator of socioeconomic position is a strength as it is a stabile socioeconomic marker and social health inequalities are detected through it (112).

As for limitations, this is a master thesis which delineates the scope naturally. Age standardization would have made for a more robust interpretation of the results of total prevalence. Socioeconomic positions are not interchangeable and different measures of socioeconomic positions acts through varying mechanisms and can be associated instinctively with health outcomes (112,126). Inclusion of occupation, income and household as indicators of socioeconomic position would have been favourable for a more robust interpretation of the results. Participants of the younger populations may have been misclassified in lower socioeconomic positions as some may not have completed their education. This may have led to underestimation of educational differences in health in this age group. As it is recommended to include all chronic conditions possible, to obtain the best possible estimates on prevalence (6,8), only 16 conditions used may be seen as a limitation. The differences in variables of some of the same conditions used, and differences in prevalence of single conditions between the three HUNTs is a limitation. It also makes the estimates more vulnerable for errors when fewer conditions are included. This study is being based on disease counts and not types of conditions which vary with socioeconomic positions. This can bias the estimates in one or the other direction.

Participation in the HUNT3 study varied by age, sex and socioeconomic position (108), which may weaken the effect estimates. A healthy elderly bias is assumed since participation required attendance at a screening station (64–66).

Even though Northern Trøndelag county has to some extend lower education and income levels compared to the Norwegian population on average (77), the HUNT Study is considered representative for Norway as a whole (64) and the development in health of this material follows closely the trends of western high-income countries (121–123).

5. **Conclusion**

This master thesis explored the distribution of multimorbidity and complex multimorbidity according to socioeconomic positions across three HUNT surveys. Repetitive measures were extracted, but comparability internally was difficult to make due to methodical differences and variations across the three HUNTs. Multimorbidity and complex multimorbidity are common across the life course, multimorbidity more so than complex multimorbidity in this study. Prevalence of both multimorbidity and complex multimorbidity varied in between HUNT2 and HUNT3 and HUNT4. The variations in prevalence between the three HUNTs can be seen in correlation to deviations in variables across the three HUNTs used and thus differences in prevalence of the single conditions, difference in age and education level and somewhat the difference in composition in the populations.

Prevalence of both multimorbidity and complex multimorbidity increased with lower socioeconomic position, female sex and older age which is according to existing literature. Educational level and age shifted during the timeframe studied which increased from HUNT2 to HUNT4. This corresponds to increased welfare and what is known of this development in Norway as a whole and existing literature.

The findings add to and strengthens the knowledge on multimorbidity and complex multimorbidity that exist and reflects the difficulties in comparison of prevalence studies on the subject. As a strengthened background study, it can add to public health policy management on the subject, highlight the severity of disease and socioeconomic differences in the timeframe we are in and give incentives to further research.

Inclusion of age standardization would have made for a more robust interpretation of trends in absolute and relative differences in prevalence. Inclusion of a larger set of conditions would be of relevance for a more robust comparison of the repeated measures and inclusion of several indicators of socioeconomic position. This would all make interpretation of development over time more accurate. As Vinjerui suggest in her doctoral thesis (63), inclusion of parameters of allostatic overload as part of social determinants of health such as adverse life experiences, may be valuable to detect vulnerable subgroups. As Tomasdottir expresses (40), these experiences affect biology and may explain development of complex co-occurring conditions and may further ease and strengthen communication with the public and policy makers.

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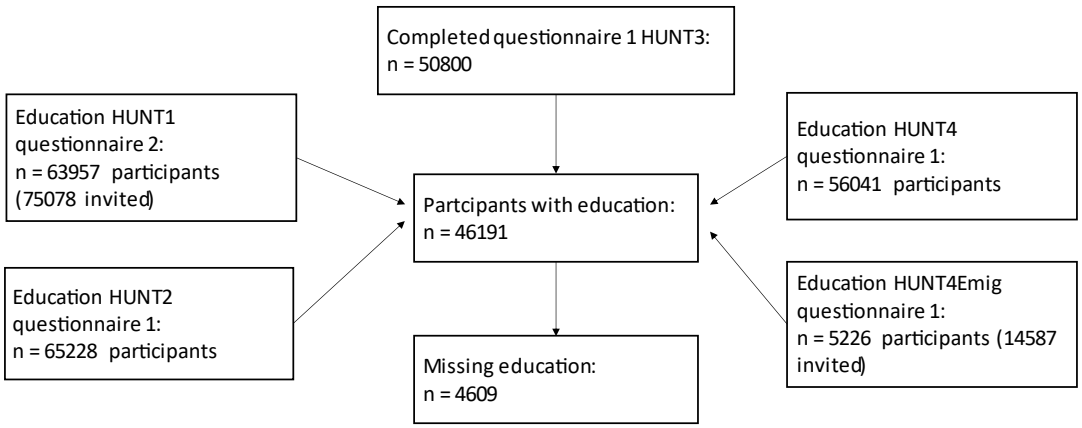
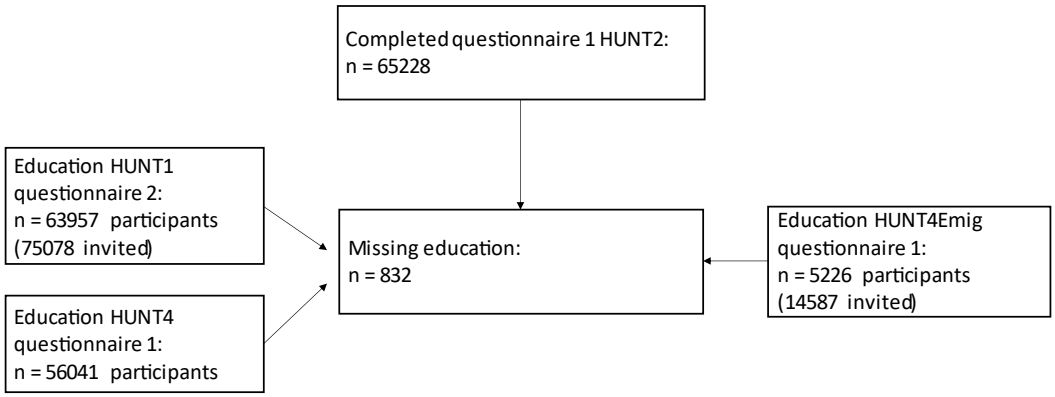
Appendix A

Imputation of educational data and missing educational data.

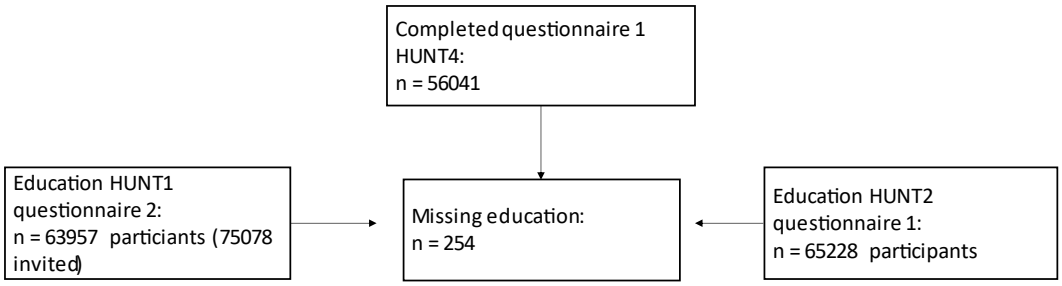
Flowchart of imputation of educational data from HUNT1, HUNT2, HUNT4 and HUNT4Emig in HUNT3.



Flowchart of imputation of missing educational data from HUNT1, HUNT4 and HUNT4Emig in HUNT2.



Flowchart of imputation of missing educational data from HUNT1 and HUNT2 in HUNT4.


Completed questionnaire 1 HUNT4:
n = 56041
Education HUNT1 questionnaire 2:
n = 63957 particiants (75078 invited)
Missing education:
n = 254
Education HUNT2 questionnaire 1:
n = 65228 participants

Appendix B

Educational level division.

https://www.ntnu.edu/hunt/data/que

Original level division and question text

Inhouse made questions for the Baseline questionnaires are used as instruments in the HUNT Surveys.

HUNT1 questionnaire 2: What is your educational background? Only specify highest level achieved. 8 answer alternatives:

- 7 years primary school or less,
- Middle school
- 9 years compulsory primary and lower secondary school
- 10 years primary and lower secondary school
- One or two years at upper secondary school
- General Certificate of Education, commercial college or sixth form college
- College or University, less than 4 years
- College or University, 4 years or more

HUNT2 questionnaire 1: What is your highest level of education? 5 answer alternatives:

- Primary school 7-10 years, continuation school, folk high school
- High school, intermediate school, vocational school, 1-2 years high school
- University qualifying examination, junior college, A levels
- University or other post-secondary education, less than 4 years
- University/college, 4 years or more

HUNT4 and HUNT4Emig questionnaire 1: What is your highest level of education? 6 answer alternatives:

- Primary school
- 1-2 years secondary school
- 3 years secondary school
- Certificate of apprenticeship or journeyman letter
- College or University, less than 4 years
- College or University, more than 4 years

Conversion into 5 levels:

HUNT1 Q2:

Level 1: 7 years primary school or less (NUS level 1), middle school (NUS level 2), 9 years compulsory primary and lower secondary school (NUS level 2)

Level 2: 10 years primary and lower secondary school (NUS level 2), One or two years at upper secondary school (NUS level 3)

Level 3: General Certificate of Education, commercial college or sixth form college (NUS level 4-5)

Level 4: College or University, less than 4 years (NUS level 6)

Level 5: College or University, 4 years or more (NUS level 7-8)

HUNT2 Q1: Maintained the same as original levels.

Level 1: Primary school 7-10 years, continuation school, folk high school (NUS level 1-2)

Level 2: High school, intermediate school, vocational school, 1-2 years high school (NUS level 2-3)

Level 3: University qualifying examination, junior college, A levels (NUS level 4-5)

Level 4: University or other post-secondary education, less than 4 years (NUS level 6)

Level 5: University/college, 4 years or more (NUS level 7-8)

HUNT4 Q1:

Level 1: Primary school (NUS level 1-2)

Level 2: 1-2 years secondary school (NUS level 2-3)

Level 3: 3 years secondary school, Certificate of apprenticeship or journeyman letter (NUS level 4-5)

Level 4: College or University, less than 4 years (NUS level 6)

Level 5: College or University, more than 4 years (NUS level 7-8)

Collapsing from 5 to 3 levels for HUNT2, HUNT3 and HUNT4:

Primary level: Level 1 and 2 (primary and lower secondary school)

Secondary level: Level 3 (upper secondary and post-secondary school)

Tertiary level: Level 4 and 5 (first and second stage of tertiary education)

Appendix C

Construction of 16 chronic, single-entities conditions from data in HUNT2, HUNT3 and HUNT4, by questionnaire 1 and measurements.

https://www.ntnu.no/hunt/databank

https://www.ntnu.no/hunt/sp-rreskjema / Additional appendix

Questionnaire 1

Cancer (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no with question text “Do you have or have you ever had cancer disease? The question appears in the clusters “Other diseases” (HUNT2), and “Illness and injury” (HUNT3 and HUNT4).

Diabetes (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no with question text “Do you have or have you ever had diabetes? The question appears in the clusters “cardiovascular diseases, diabetes” (HUNT2) and “Illness and injury” (HUNT3 and HUNT4).

Angina pectoris (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no with question text “Do you have, or have you ever had angina pectoris?” The question appears in the clusters “cardiovascular disease, diabetes” (HUNT2) and “Illness and injury” (HUNT3 and HUNT4).

Myocardial Infarction/heart attack (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no to question text “Do you have, or have you ever had myocardial infarction (heart attack)?” The question appears in the clusters “cardiovascular diseases, diabetes” (HUNT2) and “Illness and injury” (HUNT3 and HUNT4).

Stroke/brain haemorrhage (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no to question text “Do you have or have you ever had stroke /brain haemorrhage” (HUNT2 and HUNT3) / “cerebral infarction or -haemorrhage” (HUNT4). The question appears in the clusters “cardiovascular diseases, diabetes” (HUNT2), and “Illness and injury” (HUNT3 and HUNT4).

Asthma (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no to question text “Do you have or have you ever had asthma?” The question appears in the clusters “respiratory disorders” (HUNT2), and “Illness and injury” (HUNT3 and HUNT4).

Rheumatoid arthritis (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no to question text “Has a doctor ever said that you have/have had rheumatoid arthritis?” (HUNT2) / “Do you have, or have you ever had Rheumatoid arthritis?” (HUNT3 and HUNT4). This question is a part of the clusters “musculoskeletal disorders” (HUNT2) and “Illness and injury” (HUNT3 and HUNT4).

The wording in question text in HUNT2 deviate from the question text in HUNT3 and HUNT4.

Videm et. al has showed low accuracy in self-report diagnosis of Rheumatoid arthritis in HUNT data (1).

Osteoarthritis (ever)

Unchanged in StataMP17.

An original dichotomous variable with answers alternatives yes/no to question text “Has a doctor ever said that you have/have had degenerative joint disease (osteoarthritis)” (HUNT2), “Have you had or do you have degenerative joint disease (osteoarthritis)?” (HUNT3) and “Have you had in the last 12 months had pain in joints that has lasted for more than 6 weeks?” (HUNT4).

The wording and contents in the question text deviate in between HUNT2, HUNT3 and HUNT4.

The question is part of the clusters “musculoskeletal disorders” (HUNT2) and “illness and injury” (HUNT3 and HUNT4).

The variable used in HUNT4 is a replacement for Osteoarthritis and validated to use by medical doctor Kristin Hestmann Vinjerui (Kristin Hestmann Vinjerui, personal communication, 13.02.2023).

Ankylosing Spondylitis/Spondyloarthritis/Bechterews (ever)

Unchanged in StataMP17.

A dichotomous variable with answers alternatives yes/no to question text “Has a doctor ever said that you have/have had Bechterews disease (AS)”? (HUNT2), “Do you have, or have you ever had Bechterews disease (Spondyloarthritis)?” (HUNT3 and HUNT4). This question is part of the clusters “musculoskeletal disorder” (HUNT2) and “Illness and injury” (HUNT3 and HUNT4).

The wording in question text in HUNT2 deviate from the question text in HUNT3 and HUNT4.

Videm et. al has showed low accuracy in self-report diagnosis of ankylosing spondylitis in HUNT data (1)

Mental health/CONOR_MHI average

The CONOR Mental Health Index (CONOR-MHI) is meant as a method to measure mental distress for epidemiological studies and is a partly modified questionnaire based on other surveys, Hopkins Symptom Check List (HSCL-10) (2,3) for instance. CONOR_MHI is evaluated to have high internally consistency and correlates strongly with HSCL-10 and HADS (Hospital Anxiety and Depression Scale) (4).

CONOR-MHI contain seven single questions; confident and calm, happy and optimistic, nervous and restless, troubled by anxiety, irritable, down/depressed, and lonely. Each question has four answers alternatives; “No”, “a little”, “a good amount”, “very much”, with question text “In the last two weeks have you felt?” were one cross per line is put. The index consists of two positive weighted questions and five negative weighted questions. This has been converted in HUNT to be able to consider a total health index score distributed over the seven questions. The questions confident and calm, and happy and optimistic is reversed coded in HUNT to be able to calculate the average (4).

The originally numeric variable in HUNT is converted into a dichotomous variable with answers alternatives yes/no if there is positive weighted mental health or negative weighted mental health where the answer yes is defined as positive weighted mental health with score <=2.14. The answer no is defined as negative weighted mental health with a score >=2.15 (4).

The same has been done for HUNT2, HUNT3 and HUNT4.

Impaired vision and hearing

An originally categorical variable converted into a dichotomous variable with answers alternatives yes/no if there is impaired vision/hearing or not. The original alternatives for answers in HUNT2 and HUNT3 were “slight”, “moderate”, “severe”. In HUNT 4, there is an additional answer alternative; “not impaired”.

The recoding of this variable was done in a substantial degree to be able to assume chronicity. “severe” was categorized as yes, while the other answers alternatives were categorized as no.

This question is originally part of the clusters “Everyday tasks” (HUNT2) and “Health and Daily life” (HUNT3 and HUNT4) where it operates as a sub question to the index question “Do you suffer from any long-term illness or injury of a physical or psychological nature that impairs your functioning in your everyday life? (at least 1 year)” with answers alternatives yes/no (5–7).

Chronic Musculoskeletal Pain

In HUNT2 the question “During the last year, have you had pain and/or stiffness in your muscles and limbs that have lasted for at least 3 consecutive months?” with answer alternatives yes/no. An original dichotomous variable, unchanged in StataMP17. The question is part of the cluster “Musculoskeletal disorders” (8).The question is part of Standardized Nordic Questionnaire for Musculoskeletal Symptoms and the reliability of the questionnaire is evaluated to be acceptable (9) and is used in relation to pain in HUNT3 in other studies (10).

In HUNT3 and HUNT4, originally categorical variables with the question “How strong has your physical pain been during the last 4 weeks?” with 6 answer alternatives: “No pain”, “very mild”, “mild”, “moderate”, “strong”, “very strong”. These are converted into dichotomous variables with answer alternatives yes/no, were yes defined as “very strong”, and no was defined as the other five categories. The recoding was done in the degree of substantial to be able to assume chronicity. The question is part of the cluster “Health and Daily Life”. The question in HUNT3 and HUNT4 is a part of Short Form 8 Health-Related Quality of Life which is a shortened version of the SF-36 and includes the question for each of the eight dimensions in SF-36 (11–13).

Details around the variables on musculoskeletal pain used in this study can be investigated closer through HUNT Databank (8,14,15).

Measurements

Obesity

Obesity was defined as Body Mass Index (BMI) with a BMI of 35 or more. The original numeric continuous variable was converted into a dichotomous variable with answer

alternatives yes/no for HUNT2, HUNT3 and HUNT4. Yes, is defined with BMI >=35 and no defined with BMI <=34.9.

HUNT Databank constructed the body mass index (BMI) variable, defined as (Weight in kg) / (Height in m)^2 (16–18). Instrument used for measuring BMI in HUNT2 and HUNT3 is not available, but in HUNT4, InBody770 is used as instrument for measuring BMI (19).

Hypercholesterolemia

Hypercholesterolemia was defined as a total cholesterol level of 7 mmol/L or more.

The original numeric continuous variable in HUNT has been converted into a dichotomous variable with answers alternatives yes/no were yes is defined with cholesterol >=7 mmol/L and no is defined with cholesterol <=6.9 mmol/L, according to the national guidelines on prevention of cardiovascular disease (20).

Original question text; “cholesterol“ (HUNT2 and HUNT3) and “cholesterol in serum” (HUNT4). Hitachi 911 Autoanalyzer (HUNT2) and Architect ci8200 (HUNT3 and HUNT4) is used as instrument for measuring.

Hypertension

High blood pressure was defined as weather 160 mm Hg or more systolic and/or 100 mm Hg or more diastolic blood pressure was present.

The originally numeric continuous variables of systolic and diastolic blood pressure were converted into categorical dichotomous variables. Systolic high blood pressure was defined as >=160 mmHg and categorized as yes, while not systolic high blood pressure was defined as <=159 mmHg and categorized as no. Diastolic high blood pressure was defined as >=100 mmHg and categorized as yes, while not diastolic high blood pressure was defined as <=99 mmHg and categorized as no (20).

Blood pressure (BP) is measured 3 times in 1 consultation in HUNT2, HUNT3 and HUNT4 were the mean of measurements 2 and 3 is calculated by the HUNT Databank. If measurements 2 or 3 were missing, the other measurement was used as estimates for the mean (21–26). Instrument used is Dinamap (21,23,25).

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Appendix D

Differences in prevalence of single conditions between HUNT2, HUNT3 and HUNT4 (absolute numbers, proportions (%) in brackets)

	HUNT2 (60151)	HUNT3 (44756)	HUNT4 (52463)
	Freq. (%)	Freq. (%)	Freq. (%)
Cancer	2358 (4)	2633 (6)	4177 (8)
Diabetes	1946 (3)	2077 (5)	3237 (6)
Angina pectoris	3325 (6)	1896 (4)	1576 (3)
Myocardial infarction/heart attack	2108 (4)	1618 (4)	2081 (4)
Stroke/brain heamorrhage	1266 (2)	1293 (3)	1823 (3)
Asthma	5311 (9)	4955 (11)	5456 (10)
Rheumatoid arhritis	1673 (3)	1689 (4)	2792 (5)
Osteoarthirtis	6221 (10)	6949 (16)	17087 (33)
Spondyloarthritis	966 (2)	2143 (5)	760 (1)
Mental health	3797 (6)	2732 (6)	3192 (6)
Impaired vision	1244 (2)	574 (1)	641 (1)
Impaired hearing	1767 (3)	1126 (3)	1427 (3)
Chronic musculoskeletal pain	31197 (52)	500 (1)	680 (1)
Obesity	2075 (3)	2225 (5)	3109 (6)
Hypercholesterolemia	12282 (20)	4555 (10)	3614 (7)
Hypertension	10847 (18)	3697 (8)	3724 (7)

Appendix E

Table 1. Age distribution by educational level in HUNT2, HUNT3 and HUNT4[a]

		Educational level			
		Tertiary	**Secondary**	**Primary**	**Total**
		Freq. (%)	**Freq. (%)**	**Freq. (%)**	**Freq. (%)**
HUNT 2					
Age, years					
	25-44	6214 (55)	13352 (55)	3464 (14)	23030 (38)
	45-64	4245 (38)	7862 (33)	10048 (41)	22155 (37)
	65-74	617 (5)	2010 (8)	6296 (26)	8923 (15)
	75-100	257 (2)	933 (4)	4853 (20)	6043 (10)
HUNT 3					
Age, years					
	25-44	5535 (40)	5545 (27)	411 (4)	11491 (26)
	45-64	6542 (48)	10990 (54)	3833 (37)	21365 (48)
	65-74	1236 (9)	2655 (13)	3213 (31)	7104 (16)
	75-100	456 (3)	1336 (7)	3004 (29)	4796 (11)
HUNT 4					
Age, years					
	25-44	7307 (35)	5836 (23)	489 (8)	13632 (26)
	45-64	8953 (43)	11062 (44)	1363 (21)	21378 (41)
	65-74	3308 (16)	5320 (21)	2015 (31)	10643 (20)
	75-100	1300 (6)	2844 (11)	2666 (41)	6810 (13)

Freq., Frequency

[a]Decimals are rounded up from 0.5 and rounded down from 0.4. Therefore, the percentage sums are uneven some places

Appendix F

Table 3a. Prevalence ratios (PRs) and prevalence differences (PDs) with 95% CIs in multimorbidity between educational levels, stratified by sex, age 35, 70 and 85 for HUNT2, HUNT3 and HUNT4

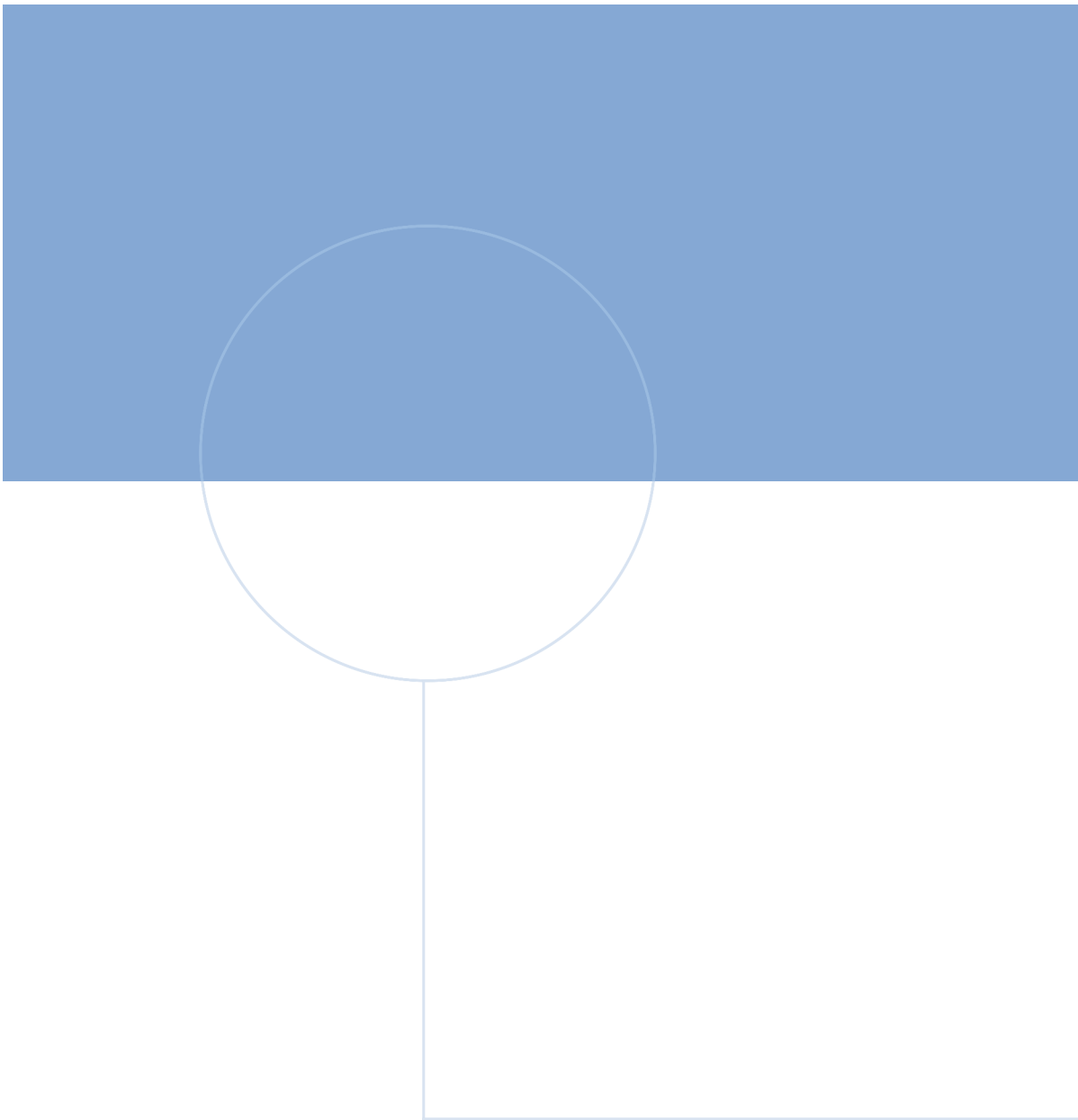
			Women		Men	
Age, years	HUNT	Educational level	PR (95%CI)	PD (95%CI)	PR (95%CI)	PD (95%CI)
35	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.49 (1.35 to 1.64)	0.06 (0.05 to 0.07)	1.37 (1.21 to 1.54)	0.04 (0.03 to 0.06)
		Primary	1.75 (0.54 to 1.98)	0.09 (0.07 to 0.11)	1.65 (1.43 to 1.91)	0.08 (0.05 to 0.10)
35	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.83 (1.57 to 2.15)	0.04 (0.03 to 0.05)	1.33 (1.09 to 1.62)	0.01 (0.00 to 0.02)
		Primary	3.09 (2.54 to 3.75)	0.09 (0.07 to 0.11)	2.74 (2.13 to 3.51)	0.07 (0.05 to 0.09)
35	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.76 (1.61 to 1.92)	0.09 (0.08 to 0.11)	1.59 (1.41 to 1.80)	0.05 (0.04 to 0.06)
		Primary	2.42 (2.10 to 2.80)	0.17 (0.14 to 0.21)	2.53 (2.08 to 3.08)	0.13 (0.09 to 0.17)
70	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.07 (1.0 to 1.14)	0.04 (-0.00 to 0.09)	1.20 (1.12 to 1.29)	0.10 (0.06 to 0.13)
		Primary	1.14 (1.07 to 1.21)	0.09 (0.05 to 0.13)	1.33 (1.24 to 1.42)	0.16 (0.13 to 0.19)
70	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.10 (1.02 to 1.20)	0.04 (0.01 to 0.07)	1.22 (1.11 to 1.32)	0.06 (0.03 to 0.09)
		Primary	1.17 (1.09 to 1.26)	0.06 (0.03 to 0.09)	1.38 (1.27 to 1.51)	0.11 (0.08 to 0.13)
70	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.11 (1.06 to 1.17)	0.04 (0.02 to 0.06)	1.10 (1.04 to 1.16)	0.03 (0.02 to 0.05)
		Primary	1.20 (1.14 to 1.27)	0.08 (0.06 to 0.10)	1.29 (1.21 to 1.37)	0.10 (0.07 to 0.12)
85	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	0.96 (0.90 to 1.02)	-0.04 (-0.09, 0.02)	1.08 (0.95 to 1.23)	0.05 (-0.04 to 0.13)
		Primary	0.96 (0.91 to 1.01)	-0.03 (-0.08, 0.01)	1.12 (0.99 to 1.27)	0.08 (-0.00, 0.16)
85	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	0.98 (0.90 to 1.07)	-0.01 (-0.06 to 0.04)	1.14 (1.02 to 1.26)	0.07 (0.01 to 0.12)
		Primary	0.94 (0.87 to 1.02)	-0.04 (-0.08 to 0.01)	1.11 (1.0 to 1.24)	0.06 (0.00 to 0.11)

85	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	0.98 (0.92 to 1.04)	-0.01 (-0.04 to 0.02)	1.00 (0.93 to 1.06)	-0.00 (-0.04 to 0.03)
		Primary	0.99 (0.93 to 1.06)	-0.00 (-0.04 to 0.03)	1.06 (0.98 to 1.15)	0.03 (-0.01 to 0.07)

Table 3b. Prevalence ratios (PRs) and prevalence differences (PDs) with 95% CIs in complex multimorbidity between educational levels, stratified by sex, age 35, 70, 85 for HUNT2, HUNT3 and HUNT4

			Women		Men	
Age, years	HUNT	Educational level	PR (95%CI)	PD (95%CI)	PR (95%CI)	PD (95%CI)
35	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	2.07 (1.57 to 2.72)	0.02 (0.01 to 0.02)	1.72 (1.25 to 2.36)	0.01 (0.01 to 0.02)
		Primary	2.79 (2.06 to 3.78)	0.03 (0.02 to 0.04)	2.16 (1.50 to 3.10)	0.02 (0.01 to 0.03)
35	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	8.78 (4.23 to 18.22)	0.01 (0.01 to 0.02)	1.34 (0.85 to 2.13)	0.00 (-0.00 to 0.01)
		Primary	23.09 (9.8 to 54.43)	0.04 (0.02 to 0.06)	4.08 (2.42 to 6.87)	0.02 (0.01 to 0.03)
35	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	2.12 (1.68 to 2.67)	0.02 (0.02 to 0.03)	2.20 (1.51 to 3.21)	0.02 (0.01 to 0.03)
		Primary	4.59 (3.22 to 6.55)	0.08 (0.05 to 0.11)	5.42 (3.17 to 9.24)	0.06 (0.03 to 0.09)
70	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.21 (1.06 to 1.38)	0.06 (0.02 to 0.11)	1.35 (1.17 to 1.56)	0.07 (0.04 to 0.09)
		Primary	1.39 (1.24 to 1.57)	0.12 (0.08 to 0.16)	1.66 (1.45 to 1.91)	0.12 (0.10 to 0.15)
70	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.01 (0.84 to 1.22)	0.00 (-0.02 to 0.02)	1.23 (1.01 to 1.50)	0.01 (0.00 to 0.03)
		Primary	1.20 (1.01 to 1.44)	0.02 (0.00 to 0.04)	1.71 (1.41 to 2.07)	0.05 (0.03 to 0.06)
70	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.14 (1.02 to 1.27)	0.01 (0.00 to 0.03)	1.15 (1.01 to 1.30)	0.01 (0.00 to 0.03)
		Primary	1.23 (1.07 to 1.41)	0.02 (0.01 to 0.04)	1.36 (1.15 to 1.61)	0.03 (0.01 to 0.05)
85	2	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)

		Secondary	0.98 (0.81 to 1.20)	-0.01 (-0.12 to 0.10)	1.25 (0.89 to 1.75)	0.06 (-0.03 to 0.16)
		Primary	1.00 (0.84 to 1.19)	0.00 (-0.10 to 0.10)	1.48 (1.08 to 2.03)	0.12 (0.04 to 0.21)
85	3	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	1.06 (0.71 to 1.59)	0.01 (-0.07 to 0.10)	1.17 (0.86 to 1.59)	0.03 (-0.02 to 0.08)
		Primary	1.20 (0.83 to 1.73)	0.04 (-0.04 to 0.12)	1.20 (0.89 to 1.63)	0.03 (-0.02 to 0.08)
85	4	Tertiary	1.00 (ref.)	0.00 (ref.)	1.00 (ref.)	0.00 (ref.)
		Secondary	0.88 (0.72 to 1.09)	-0.03 (-0.08 to 0.02)	1.33 (1.04 to 1.68)	0.05 (0.01 to 0.09)
		Primary	0.93 (0.76 to 1.13)	-0.02 (-0.06 to 0.03)	1.28 (1.00 to 1.66)	0.04 (0.00 to 0.09)



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Kunnskap for en bedre verden