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BETTER ALL THE TIME?
TRENDS IN HEALTH AND LONGEVITY AMONG OLDER ADULTS IN SWEDEN

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Better all the time? Trends in health and longevity among older adults in Sweden

THESIS FOR DOCTORAL DEGREE (Ph.D)

By

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To my family

ABSTRACT

Background. The health status of the aging population has become one of the major public health concerns today, as the number of older people increases in both absolute and relative terms and life expectancy continues to increase. The increases in life expectancy observed today is mainly the result of improved survival in old age, and as old age is a major risk factor for disease and disability, a major question of concern is to what extent increasing life expectancy comes with years with or without disability.

Aim. The overarching aim of this thesis is to assess whether the increasing old age life expectancy in Sweden has been accompanied by years with or without disability, and to what extent the development differs by gender and education. In addition, the ages and causes of death that drive the increase in life expectancy are investigated. Finally, the burden of disability at exceptional old age is explored in countries with different mortality selection.

Data. The data sources used in this thesis come from Statistics Sweden (SCB), The Swedish Cause of Death Register, the Swedish Panel Study of Living Conditions of the Oldest Old (SWEOLD), The Survey of Health, Ageing and Retirement in Europe (SHARE), and The 5-Country Oldest Old Project (5-COOP).

Study 1. Remaining life expectancy free of severe-disability, mild disability, and mobility limitations at age 77 were estimated at several time points between 1992 and 2011. This was done by combining national mortality statistics from SCB with health data from SWEOLD and SHARE. Results are heterogeneous, but in general years without disability increased more than years with disability. A more favorable development was observed among women and the gender difference in disability-free life expectancy decreased over time.

Study 2. The impact of age- and cause-specific mortality on the increase in life expectancy and the decrease in the gender gap in life expectancy between 1997 and 2014 was assessed by using data from the Swedish Cause of Death Registry. Results showed that decreasing mortality from ischemic heart disease in ages 65 and older explained most of the increase in overall life expectancy, and the convergence of the gender gap. On the other hand, certain causes of death had a diminishing impact on life expectancy, most prominently Alzheimer’s disease and unspecified dementia in the age group 85 and above.

Study 3. Disability-free life expectancy at age 77 was estimated between 2002 and 2014 by educational attainment. Mortality statistics from SCB by education were combined with disability estimates by education from SWEOLD. Results show that the increase in disability-free life expectancy was greater than the increase in life expectancy for women with both higher and lower education, and for men with higher education. However, for men with lower education, both years with and without disability increased. Overall, there was a more positive development for those with higher education and the inequalities in disability-free life expectancy increased over time.

Study 4. The main aim was to test if centenarians in countries with stronger mortality selection into exceptionally old age have a lower level of disability than centenarians in countries with a weaker mortality selection. The 5-COOP survey was used, which includes centenarians from five countries: Japan, France, Switzerland, Denmark, and Sweden. Results indicated that the probability of having disability was lower in the countries with a stronger mortality selection (Denmark and Sweden) than in countries with weaker mortality selection (Japan, France, Switzerland). Nevertheless, the highest probabilities of disability were found in Switzerland, which ranked in the middle in terms of mortality selection

Conclusion. There was an overall positive development, where disability-free life expectancy increased more than total life expectancy during the study period, except for men with lower education. Women had greater gains in disability-free years and greater reduction in disabled years than men, and consequently the gender difference in disability-free life expectancy decreased over time. However, educational differences increased over time as those with lower education did not have the same favorable development as those with higher education. The major driver of the observed increase in life expectancy was reduced mortality from ischemic heart disease among those aged 65 and older. Among centenarians, however, the burden of health problems is high and appears to be greater in countries with a weaker mortality selection into exceptionally old age.

SAMMANFATTNING

Bakgrund. Hälsan i den åldrande befolkningen är en av vår tids största folkhälsoutmaningar. Såväl antalet som andelen äldre personer i befolkningen ökar. Samtidigt fortsätter den förväntade återstående medellivslängden att öka, främst som ett resultat av ökad överlevnad bland äldre personer. Eftersom stigande ålder ökar risken att drabbas av såväl sjukdom som funktionsnedsättning så är en av de mer angelägna frågorna i vilken utsträckning den ökade medellivslängden utgörs av år med respektive utan funktionsnedsättningar.

Syfte. Det övergripande syftet med denna avhandling är att undersöka huruvida den ökande medellivslängden bland äldre personer i Sverige har åtföljts av år med eller utan funktionsnedsättning. Dessutom undersöks hur förändringar i ålders- och dödsorsaksspecifik dödlighet har påverkat den återstående medellivslängden. Därtill jämförs funktionsnedsättning bland hundraåringar från fem olika länder för att undersöka huruvida de länder med en lägre dödlighet bland de allra äldsta också har en större andel hundraåringar med funktionsnedsättningar.

Data. Data från Statistikmyndigheten SCB (SCB), Dödsorsaksregistret, Undersökningen om äldre personers levnadsvillkor (SWEOLD), Undersökning om hälsa, åldrande och pensionering i Europa (SHARE) samt en komparativ studie av hälsan bland 100-åringar från fem länder (5-COOP) användes.

Studie 1. I denna studie undersöktes i vilken utsträckning ökningen av återstående medellivslängd vid 77 års ålder mellan åren 1992 och 2011 består av år med eller utan svår funktionsnedsättning, måttlig funktionsnedsättning och mobilitetsproblem. Data från SCB, SWEOLD och SHARE användes. Resultaten visade att år utan funktionsnedsättning ökade mer än år med funktionsnedsättning under studieperioden. En mer gynnsam utveckling observerades bland kvinnor än bland män, vilket innebar att könsskillnaderna minskade över tid.

Studie 2. Med data från Dödsorsaksregistret undersöktes hur ålders- och dödsorsaksspecifik dödlighet bidrog till den ökade medellivslängden mellan åren 1997 och 2014. Utvecklingen studerades för män och kvinnor separat. Dessutom analyserades utvecklingen av könsskillnaderna i medellivslängd. Resultatet visade att minskande dödlighet av ischemisk hjärtsjukdom i åldersgruppen 65 år och äldre förklarade merparten av den ökade medellivslängden bland såväl män som kvinnor samt den minskande könsskillnaden i medellivslängd. Vissa dödsorsaker ökade dock och hade därmed en negativ inverkan på medellivslängden, det gällde t.ex. Alzheimers sjukdom och ospecificerad demens i åldersgruppen 85 år och äldre.

Studie 3. I studie 3 undersöktes utbildningsskillnader i återstående medellivslängd med och utan funktionsnedsättning mellan åren 2002 och 2014. Data från SCB och SWEOLD användes. Resultatet visar att ökningen av återstående medellivslängd bestod enkom av år utan funktionsnedsättningar för kvinnor med både hög och låg utbildning och för män med hög utbildning. Därtill minskade åren med funktionsnedsättningar. För män med låg utbildning bestod ökningen av medellivslängd dock av såväl år med som utan funktionsnedsättning. Sammantaget var det en mer positiv utveckling för dem med högre

utbildning och utbildningsskillnaderna i livslängd utan funktionsnedsättningar ökade under studieperioden.

Studie 4. I studie 4 var huvudsyftet att testa huruvida länder med en lägre dödlighet bland de allra äldsta har en större andel hundraåringar med funktionsnedsättingar. 5-COOP användes vilket är en undersökning om hundraåringar från fem länder: Japan, Frankrike, Schweiz, Danmark och Sverige. Resultatet indikerade att funktionsnedsättning var lägre i de länder där lägst andel av de allra äldsta blir 100 år eller äldre (Danmark och Sverige) än i de länder där flest uppnår en så hög ålder (Japan, Frankrike och Schweiz). Högst förekomst av funktionsnedsättningar observerades dock i Schweiz, som varken hade högst eller lägst dödlighet i hög ålder.

Slutsats. Utvecklingen har överlag varit positiv under tidsperioden, där den ökade medellivslängden vid 77 års ålder mestadels varit år utan funktionsnedsättningar. Könsskillnaderna i livslängd utan funktionsnedsättningar minskade under studieperioden, medan utbildningsskillnaderna ökade. Den ökade medellivslängden var främst ett resultat av minskad dödlighet från ischemisk hjärtsjukdom i befolkningen 65 år och äldre. Bland hundraåringar är dock funktionsnedsättningar och andra hälsoproblem mycket omfattande och mer så i de länder där sannolikheten att bli hundra år var högre.

LIST OF SCIENTIFIC PAPERS

I. Sundberg, L., Agahi, N., Fritzell, J., & Fors, S. (2016). Trends in health expectancies among the oldest old in Sweden, 1992-2011. European Journal of Public Health

II. Sundberg, L., Agahi, N., Fritzell, J., & Fors, S. (2018). Why is the gender gap in life expectancy decreasing? The impact of age-and cause-specific mortality in Sweden 1997–2014. International journal of public health

III. Sundberg, L., Agahi, N., Fritzell, J., Wastesson, J., & Fors, S. Increasing Inequalities in Disability-Free Life Expectancy among Older Adults in Sweden 2002-2014 *Under review*

IV. Sundberg, L., Andersen- Ranberg, K., Zekry, D., Herr, M., Herrmann, F.R., Jeune, B., Robine, J-M., Saito, Y., & Fors, S, on behalf of the 5- COOP group. Is there a trade-off between mortality selection and disabilities in exceptionally old age? Evidence from the 5-coop study *Manuscript*

CONTENTS

LIST OF ABBREVIATIONS

5-COOP	The 5-Country Oldest Old Project
ADL	Activities of Daily Living
iADL	Instrumental Activities of Daily Living
pADL	Personal Activities of Daily Living
AME	Average Marginal Effect
DFLE	Disability-Free Life Expectancy
DLE	Disabled Life Expectancy
mDFLE	Mild Disability-Free Life Expectancy
mDLE	Mild Disabled Life Expectancy
sDFLE	Severe Disability-Free Life Expectancy
sDLE	Severe Disabled Life Expectancy
GALI	Global Activity Limitation Indicator
GDB	Global Burden of Disease, Injuries and Risk Factor Study
HALE	Healthy Life Expectancy
HE	Health Expectancy
LE	Life Expectancy
LNU	The Swedish Level of Living Survey
SCB	Statistics Sweden
SHARE	The Survey of Health, Ageing and Retirement in Europe
SWEOLD	The Swedish Panel Study of Living Conditions of the Oldest Old
WHO	World Health Organization

1 INTRODUCTION

The public health concerns of a country are highly related to its age structure. Historically, and present in some parts of the world, a major public health concern is found in high rates of infant and child mortality. In high-income countries, where infant and child mortality are increasingly rare events, a major public health concern regards the presence of chronic disease and disabilities in the older population. These countries, Sweden included, have aging populations. Aging in terms of both an absolute and a relative increase of older adults in the population, but also in terms of increasing life expectancy. One of the major questions of concern with an aging population is to what extent increasing life expectancy is accompanied by years of good or poor health. Concerns are raised that quantity of life might compromise quality of life, that is, that a trade-off exists between increase in life expectancy and health. Are we living longer because we are healthier, or because we manage to hold off death despite disease and disability? These aspects are important from the individual perspective as well as the societal perspective regarding policy planning and resource allocation. While life expectancy historically has been a good indicator of population health, it says less about the health status of the population today. Today's increasing life expectancy largely results from increased survival among the already old, and old age is a major risk factor for chronic disease and disabling conditions. Hence, not only quantity of life needs to be addressed, but also quality. Health expectancy is a summary measure of population health that capture both these features, and it is the main focus in this thesis. Aggregated measures of population health are used in three of four studies, of which two focus on health expectancy, more specifically disability-free life expectancy, and one focus on the impact of age and cause specific mortality on life expectancy. The fourth study focuses on the potential trade-off between longevity and health in the centenarian population by using individual data. The main question of explorations is to what extent increasing old-age life expectancy in Sweden has been accompanied by years with or without disability.

1.1 The demographic and epidemiological transition

1.1.1 The demographic transition

The age structure of a society, and its characteristics, carries essential information for understanding the health, and health care needs, of a population [1]. Demography, the study of populations with regard to fertility, mortality, population growth, age distribution, migration, and other vital statistics [2], provides important information in order to plan for health care needs of a population [1]. Mortality and fertility, which can be considered as the two primary aspects of demography [3], are crucial factors for understanding why we have an aging population today, a phenomenon unprecedented in human history. Historically, the human population was characterized by a young age structure, where the youngest part of the population made up the largest proportion of the population, with proportions declining with increasing age. This is perhaps easiest visualized by population pyramids, and as the names imply, the age structure of a population resembles a pyramid, with the youngest segment of the population at the bottom and the oldest segment of the population at the top, as seen below in Figure 1a. This is still the case in some parts of the world. However, the demographic transition of the human population—from high fertility rates with high infant and child mortality rates and slow population growth, to low fertility rates with low infant and child mortality rates and vast population growth—has created an aging population. Figure 1 below, with data from The Human Mortality Database [4], and future prognosis from Statistics Sweden [5], displays this change in population age structure in Sweden, showing the shape of the population pyramid in year 1751 (a), 1900 (b), 1950 (c), 2020 (d), and 2050 (e). The left-hand side of the pyramid displays male population, and the right-hand side female. The total population size is given below each pyramid. Besides the obvious increase in population size, there is a clear shift away from the classical pyramid shape, with the youngest segment of the population decreasing, while the middle- and old-age segments increase.

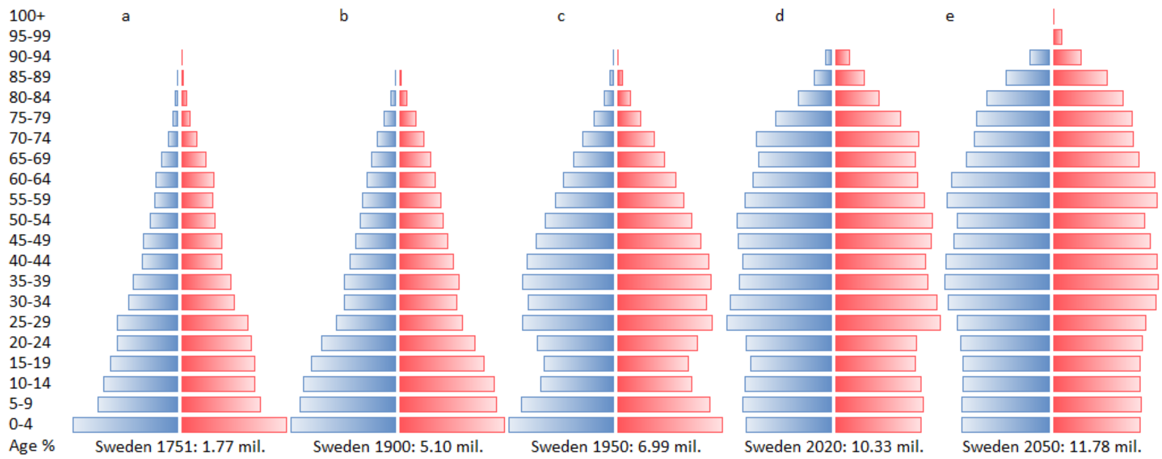

Figure 1. Population pyramids in Sweden 1751, 1900, 1950, 2020, and 2050.

The demographic transition describes a series of changes in the human population in terms of mortality and fertility. Four phases are usually put forward to describe this transition, the first two describing a mortality transition, and the latter two a fertility transition. The mortality transition is normally followed by the fertility transition, but there are exceptions [3]. The model is slightly generalized and there are several complementary, or sub-models, since the model does not fit all countries [5]. The initial phase was characterized by high fertility rates, but also high mortality rates, especially infant and child mortality. In the second phase, infant and child mortality started to decline while fertility rates stayed stable, resulting in population growth with an increasingly young population structure. The third phase of the transition began with improved survival among infants and children and was characterized by declining fertility rates. As more individuals survived into adulthood, and have offspring of their own, population growth continues. The fourth phase is characterized by low levels of both fertility and mortality [3, 6].

1.1.2 The epidemiological transition

The epidemiological transition describes the change in disease and causes of death during the demographic transition [6]. The epidemiological transition is closely related to public health, both in terms of the infectious diseases that kept mortality rates high during the initial transition, and the efforts that reduced mortality rates during the subsequent transitions [3, 7, 8], which created an aging population in the long run. The epidemiological transition describes how the main burden of morbidity shifted from infectious to chronic disease, and mortality from young to old [3, 8]. The epidemiological transition was initially divided into three phases: the age of pestilence and famine, the age of receding pandemics, and the age of degenerative and man-made disease. During the first stage, epidemics, war, famines, and poor living conditions created high and fluctuating mortality rates. The most common causes of death were infectious and parasitic diseases. The fertility rate was high, but so was infant and child mortality, and the average life expectancy (LE) at birth was less than 40 years [3, 9]. Even for those surviving past childhood, infectious disease and famine generated high mortality rates [8]. In the second stage, public health efforts, including sanitations improvements, increased public health knowledge, infectious disease counter-measures, and medical advances [3], reduced premature deaths, and average life expectancy at birth increased to about 55 years. At this stage, non-communicable diseases started to emerge and increase steadily. During the third stage, mortality is low and stable, while life expectancy at birth has reached 70 years of age and we have an aging population where disease and mortality mainly comes from non-communicable, man-made, and degenerative disease [9]. This model has been further developed since it was first published 50 years ago, mainly to explain the decrease in mortality from cardiovascular disease. A fourth stage of the epidemiological transition has been added, describing how medical advances have delayed mortality, but also the delayed onset of degenerative disease [10, 11] and how life-style factors have gained importance for our current health and mortality [5].

1.2 Population aging

The demographic and epidemiological transition thus describes a series of transitions in mortality, fertility, disease, and cause of death which have contributed to our present aging population. With aging population, we usually refer to both an absolute and relative increase of the proportion of older individuals in the population, as well as increasing life expectancy [12]. These two different processes can be described as aging from below, and aging from above respectively [13].

1.2.1 Aging from below

Aging from below is the key driver of the aging population [12]. It is the result of the decreasing size of birth cohorts and the decline in premature mortality. The population pyramid structure gives a good visualization of this change, where the base (the younger population) gets narrower over time, while the middle and top (middle age and old age) get wider. Since 1950, the population aged 65 and above in Sweden has increased by approximately 1.4 million, and today constitutes 20 percent of the population, compared to 10 percent in 1950 [4]. In 2050, this group is expected to constitute 24 percent of the population [14]. At the same time, the young population (0–14 years) has decreased from 23 percent in 1950 to 18 percent today [4], and is estimated to decrease to 16 percent by year 2050 [14]. The increase of older individuals in the population is also evident among the very old, where those 85 and above, who constitute about 2.5 percent of the population today[4], will increase to 5 percent by 2050 [14]. The once-rare centenarians, approximately 45 in number in 1950 [4, 15], have increased to approximately 2,200 as of 2020 [4, 15], and are expected to increase by an additional 5,000 by year 2050 [14]. The changing age structure is also reflected in the dependence ratio, which is the ratio of those typically not in the labor force (usually defined as the dependent ages: 0 to 14, and 65 and above) and those typically in the labor force (ages 15 to 64) [16]. It is used as an indicator of the economical and societal challenges a society faces when the proportion between these groups change; the higher dependence ratio, the greater the societal challenges. Figure 2, below, shows the change in dependence ratio from 1950 to 2050 (projections 2021–2050) [4, 14, 15]. The figure also displays the young and old dependence ratio, which together make up the total dependence ratio.

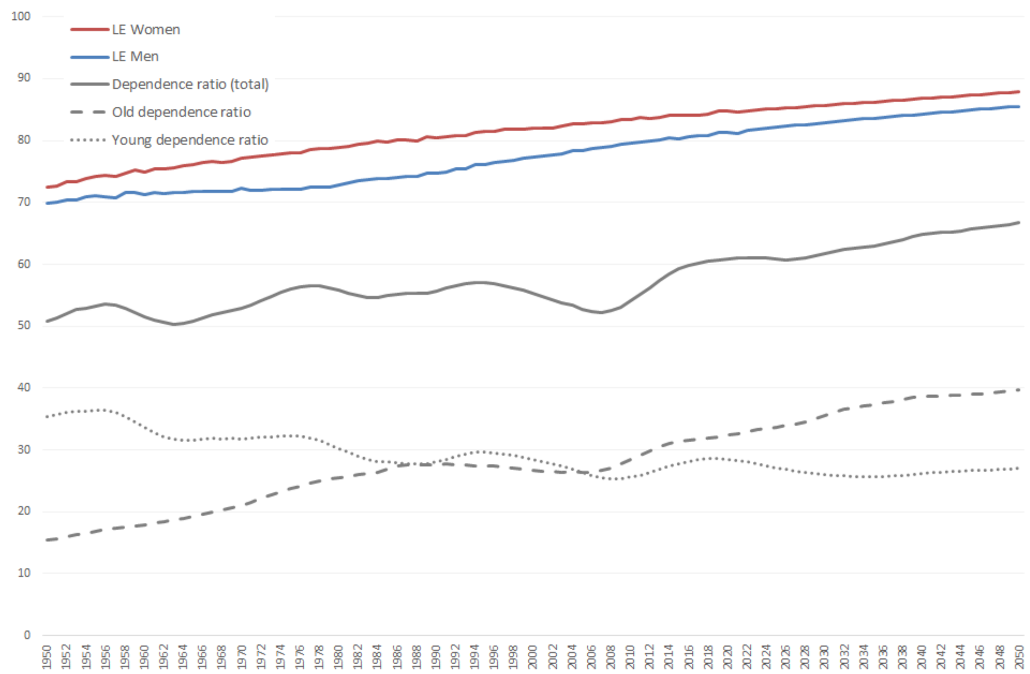

Figure 2. Total dependency ratio (solid gray line), young dependency ratio (dotted gray line), old dependency ratio (dashed gray line), and life expectancy at birth for women (red line) and men (blue line), 1950–2050 (projections from 2021).

1.2.2 Aging from above

Aging from above also has in impact on the aging population, and is the result of increasing life expectancy. Life expectancy is perhaps the best-known measure of population health, and has been referred to as the "bookkeeping of public health" [17]. Life expectancy can refer to either period-based expectancies, or cohort-based expectancies. The former reflects the mortality experience of the total population in a certain year (period), the latter reflects the mortality experience of a specific birth cohort, born a certain year. Life expectancy in this thesis refers to period life expectancy and estimates the number of years a person could expect to live if the current mortality pattern, across all ages, prevails throughout their lifetime [18]. Hence, period life expectancy estimates regard the mortality rate at all ages in a single year, which is applied to a fictive cohort of people. This is an important feature to keep in mind, as it regards the mortality rates at all ages in the population. The life expectancy of a newborn is thus based on the mortality patterns of cohorts subjected to very different conditions than what the newborn will face. Cohort life expectancy, on the other hand, is generated purely from a single cohort born a certain year, and can thus only be estimated once the entire cohort has experienced the event of death [18]. To provide a sense of the difference: in 1910, the period life expectancy (fictive) of a newborn baby girl in Sweden was 57.7 years, while the cohort life expectancy (real) was 67.7 years [4]. The earliest records of life expectancy in Sweden date from 1751, when the life expectancy of a newborn boy was 36.9 and that of a girl 39.9, low estimates that reflect the high mortality at younger ages. Since 1751, life expectancy has increased dramatically, usually quantified as three months annually since the 1840s [19].

During the last decade, the increase in life expectancy has mainly been driven by increased survival among the already old [20, 21], unlike previous increases, which were mainly a result of increased survival in the young population. Figure 2, above, displays the development of life expectancy at birth in Sweden from 1950 to 2050, with a prognosis from 2021 [4, 22, 23] . Since 1950, life expectancy has increased by approximately 12 years for both men and women, to 81.4 years for men and 84.7 years for women at birth in 2019 [4]. In year 2050, it is estimated to have increased by an additional four years for men and three years for women [23]. Improvements in life expectancy are also seen at older ages, which is where survival improvement mainly occurs at present. A Swedish woman age 65 today can expect to live 21.5 more years, a man 18.9 [22], which is an increase of seven and six years respectively since 1950 [4]. Through year 2050, women are expected to gain two additional years and men three [14]. Similarly, life expectancy at age 85 for years 1950, 2020, and 2050 (projected) shows continuous improvement: 4.1, 6.7, and 8.1 years for women, and 3.9, 5.5, and 7.1 years for men [4, 22, 23]. Besides the obvious trend of increasing life expectancy, another pattern is clear, namely the female advantage in life expectancy. As seen in Figure 2, female life expectancy is consistently higher than male, and has been since the first official record in 1751, and probably long before that [3]. Figure 2 also show that the gender gap in life expectancy started to increase in the 1950s, then began to decrease in 1980s, continuing to decline ever since. The female advantage, or male disadvantage, is discussed further below, in the section on the male-female health-survival paradox (1.4.2).

The compression of mortality to older ages is also evident when looking at age at death. Figure 3a and b below display the age distribution of deaths (proportions of all deaths) in

Sweden in 1950, 1990, and 2019 [4]. Age at death has continuously been postponed into higher ages. In 1950, the most common age at death for women was 75. In 1990, it was 82, and in 2019 it was 90. For men, the most common age at death in 1950 was at infancy, followed by age 77. The corresponding ages for 1990 and 2019 was 81 and 86 respectively. Half of deaths for women occurred after age 72 in 1950, while in 1990 and 2019 the corresponding ages were 81 and 85. For men, half the deaths occurred after age 71 in 1950, the corresponding ages in 1990 and 2018 were 76 and 80.

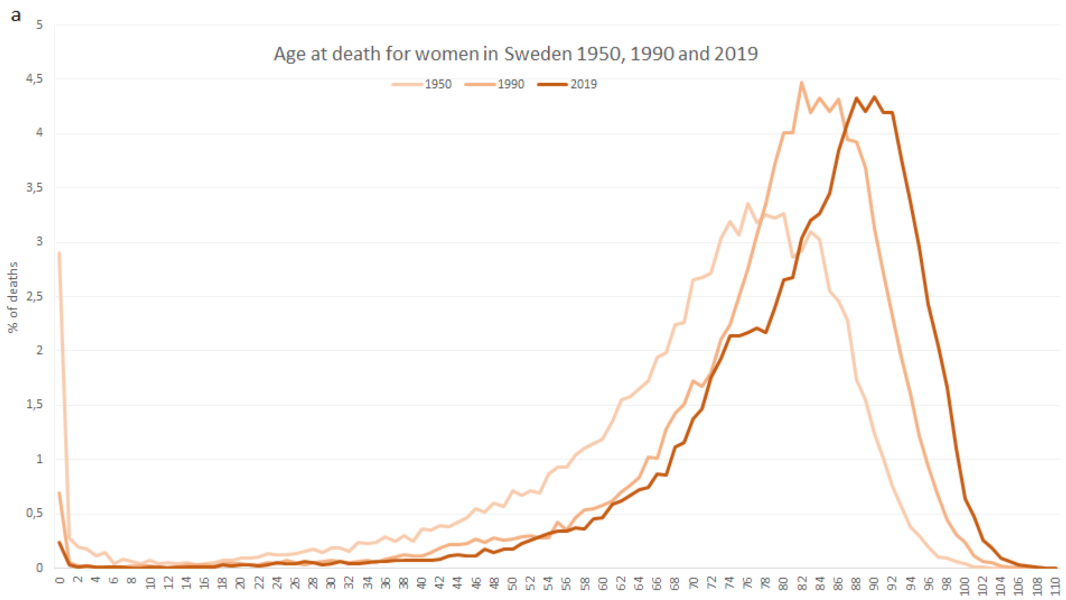

Figure 3a. Age at death for women in Sweden in 1950, 1990, and 2019.

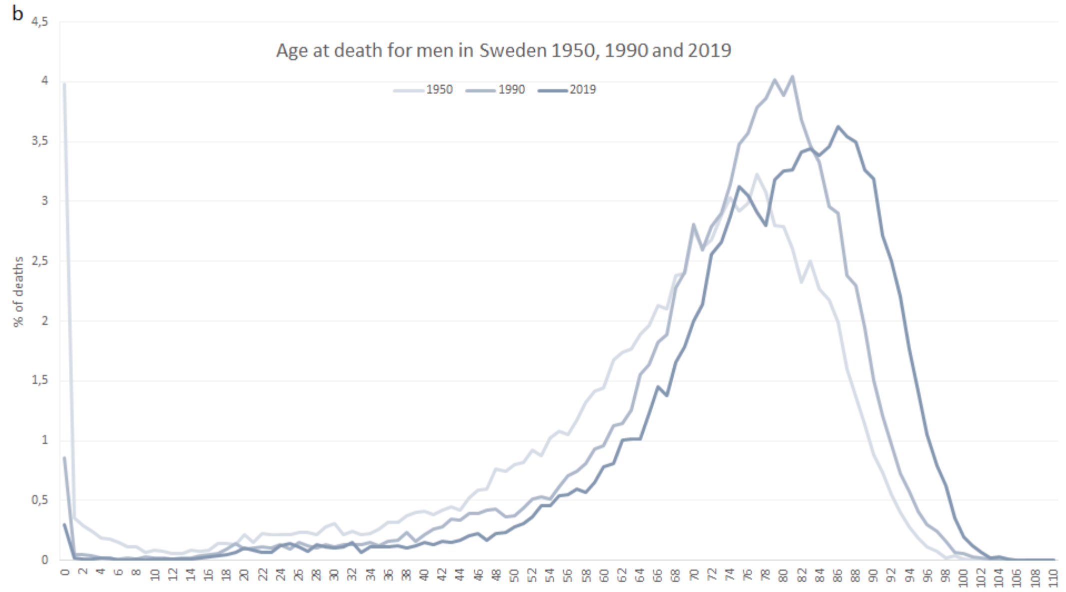

Figure 3b. Age at death for men in Sweden in 1950, 1990, and 2019

Although decreasing mortality rates in old age and increasing life expectancy are major public health accomplishment [12, 24], the aging population also creates challenges, for instance pressure on the pension system, health care, and long-term care [12, 25-28].

1.2.3 Centenarians

Reaching an age of 100 or more (i.e., becoming a centenarian) has historically been exceptionally rare, yet it is now becoming increasingly common [29-31]. In 1950, the number of centenarians globally was less than 35,000. In 2020, there were roughly 573,000 centenarians, and the prognosis for future decades is even more notable, with roughly 3.2 million estimated in 2050 and 19 million in 2100 [32]. Indeed, the 21st century has been referred to as the century for centenarians due to this impressive increase of the exceptionally old [30]. The increase is related to both aging from below and aging from above. A larger proportion of the population is becoming increasingly old, while the chance of becoming a centenarian has also increased [33], mainly due to decreased mortality at ages 80 and above [34, 35]. As this relatively new demographic segment of the population is growing steadily, increased attention is devoted to them, especially regarding their health status. Centenarians certainly raise the question of a potential trade-off between quantity and quality of life. The continues fall of mortality even at oldest old age, with the emergence of extremely old, like centenarians and supercentenarians, could potentially result in the emergence of a frail population (e.g., "sick survivors") [36, 37]. It has been suggested that a lower mortality pressure could increase the number of centenarians at the cost of poorer health [38]. One way to explore this hypothesis is to compare the health status of centenarians from societies characterized by different levels of mortality selection. It is commonly theorized that a stronger mortality selection, when the chance of becoming a centenarian is lower, will only leave the most robust individuals to reach extraordinary old age. A weaker mortality selection, when the chance of becoming a centenarian is greater, will increase the chance of more fragile individuals to also reach extraordinary old age. Thus, the hypothesis suggests that the average health of centenarians would be worse in societies with a lower mortality selection, and better in societies with a higher mortality selection.

1.2.4 Quantity and quality of life

Thus, a major question of concern with the aging population is to what extent increasing life expectancy is accompanied by years of good or poor health. Concerns are raised that quantity of life might be gained at the expense of quality of life; that is, a trade-off is made between quality and quantity of life as life expectancy increases [39, 40]. Increasing life expectancy without a similar increase of healthy years can be seen as an "empty prize" [41], or as just adding years to life and not life to years [42-45]. To what extent we are we living longer because we are healthier, or because we manage to hold off death despite disease and disability, has major policy implications. Of course, both co-exist, with younger cohorts having been shown to be in better health than older cohorts [46-50], and thus entering old age in better health. But the increase in life expectancy is also a result of reduced mortality at very advanced ages, and death is postponed to a greater extent today despite disease and disabling conditions [51, 52]. This phenomenon, the great public health accomplishments that drive population aging, in turn creating subsequent new challenges, can be seen as the "double-edged sword" of population aging [13]. The main focus of this thesis is to explore to what extent increased old age life expectancy is accompanied by healthy or unhealthy years. In the following chapter, the topics and concepts used in this thesis are presented, as well as the three major hypotheses about population aging and health.

1.3 Concepts and hypotheses

1.3.1 Population health

Health is a multidimensional concept and can refer to many different aspects (mental, social, physical, etc.), hence an extremely heterogenic outcome. A thesis dedicated to aging and health cannot fail to note the definition of health by WHO, which states that health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [53]. The definition has been subjected to criticism [54-56], mostly because "complete" is hard to accomplish for a great deal of the population. The definition has been considered even more ill-suited in the context of aging population, where health problems become more common [55]. Health is not defined in this thesis, but the outcome measures used is described further below in section 1.3.3 to 1.4. The focus of this thesis is population health. Population health, in contrast to individual health, regards the aggregated health outcomes of groups and populations. There is no formal definition of population health available, but it can be described as "the health outcomes of a group of individuals, including the distribution of such outcomes within the group" [57]. It regards both the health outcomes of a population, patterns of health determinants, and its relevance for health policy and health interventions [58]. The use of broad summary measures is advocated, which preferably should capture both the quantity and quality of life [57]. Population health and public health are concepts often used interchangeably, and they are highly related. For clarification, however, the concept of population health is used in this thesis, rather than public health, as public health usually is a concept used to describes a set of interventions or actions undertaken by agencies with official functions [58] and has been defined as "the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society" [59].

With an aging population, the additional years of life expectancy have received a great deal of attention, especially regarding the policy implications on health care and long-term care. To what extent population health, with increasing life expectancy, is accompanied by years with or without health problems is usually addressed by three different hypotheses: expansion of morbidity, compression of morbidity, and dynamic equilibrium.

1.3.2 Hypothesis

Expansion of morbidity is sometimes referred to as "failure of success" [60]. The assumption behind this hypothesis is that the increase in life expectancy is mainly due to improved medical treatments and technology, which increase survival for previously more lethal conditions (the “success”). At the same time, the incidence of these conditions are assumed to remain constant and not decrease (the “failure”). Thus, as a consequence of prolonging the duration of disease and disability in the population, without reducing the incidence, total morbidity in the population increases. Hence the assumption behind this hypothesis is that age-specific mortality rates decline at a faster rate than age-specific morbidity rates. The initial reasoning behind this scenario was based on a set of health conditions (e.g., Down’s syndrome, schizophrenia, and “senile brain disease”) affecting infants, children, the middle aged, and the older population. When this hypothesis is discussed today, in the context of the aging population, the hypothesis often refers to disability or age-related chronic disease [42, 61]. Studies often find contradictory results depending on whether the focus is on chronic disease or disability. These two concepts, chronic disease and disability, are to some extent influenced by different factors. As medical technology improves, so does the detection of disease, making early detection of disease more common, and consequently increase the disease prevalence in the population [62]. It is also possible that diagnostic criteria change with improved knowledge, also affecting the prevalence of disease in the population [62]. Hence, these aspects could lead to an increased prevalence of diagnosed diseases in the population, even when a real increase is not necessarily present. In a similar way, disability is affected by its context, being a set of conditions that occurs in the interaction between physical and mental capabilities, and environmental demands. Hence, environmental modifications can postpone disability and thus have an impact on its overall prevalence as well, even when there is no decrease in the prevalence of physical or mental impairment. However, as life expectancy continues to increase, and as old age increases the risk of developing disease and disability [63-67], the number of very old individuals with severe disability and frail conditions could increase in the population [34, 36, 68, 69], which is usually an argument for why an expansion of morbidity in the population is likely to occur.

Compression of morbidity was initially based on the assumption that there was an upper limit for life expectancy that was being approached. The force behind increasing life expectancy is assumed to be the postponement of disease and disability to older ages, due to lifestyle improvements. Thus, given a fixed maximum of life expectancy and continuous postponement of health problems, the occurrence of disease and disability would inevitably be compressed at the end of life, leading to an overall compression of morbidity in the population. The theory has, however, been revised as life expectancy has proven to continue to increase and it does not rest upon the assumption of a fixed limit to life expectancy anymore [70-73]. However, so long as age-specific morbidity rates decline at a faster rate than age-specific mortality rates, a compression will occur despite continuous increase in life expectancy. The third hypothesis, d*ynamic equilibrium*, is often described as a mix, an in-between state, or an intermediate hypothesis combining the other two hypothesis. It describes a scenario where the period of disease is prolonged (expansion) due to decreasing case fatality, but in combination with delayed disease progression and reduced disease severity. This provides a scenario of an increase in largely mild and manageable health problems which do not significantly impact quality of life until the last years, when they progress to more severe health problems [74].

Figure 4. Hypothesis about increasing life expectancy and health status of the population

Figure 4, above, is commonly used to visualize these three hypotheses. It also presents how they are discussed, and interpretated, in the context of this thesis, where life expectancy is divided into health states. The total bar represents total life expectancy. The light-grey area of the bar represents years free from disability, and the dark area represent years with disability. The top bar represents the current, or initial, status. The following three bars represent increasing life expectancy according to the three hypotheses. The second-top bar represents the expansion of disability, where the increase in life expectancy is made of years with disability. The next bar represents compression of disability, where years free from disability increase more than total life expectancy. The last bar represents a dynamic equilibrium where disability does increase, but only entailing mild problems, and where the severe problems are compressed.

The underlying factors affecting these scenarios are based on the trend in incidence, progression, and duration, and their links to mortality. Decreasing incidence, and duration, acts towards compression. While increasing incidence, duration, and increased survival with disability, acts towards expansion. And a slower progression of disease into disability acts towards a dynamic equilibrium. All factors are to some extent going on at the same time, but on the population level, one of these scenarios will outweigh the others.

1.3.3 Disability

The main outcome in this thesis is disability. Given that disability has a substantial impact for both the individual and society, it is one of the most used measurements in population health studies that aim to assess the magnitude of health problems in the aging population. From an individual perspective, disability affects quality of life and the individual's ability for independent living. From a societal perspective, an aging population with disability has a profound economic and social impact and demands resources, especially long-term [75-82]. To monitor population health and disability is thus a crucial element of both policy planning and resource allocation, but also for the promotion of healthy aging, which has become a public policy priority [45, 76, 83, 84]. Disability is a generic term and different definitions, models, and measurements are used [85]. Disability can be defined as a gap between a person's abilities and the environment. The manifestation of disability is often described by the "disablement process" [86], which starts with a pathology that leads to impairment, functional limitations, and then disability [81, 86]. This pathway is then modified by both internal and external factors. Internal individual factors that increase or decrease the susceptibility, and external factors like social and economic context and the access to health care [87]. One of the most common instrument for measuring disability in population studies is Activities of Daily Living (ADL) [81, 88], which can be described as difficulties in performing typical everyday activities as a result of health or physical problems [86]. These problems can be separated into instrumental (iADL) and personal (pADL), not seldom described as mild /moderate, and severe disability in the literature. iADL refers to households tasks and activities related to independent living in the community, like the ability to clean, shop, and prepare meals [89], whereas pADL refers to personal care tasks, like dressing, bathing, eating, getting in/out of bed, and using the toilet [90].

1.3.4 Frailty and multimorbidity

Frailty is a central concept within geriatric medicine, as it has profound impact on both individual and societal levels [87, 91, 92]. There is no international agreement about the definition of frailty, but several models suggest that it is a syndrome of decline at advanced age with multi-systemic dysfunction and increased risk for other health problems. The decrease in physiological reserve is accelerated, which results in both higher susceptibility to negative health events, and more severe subsequent outcomes. The recovery after a negative health event is never fully completed, which leaves the frail individual with a further deterioration of health after each new event [76]. There are numerous instruments used to assess frailty [93]. The frailty phenotype model is one of the most commonly used instruments in population surveys [76]. Five items are usually assessed, three of which must be present to fulfill the criteria of frailty: weight loss, weakness, exhaustion, slow walking speed, and low physical activity [94]. Frailty is closely related to both disability and multimorbidity. However, whereas multimorbidity is considered a risk factor for frailty [95], disability is considered an outcome of frailty [87]. Although these conditions intersect in the aging population, they are different entities with limited overlap and different clinical and societal consequences [87]. As with frailty, there is no international consensus of how to define and measure multimorbidity. Multimorbidity refers to the coexistence of multiple health conditions [96, 97]. Its definition has been proposed as ''... any combination of chronic disease with at least one other disease (acute or chronic) or biopsychosocial factor (associated or not) or somatic risk factor'' [98]. Different instruments and measures are used across different studies. Most common is the use of two or more chronic conditions to define multimorbidity, and this definition is advocated for consistency across studies [97].

1.3.5 Causes of death

To gain insight about the drivers of current increase in life expectancy, age- and cause-specific mortality can be addressed. By decomposing the change in life expectancy by cause of death, and age of death, knowledge is gained about how these aspects affects life expectancy [20, 99]. Since cause-specific mortality rates can both decrease and increase, certain causes that increase mortality rates, and reduce life expectancy, can be masked by simultaneous declines in other causes of death, when regarding total life expectancy. Previous studies have shown that between 1955 and 2010, decreased mortality from cardiovascular disease among those aged 65 and above was the most important contributor to the increase in Swedish female life expectancy, and for male life expectancy after 1980 [20]. External causes of death (such as traffic accidents, falls, and drowning) had a negative impact on both male and female life expectancy between 2000 and 2005, and the same was seen for infectious disease between 2000 and 2010 [20]. Other studies have found that smoking-related mortality had a negative impact on female life expectancy in recent years [99, 100]. A more detailed description of the causes of deaths with the greatest impact on increasing life expectancy in the Swedish setting has been lacking, and hence motivates the inclusion of this in this thesis.

Age- and cause-specific mortality can also be used to assess the gender gap in life expectancy. Studies exploring the impact of age have found that the reduced gender gap in life expectancy in Sweden between 1970 and 1990 was largely driven by the mortality of age group 55–75, where the gap decreased, whereas in age group 75 and above the gender gap increased. Similar results were found between 1975 and 2004, where mortality in all age groups served to decrease the gender gap in life expectancy, except mortality in the oldest age group (80+) which increased it [101]. With regard to causes of death, the major cause contributing to decreasing the gap in Sweden between 1970 and 1990 was heart disease. Lung cancer and external causes (excluding suicide) also had a diminishing effect, whereas "other diseases" increased the gap [102, 103]. Similar results have been found elsewhere [104, 105]. More recent studies for Sweden (published after the study included in this thesis) have pointed towards the impact of smoking for the decreasing gender gap, driven by decreasing mortality for men but increasing for women [100]. Avoidable mortality (deaths that could have been prevented by either public health- or health care intervention) had a substantial impact on both the increase in life expectancy and the reduced gender gap in life expectancy. Between 1997 and 2018, reduction of avoidable mortality accounted for 46 percent of the increase in female life expectancy, and 59 percent of male life expectancy, and 78 percent for the diminishing gender gap in life expectancy. Mortality reduction from ischemic heart disease was the main contributor for both the increase in life expectancy (both gender) and decreasing gender gap in life expectancy [106]. Hence, these results are consistent with regard to the major contributor of (reduced) cardiovascular mortality for both the increase in life expectancy and the decreasing gender gap in life expectancy.

1.4 HEALTH EXPECTANCY

Historically, given common premature death and high rates of infant and child mortality, life expectancy served as a good indicator for population health. Increasing life expectancy was synonymous with improving population health. Today, however, life expectancy is high, more than 90 percent of deaths occur in age group 65 and above, and the majority of those deaths occur among those aged 85 and above [107], making life expectancy a less obvious indicator of population health. To what extent increasing life expectancy is followed by the same increase in healthy years has become a highly relevant question. The notion of a potential trade-off between life expectancy and health has received much attention, and numerous studies using population summary measures that include both quantity and quality of life have been carried out. Several such summary measures are available, many developed in the 1970s, all aiming to capture mortality and morbidity, and the potential trade-off between quality and quantity of life, with a single index [108]. Today, health expectancy (HE) [109-111] is one of the most frequently used [69, 112-114], and this measure occupies the center of attention in this thesis. As the name implies, health expectancy is an extension of life expectancy, where the element of health has been incorporated. It is a summary measure of population health that captures both quantity (life expectancy) and quality (health) of life. It divides life expectancy into different health states, usually two, but gradients can also be added where three health states are present, for instance, separating life expectancy between years into severe disability, mild disability, and no disability.

Health expectancies can be estimated with different methods: using prevalence estimates in a standard period life table [115, 116]; using incidence data for a double-decrement life table with two exiting states [115, 117]; or using multi-state methods with transitions probabilities between health states (disability, recover, mortality) [115, 118]. The former is much more common given less restrictive data requirements. The period life table with prevalence estimates uses age specific mortality data in a standard period life table together with age specific prevalence data of an outcome, obtained either from cross-sectional surveys or administrative registries [119]. More specifically, the prevalence of an outcome is multiplied with the person-years expected to be lived at each age in the life table, which in the subsequent steps provides the health expectancy estimate, which corresponds to the numbers of years a person can expect to live in a certain health state if the current age-specific health and mortality rates prevail throughout the cohort [114]. Given that the prevalence life tables are based on age-specific mortality and morbidity rates, it automatically accounts for different age structures of populations [119]. This makes it an intuitive and useful tool for comparing populations. Health expectancy serves as an umbrella term for any type of life expectancy that is divided into different health states. The available literature for health expectancies thus offer a wide variety of outcomes, for instance: diseases [120], polypharmacy [121], disability [51], pain [122], well-being [123], longstanding illness [124], mobility [125], depression and anxiety [126] , self-rated health [124], mental health [127], dementia [128], sensory impairment [129] etc. Estimates are most commonly based on disability measures, known as disability-free life expectancy (DFLE) [130-134], active life expectancy [135-138], healthy life years [139-143], or healthy life expectancy [144-147]. However, there is no consistency regarding the terminology or measures used.

Figure 5 below, based on a figure from WHO [148], demonstrate the survival (proportion) of a fictive cohort from age 0 to 110 in solid black line, generated from a life table. The area under this solid black line correspond to the life expectancy of the cohort. When including prevalence of disability, survival without disability is indicated by the grey dashed line. Thus, the area under the grey dashed line correspond to disability-free life expectancy, consequently, the area between the dashed grey line and the black solid line correspond to disabled life expectancy. The third dotted line demonstrate survival without morbidity, corresponding to chronic disease-free life expectancy, and the area between the dotted line and the solid line correspond to life expectancy with chronic disease. With a compression of disability or morbidity, the disability/morbidity curve moves towards the survival curve. With an expansion of disability/morbidity, the curve moves away from the survival curve.

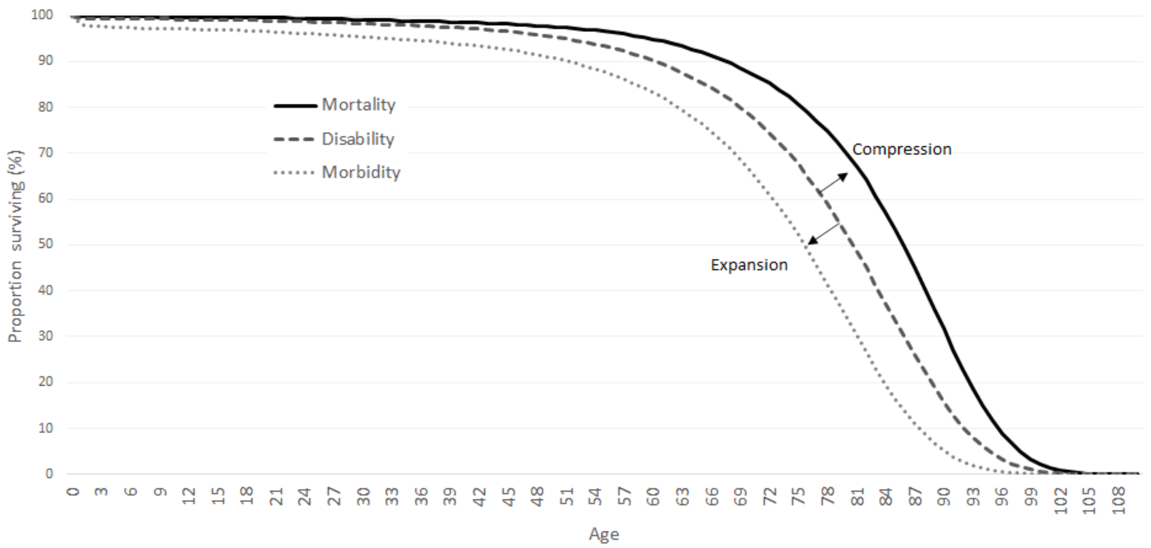

Figure 5. Survival curve including disability and morbidity, corresponding to life expectancy, disability-free life expectancy and disease-free life expectancy. Figure adapted from WHO [148].

The public health uses of health expectancy, and other aggregated population measures, are numerous. As health and mortality are constantly changing, regular monitoring is a necessity. Hence, health expectancy studies are frequently used to monitor population health, keep track of the magnitude and direction of inequalities between groups, provide information for policy planning and support health planning, evaluate interventions, and help to guide research priorities [119, 149]. Health expectancy is for instance used as monitoring tool within the European Commission [150, 151], and World Health Organization (WHO) [152], although with different methodology used. In the scientific literature, health expectancy is most commonly used to compare two groups at a single point in time (e.g., gender differences) or to compare the same group at different time points, the latter giving insight on the theories of expansion or compression. It does however have many more features and can be used to discern the impact that different diseases and causes of death have on healthy and unhealthy years. Depending on whether the focus is on absolute or relative estimates of health expectancy, different conclusions can be made regarding expansion, expression, and dynamic equilibrium. A clarification of this is provided in the section below.

1.4.1 Absolute or relative measures

Health expectancies can be estimated in both absolute (years) and relative (proportion of total life expectancy) terms. Therefore, the conclusion of compression or expansion depends to some degree on whether an absolute or relative assessment is performed. A more nuanced picture of these scenarios is provided in the *International handbook of health expectancies* [69]. Figure 5, below, is a modification of a figure presented in this book, which provides an overview of six different scenarios of change in disability-free life expectancy and disabled life expectancy (DLE). The baseline situation is seen in the two left bars, presented both in absolute (years) and relative (proportions) terms, followed by six different scenarios, again presented in both absolute (years) and relative (proportion) terms.

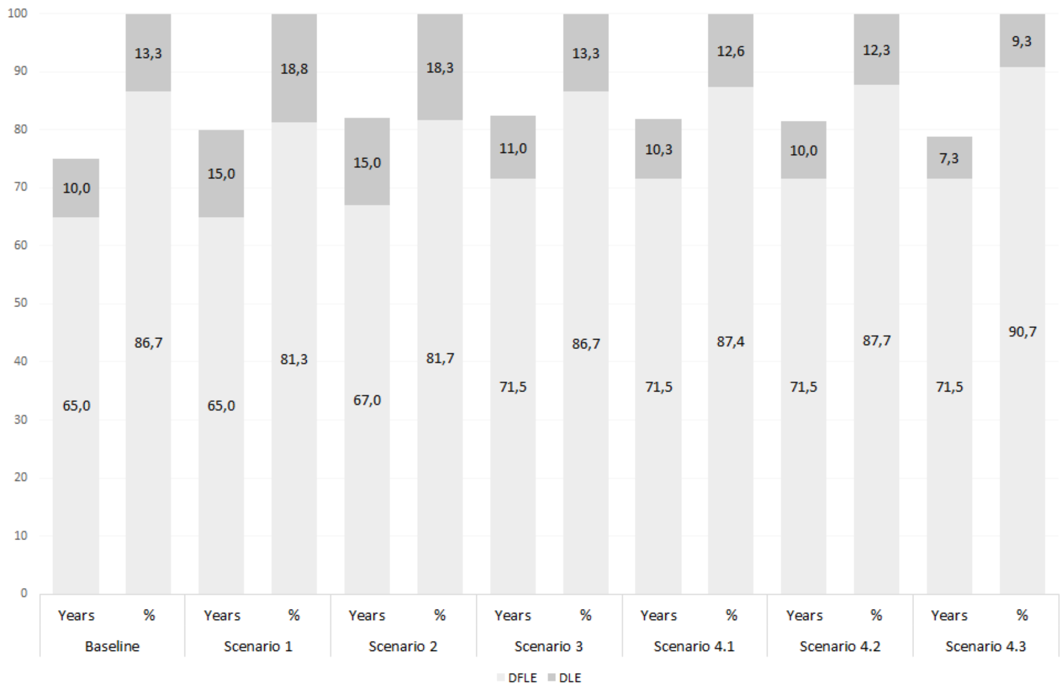

Figure 6. Different scenarios of changing disability-free life expectancy. Light grey area indicates disability-free life expectancy (DFLE), dark grey area disabled life expectancy (DLE). Figure adapted from *International handbook of health expectancies* [69].

In scenario 1, the increase in life expectancy (5 years) is entirely years with disability, and years disability-free remained the same, giving both an *absolute and relative expansion* of disability.

In scenario 2, the increase in life expectancy (7 years) is 2 years free from disability and 5 years with disability, again giving both *an absolute and relative expansion* of disability.

In scenario 3, the increase in life expectancy (7.5 year) is 6.5 years disability-free and 1 year with disability. The proportion of life spent disability-free remains the same but there is an *absolute expansion* of years with disability.

In scenario 4.1–3, disability-free years increase at a higher rate than total life expectancy, but the years with disability increase in the first scenario, stay stable in the second, and decrease in the third

In scenario 4.1, the increase in life expectancy (6.8 years) is 6.5 years disability-free and 0.3 years with disability, leading to a *relative compression* of disability. However, there is an *absolute expansion* of years with disability.

In scenario 4.2, the increase in life expectancy (6.5 years) is entirely years free from disability, and years with disability remain the same. This gives a *relative compression* of disability while the years with disability remain the same.

In scenario 4.3, the increase in life expectancy (3.8 years) is 6.5 years disability-free, while years with disability decrease by 2.7 years. Hence, disability-free years increase more than total life expectancy, giving both an *absolute and relative compression* of disability.

To what extent years with disability and/or years without disability should be regarded when drawing conclusions about compression/expansion have likely generated some confusion during the years. As life expectancy has continuously increased, and as this measure consists of both years with- and without disability in many scenarios, determining which to focus on, healthy or unhealthy years, has not always been obvious. Similarly, the focus is sometimes on absolute (years) change, and sometimes on relative (proportion) change. For example, scenario 4.1 is regarded to have an absolute expansion of disability but relative compression. An absolute expansion of disability occurs when years with disability increase, regardless of how small or large the increase is, and despite whether years free from disability increase more. An absolute compression of disability occurs when there is a reduction of years with disability, and if life expectancy does not decrease more, then this will be followed by relative compression as well. Although there are report of decreasing life expectancy in certain groups of population, in the U.S for instance [153], it has not yet been a scenario in health expectancy studies. However, in a scenario of decreasing life expectancy, and if decreasing years free from disability occur, all of the above scenarios are possible, and depend to what extent the rate of decrease in years free from disability is faster, the same, or greater than the rate of life expectancy. If life expectancy without disability remains constant, and years with disability alone decrease, then an absolute and relative compression occurs.

The same is true if life expectancy decreases but life expectancy without disability increases. However, an increase in disability-free life expectancy with a simultaneously decrease in life expectancy will most likely not be viewed as a favorable development [69]. The above scenarios only account for two states, disabled or disability-free. When including a third state, for instance by differentiating between mild and severe disability, the situation becomes more complex.

1.4.2 Male-female health-survival paradox

One of the most robust patterns that emerges from health expectancy studies are the gender differences. This is because of clear gender differences in both mortality and health. This difference is often described as a paradox, since women live longer, but at the same time, report more health problems than men. This paradox is known by many names, including "gender and health paradox"[154], "morbidity paradox" [155], and the "male-female health-survival paradox"[156], and aims to describe and explain why we see "weak but strong women" and "tough but weak men" [157]. In health expectancy studies, this paradox becomes clear. Women tend to have as many, or more, healthy years than men [113, 143, 158]. But given women's higher life expectancy, it also means that they have more years with health problems than men, and they spend a larger proportion of their lives with health problems [113, 142, 159-161]. The attempt to explain this paradox, where women live longer but experience more health problems, usually highlights that men suffer more often from lethal conditions, while women suffer more often from chronic and disabling conditions [156, 161-165]. This, in turn, is explained by several different causes: biological differences, lifestyle factors, social roles, and behaviors [164, 166, 167]. The biological factors represent inherited risks [168, 169] that are sex specific, for instance genetics and hormones. The most prominent factors seem, however, to be acquired risks [168, 169] that are non-biological in nature and thus a product of different social roles and differential expectations between men and women, creating gender differences that in turn impact behaviors and life style [164]. Some estimations indicate that acquired risks account for approximately 80 percent of the gender differences in life expectancy in Sweden [170]. However women's longevity advantage has also been found to serve some explanation of this paradox, as women's greater life expectancy has been shown to come with more years with health problems [142, 160, 161] and this explains why they spend a larger proportion of their remaining life expectancy with health problems compared to men.

1.4.3 Socioeconomic inequalities

There is a clear social gradient in health and mortality, that is, those with lowest education, lowest income, lowest occupational status, or any other measure of socioeconomic position, have on average shorter life expectancy and more disease and health problems [171-176]. This social gradient in health and mortality is also a robust pattern in health expectancy studies [113], and an expected pattern given that socioeconomic inequalities are present in both mortality and health. That health and mortality are unevenly distributed in the population between different socioeconomic strata has been explained variously. A frequent question, or hypothesis, is to what extent socioeconomic status shape health, or to what extent health shapes socioeconomic status. The former, known as the social causation hypothesis, suggests that socioeconomic status affects health thru differential access to resources, knowledge, and behavior [171]. For instance, how income and material resources impact on housing, living quality, and neighborhood. How psychosocial status hierarchy and aspects of social support- and insecurity is manifests physically. And how socio-cultural differences in lifestyle and behavior affects for instance diet, smoking and care-seeking behaviors. All with an unfavorable effect on health for those of lower socioeconomic status [177]. In the health selection hypothesis, health is thought to precede social position. Poorer health, or health deterioration, will have an impact on the possibility to attain higher education, or stay in the workforce, and therefore also impacts income [171]. In addition, the indirect selection hypothesis suggests that there is another factor, not induced by health or socioeconomic status, which creates this association, and in turn affects both health and socioeconomic status. For instance, poor maternal health behaviors could have a negative impact on both opportunities for socioeconomic success and later health outcomes, thus generating a confounded association between socioeconomic success and health. Different studies have given support to different hypotheses, partly explained by the type of indicator used for socioeconomic status (education, occupation, income). For studies using education as an indicator of socioeconomic position, the social causation hypothesis seems to get most recognition, whereas studies using income or occupation seem to find equal support in both directions [171]. Other studies support the indirect effect hypothesis [178]. These theories are not tested in this thesis, but rather serve as potential explanations why we might see differences in health expectancy estimates between different socioeconomic groups. Health expectancy studies show that those with lower socioeconomic status not only have lower life expectancy but are also expected to live fewer years in good health. It is also recognized that they may suffer from more years with health problems [179], creating a double disadvantage in terms of both quantity and quality of years. Thus, socioeconomic inequality is greater in health expectancy than in life expectancy [176, 180]. These inequalities are seen regardless of the type of socioeconomic indicator used [113, 181, 182] and this pattern generally comes across stronger among men than women [113]. That socioeconomic inequalities are greater in health expectancy than life expectancy indicates that inequalities are greater with regard to quality of life (health) than quantity (mortality) [113, 173, 183]. From a public health and policy perspective, addressing socioeconomic inequalities with health expectancy has the advantage of summarizing and quantifying inequalities in both life expectancy, healthy, and unhealthy years [184]. As social inequalities arise from causes that are modifiable, monitoring socioeconomic inequalities in health expectancy over time can give an indication to what extent determinants of health are managed and distributed within the population [184].

1.4.4 Disability-free life expectancy

Of all health expectancy measures in the scientific literature, disability-free life expectancy is one of the most frequently used [69, 112, 113]. However, disability is not consistently measured, even though measures such as pADL, iADL, or a combination of the two, are most commonplace [113, 114]. And although the same measures are used, it isn't always called disability-free life expectancy, names like 'active life-expectancy' and 'healthy life expectancy' are also used. Healthy life-expectancy can in turn, and more often, refer to estimates based on self-rated health. Hence, there is much heterogeneity with regard to both the instruments and terminology used. As a way to increase comparability among studies measuring disability-free life expectancy, the Global Activity Limitation Indicator (GALI) has been promoted, and is widely used, especially in European studies [185]. The GALI asks if a health problem has severely limited, limited (but not severely), or not limited at all an individual in performing activities during the past six months. So far however, ADL is the most frequently instrument used for estimating disability [69, 113].

1.4.5 Trends in disability-free life expectancy

Trend studies in disability-free life expectancy are not scarce, and therefore providing a picture of the trend requires some limitations. The below studies present results from the US, Europe, and Nordic countries, with estimates in the older population (65 and above), chosen on the basis of shared demographics, the availability of studies, and their relevance and comparability for this thesis.

Starting in the US, between 1970 and 2010, both years with and without disability increased at age 65 and 85, however disability free years increased more and a relative compression of disability occurred [186]. A relative compression was also observed at age 65 for the time period 1992 to 2008 [187], and for men aged 65 between 1982 and 2011, while women had no change [132]. However, another study showed a relative expansion of disability between 1991 and 2001 [188]. These studies used period-based life table estimates. Studies using multi-state approach found that between 1984 and 2000, years without disability increased at age 70, 80 and 90, mild disability had a reduction at all ages, whereas severe disability had an increase. The proportion of life spent disability-free stayed stable at age 70 (80–81 percent) but increased for those aged 80 (63–67 percent) and 90 (36–43 percent). These changes were driven by decreasing incidence and improved recovery acting towards a compression of disability. However, mortality decreased more for those with disability than those without disability, hence acting in the opposite direction, towards an expansion of disability. The force of compression was however greater than the fore of expansion for those age 80 and 90. At 70, these forces cancelled each other out with a net effect of no change [51]. Between 1992 and 2002, another study also pointed towards a compression of disability at age 65 due to later onset, reduced incidence, and improved recovery from severe disability, whereas mild disability showed no change [50].

In the European setting, country comparative studies show no clear consensus of disability-free life expectancy at age 65 during the period 1995 to 2001, since compression, expansion and dynamic equilibrium were all found [189]. Recent comparisons in the European setting, between the years 2008 to 2016 (28 countries and the use of GALI), showed similar heterogenic results including relative compression, expansion, and no change [190]. Country-specific studies show that France had a stable state, or relative compression of disability at age 65 (depending on measurements used) over the period 1980 to 2000 [85], and a similar result of relative compression was found during 1989–2000 [191]. In Spain, a compression also occurred between 1986 and 1999, both at age 65 and 85 [192]. However, more recent trends in Spain show a decrease in disability-free years at age 65 during the period 2008 to 2017 [193]. In England, years free from disability, years with mild, and years with moderate/severe disability all increased at age 65 between 1991 and 2001, and a relative expansion of disability occurred. However, this was mainly due to the increase of mild disability, and as the proportion of life with severe disability had a very modest decrease, a scenario of dynamic equilibrium was thus observed [194]. In the Netherlands during 1989–2000, there was an overall expansion of disability, however mainly from mild disability while moderate/severe disability decreased, and dynamic equilibrium was found for men aged 65. For women, however, a small expansion of disability was observed [195].

In the Nordic setting, Denmark showed a positive development with compression of disability at age 65 between 2004 and 2011, when measured by GALI [196]. Similar positive development at age 65 were seen during the period 1987 to 2005 [197]. Norway also reports compression of mild disability (measured by iADL) at age 65 between 1986 and 2008 [198]. The same positive development was observed between 1995 and 2017, when life expectancy without disability (both mild and severe, iADL and pADL) at age 70 increased more than life expectancy, and hence an absolute and a relative compression were observed [199]. In Finland, disability-free life expectancy at age 90 (based on pADL) saw a relative compression of disability between 2001 and 2018 [200]. Lastly, estimates for Sweden at age 65, measured by GALI, show that between 1980 and 2010 an absolute compression of disability occurred [141]. Healthy life expectancy (HALE) (based on period life tables) is routinely reported by the Global Burden of Disease, Injuries and Risk Factor Study (GDB) [63, 159, 201-203]. However, disability is estimated and calculated very differently compared to what is done in this thesis and in many other studies. It is based on an exhaustive list of fatal and non-fatal injuries and diseases together with disability weights [204] and quite advanced methodology [205], and therefore not really comparable to disability-free life expectancy as used in this thesis [206]. However, according to their estimates, HALE at age 65 in Sweden increased by 1.7 years for women and 2.6 years for men during 1990–2017. However, women had no change in the proportion of life with HALE and men had a slight expansion [201].

To summarize what has been done in other studies: the trends are heterogenic and inconclusive. Although many studies point towards a positive scenario of a relative compression of disability [26, 42, 69], absolute compression is less common [112]. The Nordic-specific studies seem to show similar positive trends with either a relative or absolute compression, with some exceptions.

1.4.6 Educational differences in disability-free life expectancy

Although socioeconomic inequalities in health expectancy are well explored, trends studies are fewer, and more so when restricted to educational inequalities in the older population. Studies from the US show that between 1991 and 2001 educational inequalities (at age 60 to 90) in disability-free life expectancy increased. Women had an unfavorable development at all educational levels where disability-free life expectancy decreased, and years with disability increased, but more so for those with lowest education levels. The same was seen among men, except for those in the highest education group, who had an increase in years free from disability and a decrease in years with disability [188]. Results from England for the years 1991 to 2001 show that for men at age 65, the gains in disability-free years were higher among those with high education, whereas the gains in years with disability were higher among those with lower education. Men with higher education experienced a relative compression of disability-free life expectancy, while men with lower education had no change. For women, the same pattern was observed, where those women with high education had a relative compression of disability, and those with low education had a small expansion of disability [207]. In France, an absolute compression was observed among the higher educated during 1989–2000; for those with lower education, years with disability did however also increase, and at older ages (80 and 85), disabled years increased more than years without disability, hence an expansion of disability was observed [191]. In Denmark, educational inequalities in disability-free life expectancy at age 65 (using GALI) were evident in 2006, however the educational gap did not change when measured again in 2014, but rather stayed stable [182]. Interestingly, women with higher education had an increase of severer limitation, whereas those with lower education had a small decrease, and the opposite was seen for men. Recent studies from Norway show increasing educational inequalities in disability-free life expectancy at age 70 between 1995 and 2017. Although the years with mild and severe disability decreased between educational groups (except severe disability for women), the higher-educated population had a more favorable development of years without disability, thus increasing the gap [199].

In sum, these findings also show demonstrate a heterogeneity of results, but the general trend shows increasing inequalities in disability-free life expectancy between educational groups.

1.5 KNOWLEDGE GAP

Despite many studies, there is still no consensus with regard to the hypotheses of compression, expansion, and dynamic equilibrium. For Sweden, health expectancy studies are scarce. At the beginning of this project, there was a lack of trend studies for the aging population, and those that have emerged since have rather high non-response rate and lack information about the oldest old. No trend studies of socioeconomic inequalities in health expectancy have been published for Sweden. We have high quality and accessible data for mortality by education, and national representative surveys of the oldest old with high response rates, which provide insight into the recent trends in disability-free life expectancy in Sweden. With regard to recent increase in life expectancy, previous studies exploring the impact of age and cause specific mortality has been less detailed and only covered few and broad set of causes. In this thesis, a more detailed exploration is performed. In addition, this thesis adds insight into the potential trade-off between quality and quantity of life by testing the hypothesis in the centenarian population.

2 AIM

2.1 GENERAL AIM

The general aim of this thesis is to assess whether the increasing old age life expectancy in Sweden has been accompanied by years with or without disability. This is done by exploring the change in disability-free life expectancy, and to what extent patterns differ between men and women. Educational inequalities are also addressed to see if the patterns differ depending on educational attainment. A second aim is to assess the impact of age- and cause-specific mortality on increasing life expectancy and decreasing gender differences in life expectancy Finally, an attempt to analyze the potential trade-off between health and mortality in exceptionally old age was done by comparing the prevalence of disability among centenarians from different countries.

2.2 RESEARCH QUESTIONS

1. To what extent has the increase in old age life expectancy been followed by a simultaneous increase in disability-free life expectancy?
2. Are there educational inequalities in disability-free life expectancy, and are these inequalities increasing or decreasing over time?
3. What causes of death have had the greatest impact on increasing life expectancy for men and women, and for the decreasing gender gap, during the last two decades?
4. Do centenarians in countries with higher mortality selection have lower levels of disabilities than centenarians in countries with a weaker mortality selection?

3 METHOD AND MATERIAL

This thesis has used three different population-based surveys, and two different registries. The surveys are based on individual-based data whereas the registers are based on aggregated population data.

3.1.1 SWEOLD

The Swedish Panel Study of Living Conditions of the Oldest Old (SWEOLD) is an ongoing national representative survey of older adults living conditions and health. The survey examines the type of resources that older individuals have in terms of family and social relations, housing conditions, income, education, past working conditions, political life, leisure activities, and several different health outcomes, among other things. The sample frame is based on the Swedish Level of Living Survey (LNU), which is a longitudinal multidimensional survey of the adult population in Sweden aged 15–75. LNU is based on random samples of 1/1000 of the Swedish population and has been conducted at seven occasions between 1968 and 2021 (ongoing). SWEOLD in turn has been conducted in 1992, 2002, 2004, 2011 and 2014, and is ongoing in 2021. SWEOLD includes people aged 77 and above (year 2004, age 69 and above; year 2014, age 70 and above) who were previously included in the LNU sample frame but not necessarily taking part in the LNU survey (except 1992 when the entire sample had been interviewed in LNU). In year 2011 and 2014, an additional sample of the oldest age groups was included in SWEOLD. The interviews have primarily been conducted face-to-face, except for years 2004 and 2014, where phone interviews were the primary mode of interview. In addition, questionnaires have been used when neither face-to-face nor phone interviews were possible. The study population in SWEOLD ranges between 537–1297 participants for each survey. The non-response rates range between 5–16 %. SWEOLD include participants living in nursing homes and participants interviewed by proxy. The SWEOLD sample has been used in Study 1 (years 1992, 2002, 2004, 2011) and 3 (years 2002, 2004, 2011, 2014) [208].

3.1.2 SHARE

The Survey of Health, Ageing and Retirement in Europe (SHARE) is a response to the European Commission's aim to acquire scientific knowledge about the aging population in its member states. It is a multi-national survey of people aged 50 and above in twenty European countries and Israel and has been conducted in eight waves between 2004 and 2020. We have used Swedish data from years 2004 and 2011. The sample was drawn at the household level; in 2004, the household response rate was 46.9%, and 84.6% of all eligible household members participated. Response rates for 2011 are not available. SHARE also includes by-proxy interviews and individuals living in nursing homes [209, 210]. Calibrated weights have been applied in SHARE to mitigate the impact of nonresponse and sample attrition on the estimates [211]. SHARE has been used in Study 1.

3.1.3 5-COOP

The 5-Country Oldest Old Project (5-COOP) is a sample of 1,253 centenarians from Japan (346), France (212), Switzerland (170), Denmark (251), and Sweden (274). The overarching goal of 5-COOP is to assess the health status of centenarians, but also to explore the potential trade-off between longevity and health. The five countries were chosen because of their relatively high proportion of centenarians, their high-quality mortality data, and their different levels of old-age mortality selection. The data collection took place between 2011 and 2014. The sample recruitment was national in Denmark and Sweden, and regional in Japan, France, and Switzerland. The interviews covered questions of demographics, living conditions, health status, and use of health care services. Most of the interviews were conducted face-to-face (73.3 %), but telephone interviews (14.3 %) and questionnaires (12.4 %) were also used. The interviews were conducted with either the respondent alone (27.5 %), the respondent and a proxy (39.1 %), or only with a proxy (31.9 %). The response rate varied between 30.6 % in France and 85.6 % in Sweden, with an overall response rate of 54.5 % (the response rate in Japan is unknown due to the regional sampling method) [33]. 5-COOP has been used in Study 4.

3.1.3.1 Statistics Sweden

Statistics Sweden provided population statistics for number of deaths and population size for men and women separately, divided into three educational categories (primary, secondary, post-secondary) for years 2002, 2004, 2011, and 2014. The secondary and post-secondary educational groups were collapsed into one group (above primary) since the SWEOLD sample is small and few participants have higher education. This information was used for the creation of life tables in Study 1 (gender-stratified analysis) and Study 3 (gender- and educational-stratified analysis).

3.1.3.2 Cause of Death Registry

Official statistics available from The National Cause of Death Registry provided information about underling cause of death for the entire Swedish population, stratified by gender, in years 1997 and 2014 [212, 213]. All deaths are coded in accordance with the International Classification of Disease, 10th version (ICD-10). The data set includes all deaths from people registered as living in Sweden, including deaths that occurred outside Sweden. It excludes stillborn infants, people applying for asylum, people temporarily residing in Sweden, and emigrants who are no longer registered as living in Sweden [214]. Between 1997 and 2014, missing data (due to non-reports) increased from 0.4 to 1 percent in 2014 [215, 216], and missing information (due to insufficient case specification) increased from 1.8 to 2.6 percent in 2014 [216, 217]. The cause of death registry was used for Study 2.

3.2 VARIABLES/OUTCOME MEASURES

3.2.1.1 Personal Activities of Daily Living

Severe disability is the main outcome in this thesis and was measured with five items of pADL [90]. An index was created from these items, and disability was regarded as present if the respondent required help in at least one of the items. Hence a respondent was regarded as disability-free if they managed all five items independently without help. For SWEOLD, the index was created based on the ability to independently eat, dress, get in and out of bed, go to the toilet, and wash hair. For SHARE and 5-COOP, the index was created based on the ability to independently eat, dress, get in and out of bed, go to the toilet, and take a bath/shower. This information was used in Studies 1, 3, and 4.

The following questions and answer were used in the three different surveys:

SWEODL. *Can you eat/go to the toilet/dress and undress/get in and out of bed/wash your hair, by yourself?* (Yes, completely by myself; Yes, with help; No, not at all; Not relevant/has no hair).

SHARE. *Do you, due to problems with your health or memory, have difficulty performing some of the following activities*? Dressing, including put on shoes and socks; Bathing or showering; Eating, such as cutting up food; Getting out of bed or laying down; Going to the toilet, including getting up or sitting down. (These questions were asked with the use of showcards, and the respondent could answer yes or no.)

5-COOP. *Can you, by yourself, get out of your bed/use the toilet/dress and undress/eat/shower or bathe by yourself?* (Yes, by myself; Yes, with help; No, not at all).

3.2.1.2 Instrumental Activities of Daily Living

Mild disability was measured by two items of iADL: shopping and preparing meals [89]. An index was created from the two items and disability was regarded as present if the respondent required help in at least one of the items. This information was used in Study 1.

The following questions and answer were used in SWEOLD and SHARE:

SWEOLD. *Do you usually prepare/buy food yourself?* (Yes, completely by myself; Yes, with help; No, not at all). *Would you be able to if you had to*? (Yes; No; Don’t know).

SHARE. *Do you, due to problems with your health or memory, have difficulty performing some of the following activities*: Cooking a hot meal; shopping for groceries. (Showcards, yes or no.)

3.2.1.3 Mobility

Mobility problems are also frequently used in aging studies [80, 218], sometimes referred to as mobility disability [219, 220], and were measured by two items: ability to walk, and to climb stairs. An index was created from the two items and mobility problems were regarded as present if the respondent was unable to perform at least one of the tasks. This information was used in Study 1.

The following questions and answer were used in SWEOLD and SHARE:

In SWEOLD: *Can you walk 100 meters fairly briskly without difficulty? Can you go up and down stairs without difficulty?* (Yes or No).

In SHARE: *Do you, due to health problems, have difficulty performing some of the following activities*: Walking 100 meters; Going up a flight of stairs without resting (Yes or No). (Showcards, yes or no.)

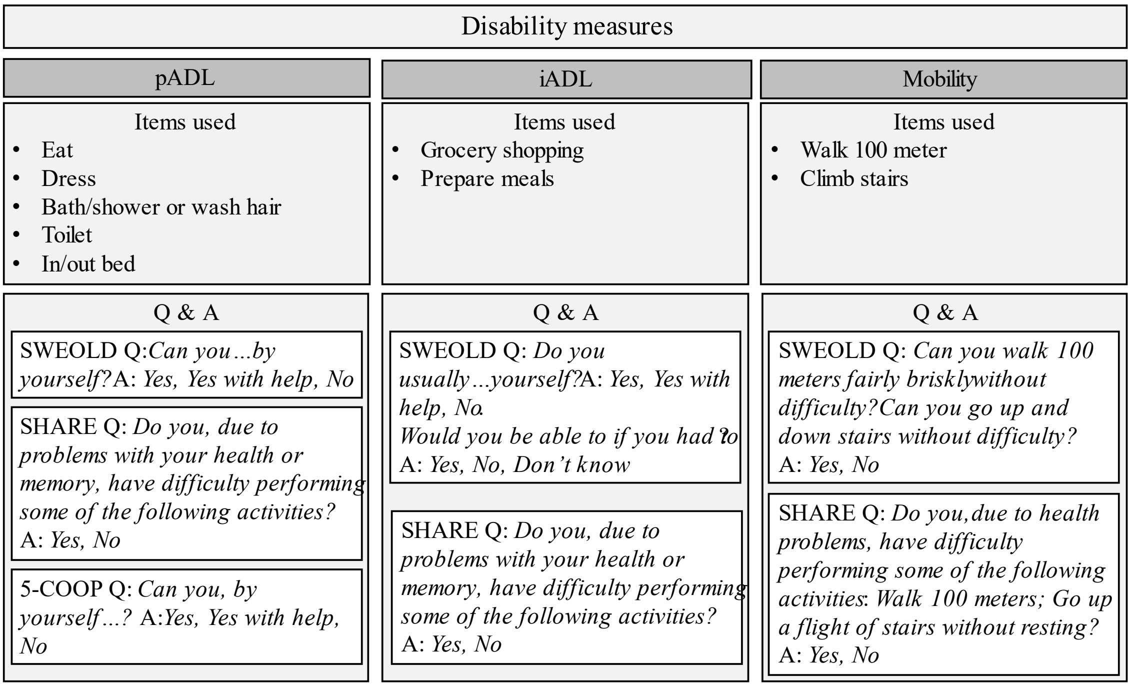

Figure 7. Overview of disability measures

3.2.1.4 *Frailty*

Frailty was assessed by five items derived from the construct in the Cardiovascular Health Study [94], namely exhaustion/fatigue, weight loss, physical activity (low), weakness, and walking speed (slow). The following categorization was done for the five frailty items. *Fatigue*: Experiencing fatigue when moving, resting, or all the time. *Weight loss*: 5 kg during the past year, and/or weight loss of 3 kg during the past 3 months, and/or body mass index ≤18.5 kg/m2. *Low level of physical activity*: No regular exercise or outdoor activity), and/or bedridden or unable to transfer from bed to chair without help. *Weakness*: if not managing to carry a 5 kg bag. *Slow walking speed*: the general waking speed reported as low, and/or difficulty walking up a flight of stairs, and/or bedridden or unable to move from bed to chair independently. *Frailty*: an index of the above five items was created and a respondent was categorized as frail if three or more of the items were fulfilled [221]. Frailty is used in Study 4.

3.2.1.5 Multimorbidity

Multimorbidity was defined as having two or more of the following diagnosed conditions: cardiovascular disease: heart attack/myocardial infarction, and/or congestive heart failure, and/or any other heart problems, and/ or hypertension/high blood pressure, and/or stroke; musculoskeletal disease: rheumatoid arthritis/osteoarthritis, and/or osteoporosis; chronic lung disease; diabetes/high blood sugar; malignant cancer; dementia. Multimorbidity is used in Study 4.

3.3 ANALYSIS

Studies 1 and 3 have a repeated cross-sectional design with life tables analysis, decomposing life expectancy into different health states based on the Sullivan method [109]. In addition, Study 1 decomposed health expectancies into mortality- and disability-effect [222]. Study 2 is also based on life table analysis and decomposed into age- and cause-specific mortality according to Arriaga's decomposition method [18, 223, 224]. Study 4 uses predictive probabilities and average marginal effect (AME) to estimate the prevalence of disability [225, 226] and, in addition, Venn diagrams were used to visualize the interplay of disability, frailty, and multimorbidity.

Life Table Analysis

A life table contains different pieces of information about the dying of a cohort and measures the longevity of a population [16]. As mentioned previously, cohort life tables describe the real dying of a cohort, while the period table describes a fictive dying. The period life table assumes that age-specific mortality stays constant over time [18]. In addition, the period life table with prevalence estimates (for health expectancy estimations) assumes that the prevalence estimates stays constant [227] and that the mortality rate is the same for those with and without disability [227, 228].

Age is the first component of the life table, and mortality information for each age is produced accordingly. Information can be obtained for a specific age, like the probability of dying in a certain age, or life expectancy at a certain age, or information for the entire cohort, like the survival curve or life expectancy at birth. Age-specific mortality rates are the first step of the table, which in this thesis were obtained from Statistics Sweden based on the numbers of deaths and mid-year population for a specific year. The subsequent information produced in the table rests upon these mortality rates. Life table calculations can be done in slightly different ways, using the same available information. Different textbooks use different manners and formulas. The following notions, and explanation, describe the table from the initial mortality rates to the endpoint of life expectancy [16, 18]:

$m_x = \frac{d_x}{P_x}$	Mortality rate between age x and age x+n: derived from the total number of deaths in the population by the number of the population
a_x	Average person-years lived from age x to age x+n among those who die in the age interval
$q_x = \frac{2m_x}{2 + m_x}$	Probability of dying between age x and age x+n is the number of deaths divided by the population at risk of dying
$p_x = 1 - q_x$	Probability of survival to exact age x+n
$l_{x+n} = l_x \cdot p_x$	The number of survivors in the fictive cohort (usually set to 100.000, $l_x = 100.000$) at age x.
$L_x = l_{x+n} + a_x \cdot d_x$	The number of person-years lived between ages x and age x+n
$T_x = \sum_{a=x}^{\infty} L_a$	Person-years lived beyond age x.
$e_x = \frac{T_x}{l_x}$	Life expectancy (LE) at age x

To obtain disability-free life expectancy using the Sullivan method, prevalence estimates are incorporated into the life table. Prevalence of disability is applied to person-years lived at age x (L_x), and the life table executes the above procedure to estimate the expected lifetime without disability [229]. The relation of absolute years without and with disability in relation to life expectancy is thus [34]:

$DFLE_x + DLE_x = LE_x$.

And proportion of year lived without disability in relation life expectancy:

$(DFLE_x / LE_x) \cdot 100$

Health expectancy estimates are assumed to be independent of each other and follow a normal distribution, and the classical hypothesis test for difference between groups is used [229, 230].

Decomposition of morbidity and mortality effect

In Study 1, the change in life expectancy without health problems between two time points was further decomposed into mortality and disability effect. The mortality effect reflects the change in the number of person-years lived without disability due to a change in the number of person-years lived. This reflects the change in estimates due to changing mortality rates, rather than a change in prevalence estimates. Hence a positive mortality effect reflects an increase in the number of person-years lived without disability due to increased survival. A negative mortality effect reflects a decrease in the numbers of person-years lived without disability due to increased mortality. The disability effect reflects the change in the number of person-years lived without disability due to a change in the proportion with disability. This reflects the change in disability-free life expectancy due to a change in prevalence, rather than survival. And a negative disability effect reflects a decline in the number of person-years lived with disability due to increasing prevalence [43, 231, 232].

Decomposition of age and cause specific mortality

Decomposition was also used in Study 3 to estimate the impact of age- and cause-specific mortality on the change in life expectancy. The periodic life table is used and includes cause-specific mortality. In a first step, the difference in life expectancy is decomposed by the contribution from each age group. This is based on the direct, indirect, and interaction effect (except for last age group, which is only exposed to the direct effect). The direct effect is the numbers of years that an age group contributes to the difference in life expectancy estimates between two groups, due to higher or lower mortality in that age group. The indirect and interaction effects are the product of how changing mortality rates at one age affect the subsequent ages, accounting for the continuously changing numbers of survivors with each age group. By adding the direct, indirect, and interaction effects, the total contribution of each age group to the change in life expectancy is obtained. In the second step, this method is extended to cause-specific decomposition. For each separate age group, all-cause mortality is divided according to causes of death. By summing the contributions from each cause of death across all age groups, the total contribution from any given cause is obtained [223, 224]. The below notation gives the direct and indirect effect of the mortality difference between two populations. The two different populations are indicated by 1 and 2, and refer to either two different time points (1997 or 2014) or two different groups (men or women) [18]:

Direct effect: $n\Delta x = \left[\frac{l_x^1}{l_0^1} \cdot \left(\frac{nL_x^2}{l_x^2} - \frac{nL_x^1}{l_x^1}\right)\right] +$

Indirect effect: $\frac{T_{x+n}^2}{l_x^2} \cdot \left(\frac{l_x^1}{l_x^2} - \frac{l_{x+n}^1}{l_{x+n}^2}\right)$

Predictive probabilities and average marginal effect

In Study 4, predictive probabilities, generated from the logistic regression model with marginal standardization, were used to estimate the probability of disability in the centenarian population. With a sufficient model, assuming no measurement errors or uncontrolled confounding, it provides the adjusted probabilities of disability in the population [225]. Sample weights were applied to account for the over sampling of male centenarians in Sweden. The analysis was performed without adjusting for gender since the estimates only changed slightly and patterns did not change, nor did the conclusion of the study result. Secondly, average marginal effect (AME) was calculated to assess the differences in predicted probabilities among the countries [226]. Although there are differences among the countries with regard to education, gender distribution, living arrangement, etc., these are also the characteristics of the population affected by selective mortality. Hence, controlling for these factors, we would control away the effect of selective mortality on the population, and the potential differences in the prevalence estimate that we wish to capture.

Table 1. Overview of studies.

	Study 1	Study 2	Study 3	Study 4
Title	Trends in health expectancies among the oldest old in Sweden, 1992-2011	Why is the gender gap in life expectancy decreasing? The impact of age-and cause-specific mortality in Sweden 1997–2014	Increasing Inequalities in Disability-Free Life Expectancy among Older Adults in Sweden 2002- 2014	Is there a trade-off between mortality selection and disabilities in exceptionally old age? Evidence from the 5-coop study
Aim	To explore trends in health expectancies among the oldest old in Sweden from 1992 to 2011	To assess the contribution of age and cause specific mortality to the increase in life expectancy, and decreased gender gap in life expectancy, in Sweden 1997-2014	To assess educational inequalities in disability-free life expectancy among the oldest old in Sweden between 2002- 2014	To assesses the prevalence of disability among centenarians from five different countries, and to assess the interrelationship of disability, frailty and multimorbidity
Study population	Swedish population aged 77 and above	Entire Swedish population	Swedish population aged 77 and above	Centenarians (100+) in Japan, France, Switzerland, Sweden, and Denmark
Method	Prevalence based period life tables, disability-mortality decomposition	Age and cause specific life table decomposition	Prevalence based period life tables	Predicted probabilities and average marginal effect.
Data sources	Statistics Sweden, SWEOLD, SHARE	Cause of Death Registry	Statistic Sweden, SWEOLD	5-COOP
Outcome	Severe disability-free life expectancy, mild disability-free life expectancy, mobility problems-free life expectancy	Age and cause specific mortality (24 different causes of death)	Disability-free life expectancy	Disability, Frailty, Multimorbidity

3.4 ETHICAL APPROVAL

This thesis has used both aggregated population data and individual-level survey data. The aggregated population data from Statistics Sweden, and from The National Board of Health and Welfare (cause of death registry) and are publicly available data that do not require ethical permission for use. The individual survey data come from SWEOLD and are covered by the ethical approval Dnr. 2014/1003-31-5, and 5-COOP covered by Dnr. 2011/306-31/3. Informed consent was obtained from SWEOLD and 5-COOP participants or from a relative of those participants too impaired to give consent. All data have been pseudonymized before use to ensure anonymity for the participants. SHARE is an open-access data set provided free of charge for scientific use. It follows the European Union and national data protection laws as well as the publicly available Conditions of Use. Access is obtained upon request. SHARE has been reviewed and approved by the ethics committee with regard to questionnaires, consent documents, etc. Detailed information is found on SHARE's home page [233].

4 RESULTS

This thesis consists of four studies. The first three are based aggregated population measures, and the fourth is based on individual data from a comparative centenarian study. In Study 1, old age life expectancy is estimated according to presence/absence of severe disability, mild disability, and mobility problems in 1992, 2002, 2004, and 2011. The findings from this study showed different patterns between men and women and raised questions regarding recent changes in age- and cause-specific mortality. Hence, Study 2 explores these changes, and their impact on life expectancy between 1997 and 2014. Study 3 estimates educational inequalities in disability-free life expectancy between 2002 and 2014 and the direction of these inequalities, which also provided insight on the results of Study 1. Study 4 explores the disability patterns among countries with different mortality patterns among the exceptionally old, offering insight into the question of a potential trade-off between quality and quantity of life at very advanced age.

4.1 STUDY I

The first study aimed to explore to what extent increasing old-age life expectancy has been accompanied by years with or without health problems [234]. Thus, life expectancy with and without severe disability, mild disability, and mobility problems was assessed in 1992, 2002, 2004, and 2011. SWEOLD is used as the main source for disability and mobility problems. SHARE conveniently also executed their survey in years 2004 and 2011, and thus serves as a good complement to SWEOLD and helps to validate the result. Both SWEOLD and SHARE are based on a random sample of the Swedish population and include both by-proxy interviews and people living in nursing homes. Severe disability was assessed by pADL (ability to independently: eat, dress, get in/out of bed, shower/wash hair, use the toilet), mild disability by iADL (ability to independently shop and prepare meals), and mobility problems (ability to walk 100 meters and climb stairs). Period life table estimates of life expectancy with and without severe disability, mild disability, and mobility problems at age 77 were obtained for each survey year using the Sullivan method. Changes in health expectancies between time points were decomposed into the contributions attributed to changes of mortality rates, and changes in disability/mobility prevalence.

Severe disability

Figure 6a and b show the change in life expectancy between different survey years. The trends in severe disability-free life expectancy (sDFLE) are similar from both survey samples. sDFLE increased more than total LE for women, hence they experienced both an absolute and relative compression of severe disability. For men, however, LE was followed by both years with and without disability, and they experienced a relative expansion of severe disability. However, in the SWEOLD sample, the gains in sDFLE years were greater than the gains in severe disability-free life expectancy (sDLE) years. The opposite was found in the SHARE sample where the gains were mostly seen in sDLE.

Mild disability

For both men and women in the SWEOLD sample, mild disability-free life expectancy (mDFLE) increased more than mild disabled life expectancy (mDLE), but not more than total LE, and both sexes had a relative compression of mild disability. In the SHARE sample, women's gains in mDFLE were greater than total LE, and women had an absolute and relative compression of mild disability. For men in the SHARE sample, mDLE increased more than mDFLE and they had a relative expansion of mild disability.

Mobility problems

Women from the SWEOLD sample had a relative expansion of mobility problems as the years without mobility problems decreased, and years with mobility problems increased. Men from the SWEOLD and SHARE sample had an increase of both years without and with mobility problems and they had a relative expansion of mobility problems. For women from the SHARE sample, life expectancy without mobility problems increased more than total LE and they had both an absolute and relative compression of mobility problems.

Mortality-disability effect

The mortality-disability decomposition of the change in years free from severe disability, mild disability, and mobility problems, show that it was predominantly driven by the mortality effect for men, whereas for women it was predominantly driven by the disability effect [235].

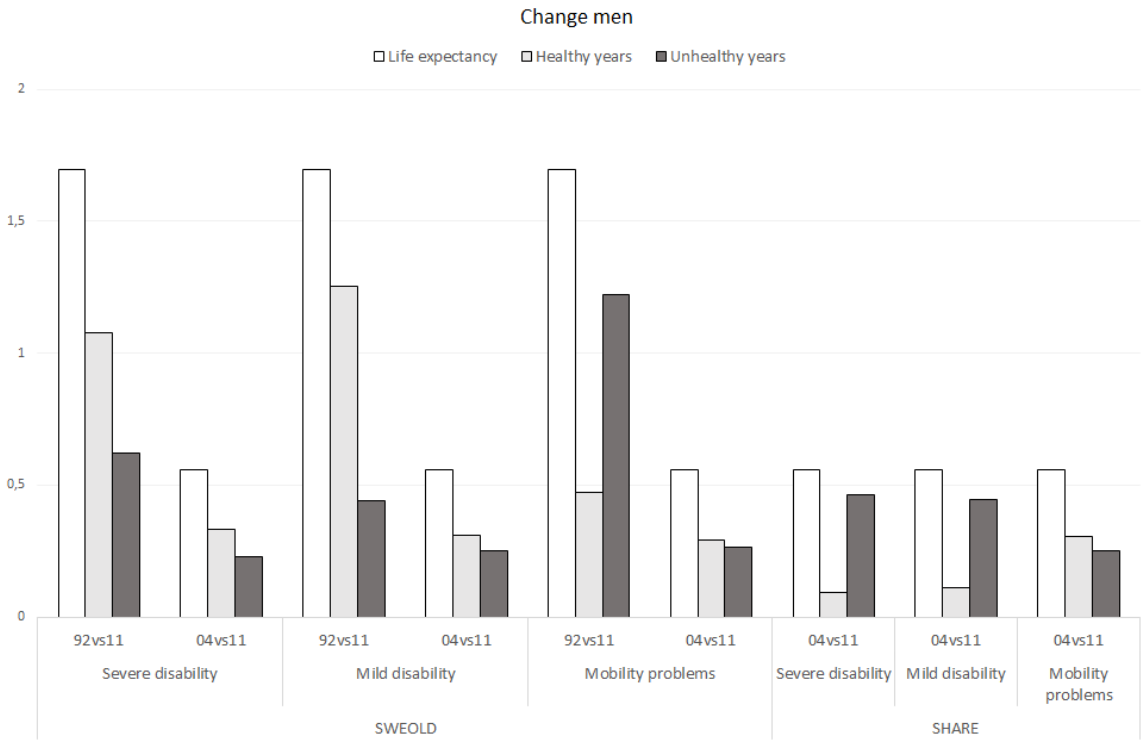

Figure 6a. The change in life expectancy (white bar), healthy years (light grey bar) and unhealthy years (dark grey bar) for men in Sweden, by severe disability, mild disability, mobility problems) and survey (SWEOLD, SHARE).

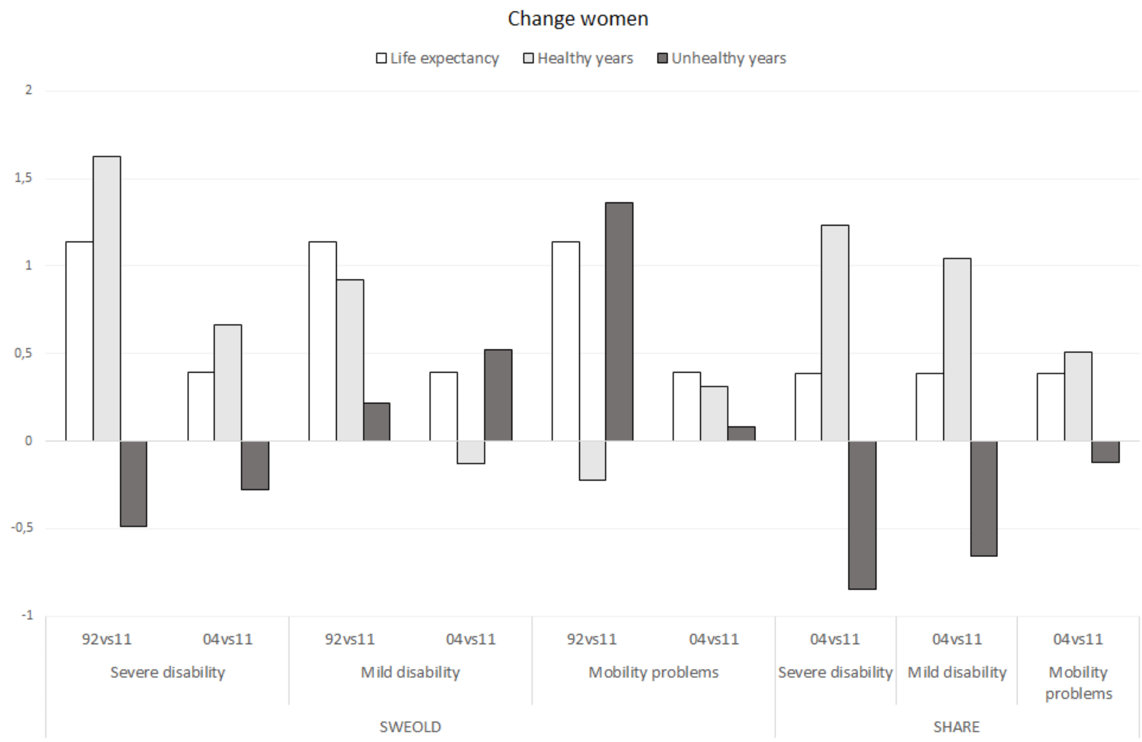

Figure 6b. The change in life expectancy (white bar), healthy years (light grey bar) and unhealthy years (dark grey bar) for women in Sweden, by severe disability, mild disability, mobility problems) and survey (SWEOLD, SHARE)

4.2 STUDY II

After Study 1, which showed slightly different results depending on sex, the second study aimed to shed some light to the mechanisms driving the change in male respectively female life expectancy, and the decreasing gender gap, by addressing age- and cause specific mortality patterns in the population [236]. Data for underlying cause of death was obtained from official statistics at the National Board of Health and Welfare in Sweden for the years 1997 and 2014. Causes of death included were chosen by their impact on the overall life expectancy and decreasing gender gap in life expectancy. The result shows that life expectancy increased by 3.6 years for men and 2.0 years for women between 1997 and 2014. For men, reduced mortality in age group 70–74 had the largest impact for the increase in LE, accounting for 18 percent of the total increase. For women, reduced mortality in the age groups 70–74, 75–79, and 80–84 had the largest impact, accounting together for 17 percent of the total increase. The analyses of cause-specific mortality showed that decreasing mortality from ischemic heart disease had the largest impact on the increasing life expectancy for both males and females (accounting for 48% and 53% of the increase respectively), especially in the age group 65–84 among men and in the age group 70–85+ among women (Figure 7a). Reduced mortality from various cancers explained 19 and 20 percent respectively of the increase among men and women. Smoking-related mortality in the age groups 55 and above had a diminishing impact on female life expectancy, whereas there was a clear opposite trend among men (Figure 7b). A diminishing impact was also found for both men and women with regard to mortality from falls, diseases of the nervous system (including Alzheimer's), unspecified dementia, and parasitic and infectious disease (Figure 7c for diseases of the nervous system and unspecified dementia). The gender gap in life expectancy declined by 1.55 years during the study period, and mortality from ischemic heart disease explained most of the decrease, due to larger mortality reduction among men. Smoking-related mortality also had an impact, due to reduced mortality among men but increased mortality among women. Other causes had a diminishing impact due to increased mortality for both sexes, but more so for women. This was the case for unspecified dementia and Alzheimer's disease.

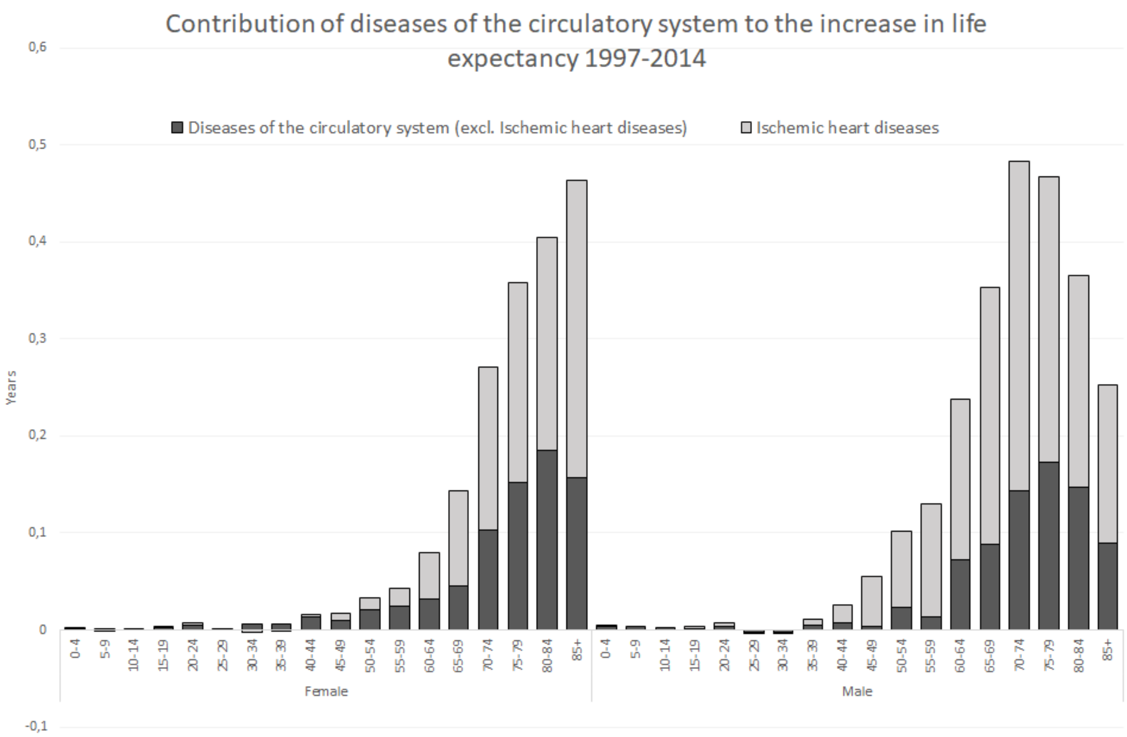

Figure 7a. The impact of diseases of the circulatory system and ischemic heart disease, by age group, for the increase in female and male life expectancy 1997–2014

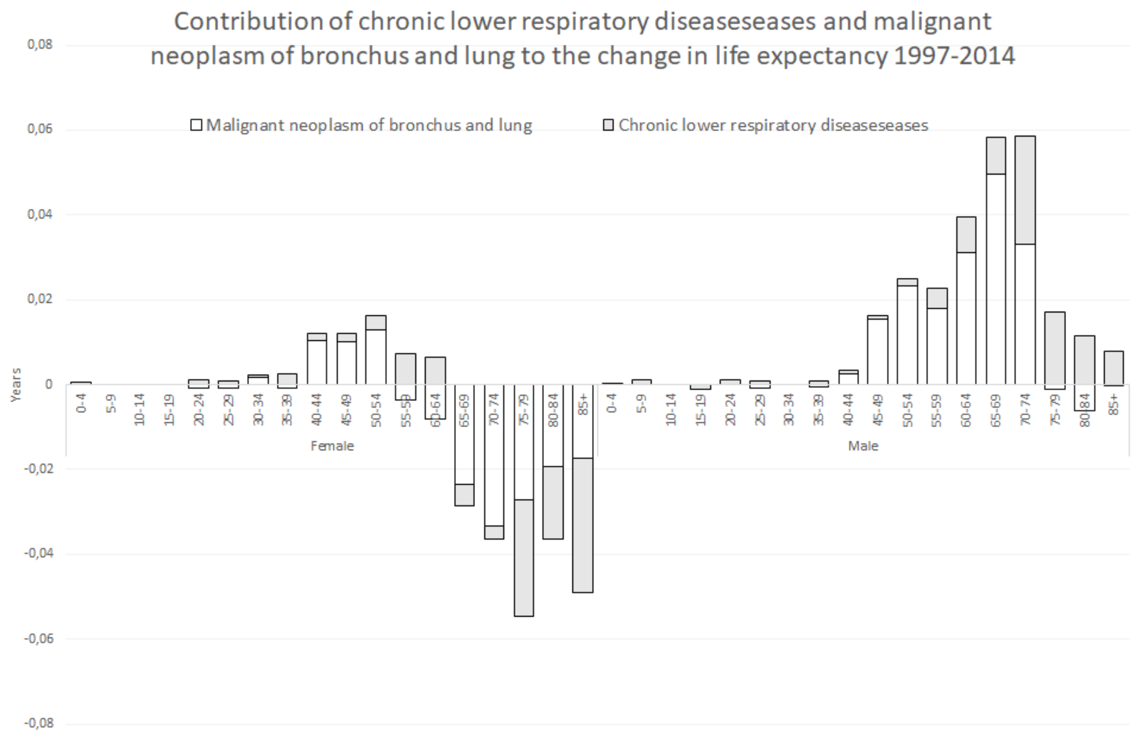

Figure 7b. The impact of chronic lower respiratory disease and malignant neoplasm of bronchus and lung, by age group, for the increase in female and male life expectancy 1997–2014.

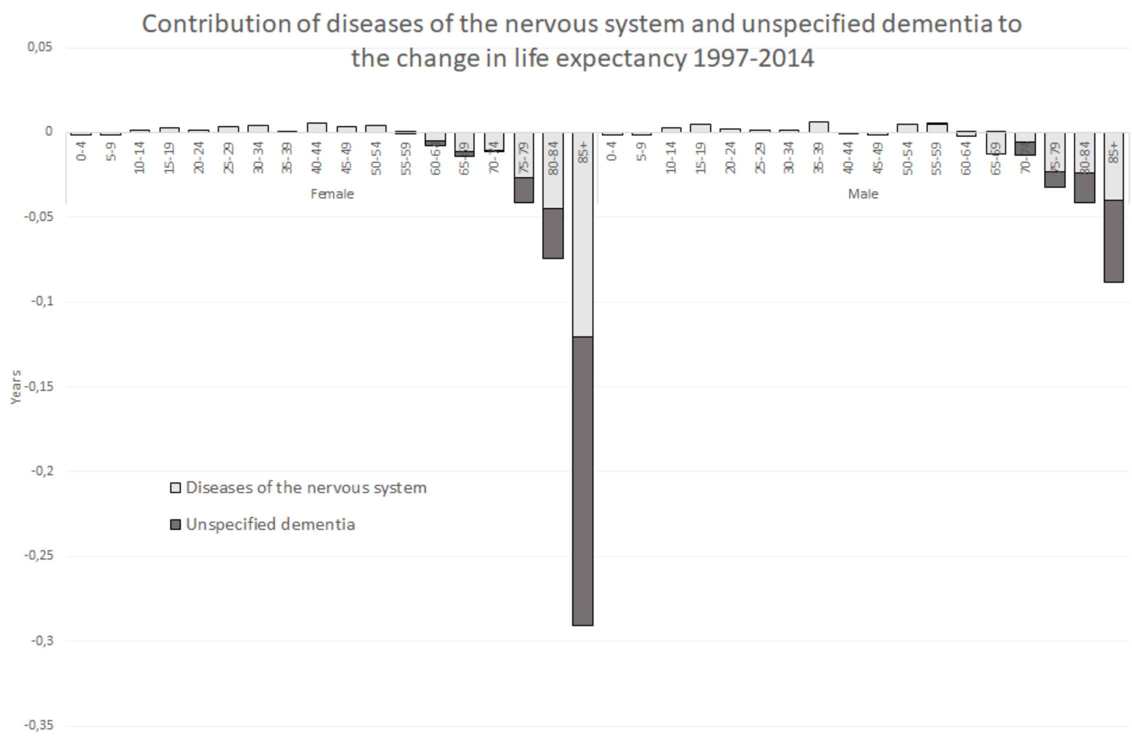

Figure 7c. The impact of diseases of the nervous system and unspecified dementia, by age group, for the increase in female and male life expectancy 1997–2014.

4.3 STUDY III

Study 3 assesses educational differences in DFLE in Sweden between 2002 and 2014. Period life table estimates for educational-specific mortality rates, obtained by Statistics Sweden, were combined with educational-specific disability estimates, obtained by SWEOLD. Educational-specific DFLE and DLE at age 77 and 85 was estimated by the Sullivan method.

The results show that DFLE increased for both men and women and in both educational groups. The increase was more pronounced among those with higher education compared to those with primary education, both at ages 77 and 85. DLE decreased for women in both educational groups, but more so for those with higher education, both at ages 77 and 85. For men, however, DLE only decreased for those with higher education, whereas men with lower education had an increase. Hence, an absolute compression of disability was observed for women in both educational groups, and men with higher education. For men with lower education, however, a modest relative expansion of disability was observed. Due to a greater increase in DFLE among those with higher education, the educational gap in DFLE increased during the study period.

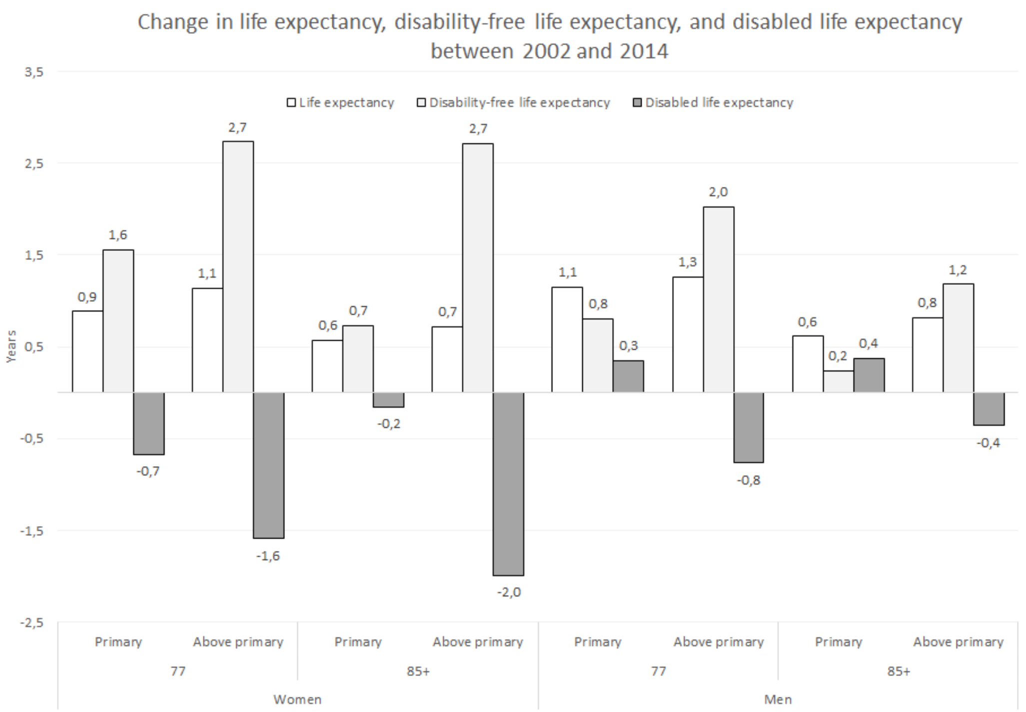

Figure 8. Change in life expectancy, disability-free life expectancy and disabled life expectancy, by low (primary) and high (above primary) education at age 77 and 85 and above. For women and men separately.

4.4 STUDY IV

Study 4 assess the presence of disability among centenarians in different countries, and to what extent the observed disability patterns are in accordance with the mortality-selection hypothesis. In addition, the burden of health problems is assessed by addressing the interrelationship of disability, frailty, and multimorbidity. The 5-Country Oldest Old Project (5-COOP) is a comparative study of 1,253 centenarians living in Japan (n=346), France (n=212), Switzerland (n=170), Denmark (n=251), and Sweden (n=274). These countries have experienced a different pace of increase in the centenarian population [33], which creates the possibility to explore the potential trade-off between quantity and quality of life. The proportion of 80-year old’s that can expect to celebrate their 100-birthday has been found to be highest in Japan (2.4 times higher than in Denmark), followed by France and Switzerland (1.5 times higher than in Denmark), and with the lowest chance to become a centenarian from age 80 is found in Denmark and Sweden [33]. We expect that Japan, with a milder mortality selection among the oldest old, to have the highest proportion of centenarians with disability, followed by France and Switzerland. Denmark and Sweden, with a stronger mortality selection, is expected to have the lowest proportion of centenarians with disability. All outcomes are based on self-reports. People living in care homes are included and by-proxy interviews have been carried out when necessary. The countries vary in terms of response rate (from 36 to 86 percent), centenarians living in nursing homes (from 40 to 75 percent), and the use of by-proxy interviews (from 49 to 93 percent). Predicted probabilities and average marginal effect (AME), with sample weights for the over-sampling of males in the Swedish population, were used to predict the probability of disability in each country.

The result shows that disability was highest in Switzerland, with 90 percent, followed by Japan and France, with 82 percent each. The lowest estimates were found in Sweden and Denmark, with 63 and 73 percent respectively. Hence with regard to the countries with higher mortality pressure (Sweden and Denmark), the estimated prevalence was lower than in the countries with lower mortality pressure. Japan with the lowest mortality pressure had however not the highest estimates of disability. The burden of health problems was overall high among the centenarians. Disability, frailty, and multimorbidity were all highly prevalent and a clear majority of centenarians have either two or three of these conditions. In Japan, Denmark, and Sweden, it was more common to have two of the conditions, while in Switzerland and France it was more common to have all three conditions. All three conditions were most prevalent in Switzerland (64 percent) and least prevalent in Sweden (16 percent), hence also following the patterns found for disability. Not having any of these three conditions was rare and ranged between 3 to 19 percent.

Table 2. Prevalence of disability, frailty, and multimorbidity, and the presence of each of them alone or different combinations.

%	Japan %	France %	Switzer-land %	Sweden %	Denmark %	All %
Disability (D)	**82.0**	**82.1**	**89.8**	**63.2**	**73.4**	**77.4**
Frailty (F)	69.6	72.5	79.0	52.8	59.3	65.8
Multimorbidity (M)	50.0	58.0	80.8	30.2	47.2	51.1
Only one condition:						
D	8.5	10.1	4.8	15.9	8.9	9.9
F	5.6	3.9	0.6	7.8	5.2	5.7
M	2.9	6.3	3.0	7.8	6.0	5.2
Any one	17.0	20.3	8.4	31.3	20.2	20.2
Two conditions:						
D+F	29.1	23.7	10.8	27.0	25.0	24.2
D+M	12.1	6.8	10.2	4.2	12.1	9.2
F+M	2.6	3.4	3.6	2.1	1.6	2.6
Any two	43.8	33.8	24.6	33.3	38.7	36.0
All three conditions:						
D+F+M	32.4	41.5	64.1	16.1	27.4	34.1
Any condition (1,2 or 3)	93.1	95.7	97.0	80.7	86.3	90.1
No condition	6.9	4.3	3.0	19.3	13.7	9.9

5 DISCUSSION

Two discussions take place in this section. The first is dedicated to methodological considerations and mainly concerns the population measure used, disability-free life expectancy by period life tables, and the surveys used, SWEOLD, SHARE, and 5-COOP. The second part is the result discussion begins with a summary of the main findings, and then discusses these findings in the light of other studies. The discussion emphasizes disability-free life expectancy, as it is the main focus of this thesis. The findings from Studies 2 and 4 add to this discussion, rather than being discussed in themselves.

5.1 METHODOLOGICAL CONSIDERATIONS

5.1.1 Disability-free life expectancy

Two main sets of methodological considerations are usually discussed with regard to health expectancy studies. The first concern the use of the period life table with prevalence estimates (compared to multistate methods), and the other concern comparability issues among studies [111, 115, 119, 149, 237-242]. The first consideration, the use of prevalence estimates, is an issue, as information about the underlying forces affecting the estimates is lacking. A reduction in prevalence could be the result of a decrease in incidence, an increase in recovery, or an increase in mortality [51, 243-245], all acting towards reducing the prevalence in the population. Increased prevalence can be the result of increase in incidence, decrease in recovery, or increased survival. Increased prevalence could also be observed, despite a decrease in incidence and recovery, if increased survival has a stronger impact than decrease in incidence. In a similar way prevalence can remain stable while the underlying forces act in opposite directions. Hence, although period life tables estimates are informative when estimating the magnitude of disability in the population, and they are considered a useful indicator for estimating health and long-term care needs in the population [246], they do not explain why we see potential change in disability-free life expectancy, and mask important information about the underlying forces. Another aspect of period-life tables concerns the implicit assumption that people with and without disability have the same mortality rate. Prevalence estimates are usually applied to the mortality conditions of the entire population. However, in reality, mortality rates are higher among individuals with disabilities and other health problem [247], which is disregarded in most period life table studies [227, 228]. Hence, when assuming equal mortality between those with and without disability, the time spent with disability in the population gets overestimated. Related to this matter, the life period estimates assume that disability (or any other health measure used) is an absorbing state. That is, no recoveries are possible after the onset of disability. Initially, when health expectancy estimates emerged, the transition to disability was considered to be irreversible [117]. Since this assumption does not hold in real life, the multistate methods were developed [115]. Hence, when using the life table method it is preferable to use an outcome with low recovery rates. Given the study context of this thesis, severe disability in the population age 77 and above, this assumption is strong in comparison to other outcomes and other ages, as the probability of recovery from severe disability decreases with age [51, 248]. Despite the shortcomings that hamper period-based health expectancy, it has gained recognition and is widely used, and been proven to provide a good approximation of the true estimate of health expectancies (comparing periodic life tables with multi-state estimates), as long as the outcome is rather stable and does not fluctuate too much over time [237, 249]. And although period life tables estimates lack the ability to account for individual trajectories, they are regarded as a useful, and preferable, summary measure for capturing population health [229, 246].

In relation to this, the potential misinterpretation of life table estimates is sometimes raised as a concern [250-252]. Period life expectancy, or health expectancy, doesn't reflect the true life expectancy of any real individuals. It rather reflects the current mortality and health of the entire population and displays an average expected value at a certain age, which is only correct if current mortality and morbidity rates prevail in the future, which they never do. Hence, this estimate rests upon a strong assumption made for mortality, but even stronger for morbidity, as the latter is affected by both incidence, recovery, and mortality transitions in both the healthy and unhealthy population [51, 241, 250]. However, although period based life expectancy estimates can be misinterpreted, as it reflects current mortality rates for the entire population, the interpretation of current mortality conditions is perhaps not straightforward either. The life expectancy estimate of a newborn baby today (year 2021) is based on the mortality experience of those aged 90, born in 1931, as well as those aged 60, born in 1961. Hence, a cohort effect is also present. The mortality reflected in a life table has been described as "a set of age-specific death rates that results from an underlying biological age pattern of human mortality under the impact of current period influences" [252]. Hence, it includes both period effects (current situations affecting mortality patterns) and cohort effects (since the differences in biological age patterns can differ between cohorts).

The other aspects concern the heterogeneity of health expectancy studies and hampered comparability. However, these are of no more concern for health expectancy studies than other types of studies. Point estimates of disability-free life expectancy will be very different between studies despite assessing disability in the exact same manner and using estimates from the same year, if the study populations are very different, which they usually are. The main features that hamper comparability regard the inclusion/exclusion of people living in care homes, the inclusion/exclusion of by-proxy interviews, and response rates. If people living in care homes are excluded, estimates of disability-free life expectancy will be underestimated, as those with the highest disability burden are excluded. The same applies if by-proxy interviews are not carried out. In a similar manner, low response rates produce an underestimation, as non-respondents tend to be those with more health problems [119, 253, 254]. The measures used for assessing disability also vary, which not only hampers comparability among studies, but can also yield different results within a country [85]. The items used, questions asked, mode of data collection, and decisions about index creation and cut-offs will likely differ among studies even if the same measure (e.g., pADL) is used. All these factors hamper comparability [111, 119, 149, 255, 256]. Hence, the proposal of and encouragement to use the GALI measure makes sense to enhance comparability among studies, but these studies still suffer from comparability issues with regard to study population [250]. To summarize, the main methodological considerations of disability-free life expectancy studies regard methods, assumptions, and comparability. Despite these methodological concerns and comparability issues, health expectancy studies have gained large recognition for monitoring population health. And although direct comparisons between estimates from different studies are unwise, the differences observed between groups, and time trends, can be compared between studies to see if the same patterns emerge.

5.1.2 Validity

Potential survey bias

Three of the studies in this thesis include survey samples, and there are some methodological considerations that need to be regarded accordingly. SWEOLD and SHARE are used in Study 1 and there are aspects that differs between these survey samples. Although both are based on a random sample of the Swedish population that includes both people living in care homes and the use of by-proxy interviews, the response rates, survey modes, and phrasing of questions differ, aspects that may have an impact on the result. 5-COOP is used in Study 4, and in a similar manner the countries included in this study differ in terms of sampling recruitment (regional in Japan, France, and Switzerland; national in Denmark and Sweden), response rates (varying between 31–86 percent and unknown in Japan), however phrasing of the questions is similar between the countries in 5-COOP.

Survey mode

Survey mode is known to have an impact on results. One reason is that questions can be phrased differently in a direct interview, a telephone interview, or a questionnaire [257]. SWEOLD, the main sample used in this thesis, has applied different survey modes at different waves. However, the questions are phrased in the same manner despite survey mode used and is thus not affected by this issue. But survey mode could also have an impact with regard to “social desirability”, that is, answers to questions may be adjusted according what are considered socially desirable answers, or to avoid the potential discomfort of answering truthfully [258-260]. The respondent therefore adjusts their answers according to perceived desirability [261, 262]. This phenomenon has been shown to be affected differently according to survey mode. Telephone interviews are more affected by this than face-to-face interviews. And telephone and face-to face interviews are likely more sensitive to this effect than questionnaires, as the latter do not require interpersonal interaction [263-265]. This phenomenon will be more prone to arise when more sensitive questions are asked [258]. Thus, the impact of a potential bias according to survey mode depends to some degree on the questions asked. In the case of this thesis, one could speculate that loss of independence could be a sensitive question for some individuals and therefore answers might be influenced by both social desirability (as independence is valued by society) and possible feelings of embarrassment regarding loss of independence [266, 267].

Response rate

Response rates are a challenging aspects of surveys as it can have an impact on results if none-response is related to the outcome of interest [268]. The challenge has become greater in more recent years due to a general decline in response rates [269, 270], making both comparisons of results [270] and generalizations towards the general population problematic [269]. In surveys assessing health it is recognized that lower response rates can produce an underestimation of health problems, as non-respondents tend to be those with more health problems, especially in the older population [119, 253, 271]. This has a potential impact both when comparing results of different surveys, and for the same survey when used repeatedly. SWEOLD has a high response rate, ranging from 84–95 percent. In comparison, SHARE's response rate on the household level in 2004 was 47 percent (85 percent for household members). For 2011, the numbers are not available. Given that non-response is not necessarily a random event, and can differ systematically among respondents with regard to health status, education, and gender [272], it likely has a differential impact on the surveys and therefore the outcome measures. However, although a low response rate like SHARE's may indicate a healthier sample (if those with worst health decline to participate), we do not see this in the SHARE sample. Rather, it is the opposite for mild disability and mobility problems. It could however also be the result of phrasing the questions differently. The consistency for questions between SWEOLD and SHARE is greater for severe disability than for mild disability and mobility problems.

The response rate in 5-COOP varies among countries. Sweden had a high response rate compared to the other countries. A healthier sample for those countries with lower response rates is not observed in 5-COOP. Switzerland had the highest burden of health problems among centenarians, but their mortality selection was in parity with that of France, while their response rate was higher. A possible explanation for the high burden of health problems in Switzerland could perhaps be found in the proportion of centenarians living in nursing homes, 75 percent, compared to other countries, with 40–47 percent.

Phrasing the question

SWEOLD and SHARE are used for the comparison of consistence between estimates of severe disability, mild disability, and mobility problems. However, the phrasing of the questions differs between the two studies, which will likely impact the result [61, 256, 273]. In SWEOLD, questions of severe disability (pADL) were phrased: "*Can you…by yourself?*", whereas SHARE asked: "*Do you, due to problems with your health or memory, have difficulty performing some of the following activities?*". It is possible that these different phrasings give rise to different answers to some extent. SWEOLD's phrasing is perhaps less subject to interpretation by respondents. In SHARE, it is possible that respondents are to a greater degree affected by the phrasing *health or memory… have difficulty,* as they need to determine what health is and their own health status, then consider to what extent they have difficulty, and to what extent it arise from health or memory. However, mild disability (iADL) is more likely to result in different answers, as the question was asked in two steps in

SWEOLD: *Do you usually prepare/buy food yourself?* ; and *Would you be able to if you had to*? In SHARE, the question was asked in the same manner as above. As iADL questions are more subjected to gender differences [274], especially in older cohorts, it is expected that SWEOLD manages to capture more men with iADL disability than SHARE, as they are not asked whether they *would be able to* in SHARE . The respondent in SHARE might not perceive that difficulty is present if they do not perform the task in the first place. Even larger differences were found between the two studies for mobility problems. Again, it is possible that the phrasing of the question has an impact. In SWEOLD, the questions were whether the respondent could *walk 100 meters fairly briskly without difficulty* and *go up and down stairs without difficulty*. In SHARE: *Do you, due to problems, have difficulty to walk 100 meters: go up a flight of stairs without resting?* It is possible that respondents in SWEOLD focus to a great extent on *fairly briskly*, and in SHARE on *without resting* (i.e., if you don't need to take a break, then no difficulty exists). This could explain why mobility problems are more prominent in SWEOLD.

In 5-COOP, the questionnaire was harmonized among countries, hence the chance of obtaining different estimates among countries due to different question phrasing is considered minimal.

Selection and information bias

The discussion of response rates above is related to selection bias, that is, the estimates obtained are conditioned on participation [275]. However, all study participants included in the three studies used in this thesis rely on random population samples that include those living in nursing homes and those unable to answer themselves by-proxy interviews. Thus, selection bias based on exclusion of the individuals with most health problems, which would underestimate disability in the population, is not present [276, 277]. However, by-proxy interview can also introduce bias, as proxies can overrate the presence of disability. Hence an overestimate of disability could be present [277-279]. Given the use of surveys based on self-reports, reporting bias can also be present, as the respondent needs to evaluate their own health, evaluate their ability/inability to execute certain tasks, and might in turn be affected by the willingness to declare health status (social desirability as described above) [280]. Information bias can also arise from recall bias [259], which refers to a failure to remember past events or experiences. The questions asked in the surveys used in this thesis does not refer to distant events for the outcome variables (disability and mobility), which for instance is used in the GALI measure [281].

Generalizability

External validity regards to what extent the findings from this study can be generalized to the general population. The target population in this thesis is Sweden, except for Study 4, where four other countries are included. Generalizability can only be done by judgment [282]: to what extent the sample used may be assumed representative for the studied population. In this thesis, all sample recruitment relies upon a random sample of the entire population, including those with the most severe health problems. Sweden has high response rates both in the SWEOLD samples and in 5-COOP. These aspects certainly favor a sound generalizability to the Swedish context. The methodological shortcomings of the health expectancies studies (small sample sizes, strong assumptions within the period life table) limit the possibility to draw conclusions about compression or expansion of disability. However, bearing these aspects in mind, the findings from this thesis are likely to have good generalizability to the Swedish context. The findings are however not necessarily generalizable to other countries. Different demographic and epidemiolocal profiles, and difference in welfare system, for instance access to health care, rehabilitation opportunities, and assistive technology, makes generalization difficult. However, given similarities between Nordic countries in many of these aspects, and given similar results obtained in this thesis as in other Nordic countries [199], a generalization to the Nordic context can probably be done to some extent.

5.2 RESULT DISCUSSION

Summary of main result

- The increase in old age life expectancy between 1992 and 2011 was mainly followed by years without severe disability. For women, the increase in severe disability-free life expectancy exceeds the increase in total life expectancy, and an absolute compression of severe disability occurred. For men, the increase in life expectancy was mainly years without severe disability, but severe disabled years increased as well, and both an absolute and relative expansion of disability occurred.
- Educational inequalities increased between 2002 and 2014. Years without disability increased more than total life expectancy for women with both high and low education, but more so for those with high education. The same was observed for men with high education, for men with low education most of the increase was years without disability, but years with disability also increased and they had both an absolute and relative expansion of morbidity.
- The gender gap in disability-free life expectancy decreased during the study period as women had a more favorable increase in years without disability and a more favorable decrease of years with disability. However, men had greater gains in life expectancy.
- The increase in life expectancy between 1997 and 2014 was mainly driven by reduced mortality from cardivascular disease, ishemic heart disease in particular, especially promenent in the age group 65 and above. Most causes of death decreased, but smoking-related mortality among women increased in the age group 55 and above, as did mortality from Alzheimer's and unsepsified dementia in both men and women, especially promenent in age group 85 and above.
- Health problems among centenarians are highly prevalent and co-occurring and seem to be more prominent in countries with a weaker mortality selection.

With regard to disability-free life expectancy, a compression is apparent, although men with lower education appear to lag behind. A relative compression of disability is in line with a majority of the trend studies found elsewhere [51, 67, 141, 196, 198-200, 283, 284], although there are studies pointing towards expansion and dynamic equilibrium as well [125, 188, 193, 195, 285].

The impact of onset, duration, and mortality

Population health is the sum of all the single individual health trajectories in the population, some acting towards an expansion, others towards compression and/or a dynamic equilibrium of disability [68, 70]. However, one of these scenarios will outweigh the others on the population level. To what extent there is a compression, expansion, or a dynamic equilibrium of disability can be seen as the net sum of onset, incidence, recovery, and mortality. Delayed onset, reduced incidence, and improved recovery from disability act towards a compression, whereas the opposite, and decreased mortality with disability, acts towards expansion of disability [68, 70, 286]. A prolonged duration of very mild disability, a dynamic equilibrium. As old age disability is highly related to chronic disease, the onset, incidence, and progression of disease plays a crucial role for disability. However, disease and disability tend to show opposite patterns, with an increase of disease in the population but a decrease of disability [42, 120, 218]. This divergent pattern can to some extent be explained by improved diagnostic tools to detect disease, changes in diagnostic criteria, and greater awareness increasing the health care-seeking behavior of individuals [62, 287]. The downstream from disease to disability is furthermore related to both lifestyle and medical treatment. The improved health status observed in later born cohorts [46, 49, 50, 288, 289], together with earlier detection of disease, and improved medical treatment, will likely reduce the disabling impact of disease. Hence the disabling impact of disease appears to become weaker [290-293]. Thus, improved lifestyle and medical treatments are forces that act towards compression. However, the same forces can also act towards expansion. Improved lifestyle and medical treatment have a positive effect on life expectancy, but as age is a major risk factor for developing chronic disease, increasing life expectancy itself increase the risk of developing subsequent chronic disease and disability. [294].

Previous studies have found that the effect of later onset and improved recovery of disability was offset by decreasing mortality with disability. Hence, the forces acting towards compression were as great as those acting towards expansion, and gains in survival were greater among those with disability than those without [51]. Improved survival with disability has not been supported in the Swedish context [295], but other studies have shown a larger improvement in life expectancy for certain disease groups compared to the general population [52]. These competing forces, compression and expansion acting in different directions, likely fluctuate across time and space as disease patterns, lifestyle, and medical treatments are constantly changing. It has been suggested that an increased survival among sick individuals, thanks to medical improvements, will lead to an initial expansion of disability. But as medical treatment gets better, and control of disease progression improves, the disabling impact of disease will be reduced, moving towards a dynamic equilibrium. And as new cohorts emerge and enter old age with better health status, compression of disability occurs as incidence is lower, and recovery and management of disease is better [5, 36, 68]. However, as a result, the emergence of exceptional old and frail individuals in the population (centenarians, for example) is expected to increase [36]. The results from Study 4 (centenarians) indicate that exceptional old age does come with a high morbidity burden, and higher in those countries with a weaker mortality selection. A weaker mortality selection, driven by improved medical treatment, could thus possibly be accompanied by increasing health problems in the future older cohorts. In addition, it is anticipated that later cohorts must not necessarily enter old age in better health status [296], and that this could possibly have a negative impact on future disability-free life expectancy.

The impact of disease and lifestyle factors

Disability in general is caused mostly by chronic and non-life threatening conditions/diseases [5], for instance musculoskeletal disease, sensory impairment, cognitive impairment, depression, hypertension, heart disease, diabetes, chronic lung disease, and falls [201, 297-303]. The prevalence of these chronic conditions increases with age, as does their disabling impact [304]. To what extent certain diseases have an impact on disability-free life expectancy depends on the impact of a given disease on both mortality and disability. Causes with a large impact on disabled life expectancy are those with strong disabling impact but very low or no mortality impact, for instance arthritis, back problems, and sensory impairments [43, 294, 299]. Hence, eliminating these diseases would have a positive impact on disability-free life expectancy, as they only affect disability and not mortality. High mortality from specific diseases/conditions may have a "positive" impact on disability-free life expectancy, as the opposite result, survival, could result in increased disability. Increased survival from these diseases can either result in disability as a direct consequence of surviving the previous lethal condition, or by being subject to new chronic diseases with disabling impact [294]. Elimination of cancer and heart disease is thought to have a greater impact on disabled life expectancy than disability-free life expectancy for that reason. Both years with and without disability is expected to increase, but the former by a greater extent [305]. Thus, eliminating fatal disease, or the mortal consequences of a chronic condition, could result in an expansion of health problems, whereas eliminating disabling diseases/conditions will result in a compression of disability [294]. However, recent findings from the US indicate that the major contributor to increasing disability-free life expectancy at age 65 was reduced mortality from cardiovascular disease, which accounted for about half of the increase in disability-free life expectancy. However, it also increased years with disability, but more modestly in comparison to the disability-free years gained. Increased survival from cancer had a smaller impact on disability-free life expectancy, but the reduced mortality observed had a larger impact on years without disability than with. Vision problems also had a positive impact on disability-free life expectancy. The gains were due to improvement in vision (due to cataract surgery), which is a good example of the elimination of disabling diseases unrelated to mortality. Increased prevalence of Alzheimer's and Parkinson's disease reduced however disability-free life expectancy [187]. Thus, in relation to the results of Studies 1, 2, and 3, this can be interpretated as the reduced mortality from cardiovascular disease had an overall positive impact on disability-free life expectancy. But it is also likely that other forces acted in the opposite direction as well, for instance by the increase of Alzheimer's resulting in more years with disability. The result can also be extended to Study 4, which shows a high burden of health problems among centenarians. As basically all chronic conditions increase with age, and so does the disabling impact, and Alzheimer's is especially elevated after age 85 [306], a high burden of health problems seems inevitable at exceptional old age, at least for now.

Although lifestyle is generally considered improved nowadays, it is also a growing point of concern. Declines in life expectancy has been observed in the US [183, 307, 308]. These declines have mainly been explained as "deaths by despair" (drug-, alcohol-, and suicide-related mortality) among certain middle age and low education individuals [153, 183, 308]. However, reduction in the pace of decline for CVD mortality also had an impact, slowing down the increase in life expectancy [153, 309]. Declining health status has been observed in younger cohorts in the US [296], and the general trend of overweight, obesity, and sedentary lifestyle is an ongoing public health concern. As overweight, obesity, and sedentary lifestyle are thought to have a larger impact on disability than mortality [310], the ongoing obesity epidemic raise concerns that disability-free life expectancy will decrease in coming years [42, 145, 289]. Overweight and obesity in Sweden are no exception, and show an increasing trend in the adult population [311]. To what extent this will have an impact on overall estimates of population health depends on the extent of the population that is affected. It is likely that certain groups will be more affected than others, and it is plausible that different trends will be observed for different subgroups of the population.

Male-female health survival paradox

The results from both Studies 1 and 3 indicate that the gender difference in disability-free life expectancy decreased during the study period: women had greater gains in DFLE and greater reductions in DLE than men. Women's disadvantage in DFLE (spending a higher proportion of their total life expectancy with disability) has been explained by their advantage in survival [168]. But the trend of a greater decrease in severe disability among women, observed in some studies as in this thesis, has been explained by later onset and incidence, and better recovery [50]. The observed change of a less favorable development for men could possibly be explained by males' greater increase in life expectancy during the study period. As survival from previous more lethal conditions has improved, the increased survival itself, or the exposure to other diseases/conditions, could leave the more susceptible for disability [294].

As mortality and causes of death become more similar between men and women (as seen in Study 2), partly reflecting how social roles and lifestyle becomes less gender specific in Sweden, the findings of decreasing gender differences in disability-free life expectancy likely reflects this trend. Recent gains in male life expectancy have, to a large extent, been explained by reduced preventable mortality (mortality that can be avoided through public health policies, which reflects lifestyle improvements) than for amenable mortality (mortality that can be avoided by health care and medical interventions); for women it was the other way around [106]. This could also be an indication of decreasing differences in lifestyle behaviors between men and women, as the gains in male life expectancy are explained to a greater extent by improved lifestyle factors than female life expectancy. However, the birth cohorts included in Studies 1 and 3 (including people born in 1890s and early 1900s) were probably less affected by some of these changing gender roles. But disability-free life expectancy can be assumed to become more similar between men and women as gender specific social roles dissolve. However, social roles, behaviors, and lifestyle only explain part of the gender differences. As the disabling impact of certain diseases affects women and men differently [304], perhaps explained to some extent by life style factors related to social roles, biological differences may also have an impact and affect disability-free life expectancy differently according to gender.

Educational differences

Although Study 3 show a favorable overall development of disability-free years, the development for those with lower education was not as great as for those with higher education, especially among men. Increasing educational disparities in disability-free life expectancy are also found elsewhere [147, 184]. A recent Norwegian study [199] assessed educational differences in disability-free life expectancy (based on ADL) at age 70 between 1995 and 2017 and found a result very similar to that of Study 3. A general increase in disability-free life expectancy was observed in all educational groups, the greatest improvements among those with higher education, and greater improvement among women. Years with pADL disability decreased for both men and women in both educational groups, but with a very small decrease for men (-0.1 year for low education and -0.2 years for high education). The increasing impact of education (or other socioeconomic indicators) on disability-free life expectancy (or other measures of health) can to some extent be understood by putting it in the context of the epidemiological transition. During the initial transition state, when infectious diseases were high, public health efforts like immunization and improved sanitation had an overall impact for population health. Infectious disease and contagion more equally affect the population, with less regard for socioeconomic status. And in general, public health efforts had a large effect on the total population. As the disease panorama has shifted towards chronic diseases, which today are highly related to lifestyle behaviors, the impact of lifestyle, and living circumstances have become more prominent. And as health and mortality follow a social gradient, those in the highest social position tend to be favored [5]. The increase in educational differences could possibly also be explained by a change in educational composition in the population. As a larger proportion of the population attend higher education, those with lower education could become a more selected group, characterized with a worse health status [312, 313].

Studies that have addressed causes that contribute to educational differences in disability have estimated that about two-thirds of the difference in prevalence in disability between those with low and high education is attributed to chronic disease. For men, the educational difference in disability was mostly due to back pain, neck or arm conditions, and peripheral vascular disease. For women, it was attributed to arthritis, back pain, and chronic nonspecific lung disease. However, the disabling impact of these conditions, rather than prevalence itself, explained most of the difference [314]. An explanation for the different disabling impact between educational groups could possibly be found in different health status, as those with higher education general have better lifestyle-related behaviors throughout life. As overweight and obesity is a contributing factor for disability [315-317], and obesity and overweight is more prevalent among those with lower education [311], this could perhaps partly also serve as an explanation to why certain conditions also have a more disabling impact for those with lower education. In addition, those with higher education are more likely to have better material resources, and therefore better housing and living environment, which can also diminish the impact on disability to some degree. Smoking, on the other hand, which have an impact on educational differences in life expectancy, have been found to have a small effects on disability-free life expectancy, as a consequence of higher mortality [318].

As previous studies show that decreasing mortality from cardiovascular disease has a positive impact on disability-free life expectancy [187]; and the result from Study 2, showing that increasing life expectancy, especially among men, was mainly the result of improved survival from cardiovascular disease; and the result from Study 1 and 3 showing that years with disability increased for men, but only those with low education, it is tempting to draw the conclusions that, 1) survival from cardiovascular disease among men with lower education has not been as beneficial, and/or 2) decreasing mortality from cardiovascular disease has a larger disabling impact for those with low education. To assess how age and cause specific mortality has changed within different educational groups would have brough insight to this matter. Recent studies assessing educational inequalities in cardiovascular mortality in Europe show however that those with lower education had a larger absolute decline in cardiovascular mortality between 1990 and 2014, compared to those with higher education [319]. This could possibly indicate that improved survival from cardiovascular disease among those with lower education comes with more disabling conditions.

Reductions in cardiovascular mortality have mainly been attributed to improvements in lifestyle, more specifically reductions of cholesterol, blood pressure, smoking, and physical inactivity. Other lifestyle related factors, like increase in body mass index (BMI) and diabetes, are however thought to have partly counteracted this decline. The impact of medical and surgical treatments for the reduction in cardiovascular mortality is recognized to be substantial as well [320, 321]. Given that lifestyle-related health problems are more common among lower socioeconomic groups, which also have more risk factors and higher burden of cardiovascular disease [176, 322-327], it is plausible that not just mortality, but also the disabling impact of cardiovascular disease, differs between educational groups.

Different results depending on outcome

Study 1 shows different results for different outcomes, and different trend depending on time period assessed. The differences between estimates are expected since the prevalence of outcomes vary with the hierarchy of disability limitations [328-330]. That the trends vary, and fluctuates, is however less clear. A decrease in mild disability can likely reflect both better health status in general, and improved management of disease with postponement of severe disability. As disability occurs in interaction with the environment, external factors will have an impact, and it is likely that environmental modifications and/or the use of aids will have an impact on the presence or absence of disability [218]. iADL (shopping and preparing meals) can for instance be affected by the use of a walker to increase mobility to go and shop. Similarly, use of microwaves, or meal delivery services, can increase the ability to prepare meals. pADL, on the other hand, are self-care tasks that to some degree can also be enabled by aids, but probably not to the same extent (e.g., eating, dressing). Mobility problems gave perhaps the more surprising result, with an expansion of mobility problems among women in the SWEOLD sample, who otherwise showed a favorable development of both mild and sever disability. However, year 1992 appears to be an outlier compared to the other years. Hence, when analysis is restricted to 2002 and onwards, the pattern looks differently. The possibility that mobility problems worsened for women but disability improved seems contradictory, especially as later cohorts have shown better health status than previous cohorts. However, while aids like walkers can increase independence to some degree, they probably have less impact on the ability to walk “briskly” and climb stairs. Beside the potential impact of environmental factors of decreasing disability, it is also possible that rehabilitation activities might have changed, which could possibly have a different impact depending on disability items. The fluctuating results can probably also be a result of small sample sizes.

Exceptionally old, exceptionally sick?

It seems like favorable gains has been made in onset, incidence, progression, and recovery from disability, but also in survival with disability [50, 51, 187, 290-292]. However, the net effect comes out greater for the forces acting towards compression. Results from this study show a compression at age 85, and other studies have also found compression at age 90 as well [51, 200]. However, results from Study 4 indicate that becoming a centenarian brings a high burden of health problems, and more so in countries with a weaker mortality selection. And while disability, frailty, and multimorbidity tend to be separate entities among the young-old [87], they seem to coincide to a large degree among centenarians, indicating that the health status becomes burdensome and complex. Previous centenarian studies show that centenarians have generally been healthier than the non-survivors of their cohorts [331, 332] but after age 85 an acceleration and accumulation of disability occurs [332]. Similarly, Alzheimer’s shows an acceleration after age 85 [306]. Hence, as disease and health problems accumulate with increasing age, it appears difficult to avoid a high burden of health problems at exceptionally old age.

6 CONCLUSION AND FURTHER DIRECTIONS

Disability-free life expectancy is a summary measure of population health that is especially relevant to assess in the older population. The question of whether increasing life expectancy is accompanied by years with or without disability is important for many reasons, but especially with regard to the need for long-term care.

The results from this thesis indicate that most of the increase in old age life expectancy between 1992 and 2014 has been accompanied by years free from disability. In addition, disability-free life expectancy exceeded the increase in life expectancy in many cases. This is a favorable and desired development as it adds life to years, not just years to life [42-45]. The gender difference in disability-free life expectancy decreased, as women have had a larger increase of years free from disability, and larger decrease of years with disability. However, the educational differences in disability-free life expectancy increased during the period, as those with lower education had a smaller increase in disability-free years, as well as a smaller decrease of years with disability or, in the case of men with lower education, an increase of years with disability. This is concerning. However, drawing conclusions about population health based on a single measure and outcome is problematic. The result should, as in all research, be seen as complementary knowledge adding to a puzzle, and should be recognized as only a part and not the whole of understanding [57]. The result found in the Swedish setting, namely a general compression of disability, decreasing gender differences, and increasing educational inequalities in disability-free life expectancy, has however been observed elsewhere as well [199].

Since population patterns of mortality and disability are constantly changing, a need to monitor health trends in the old population, including disability-free life expectancy, will continue to exist [61]. Scientific knowledge will grow, as may the heterogeneous results. Lumping the total population into a single measure may appear crude, but the information obtained from such summary measures yields important insights into the direction of population health, and may uncover empirical regularities of importance for both policy and research. Given the observed educational differences, and increasing inequalities, future research should aim to assess disability-free life expectancy in different subgroups of the population as trends might move in different directions in different groups [333]. Due to the smaller sample size in this thesis, and few older adults within the highest educational group, education was dichotomized into high and low. With larger sample sizes that allow for several different educational groups, a more nuanced picture of educational inequality could be provided. In a similar manner, a more comprehensive picture could be provided by including different severity levels of disability. Additional knowledge also needs to be gained with regard to how certain causes of death and disease have differential impacts on disability-free life expectancy depending on socioeconomic status and other subgroups of the population.

For disability-free life expectancy specifically, overweight and obesity give rise to concerns, as they have a disabling impact and constitute a major public health concern. Overweight and obesity are more common among those with lower socio-economic status and should therefore be regarded as a risk factor with increasing importance, both for population health in general and for increasing health inequalities in particular. As overweight and obesity are highly modifiable risk factors, there is room for improvement. Given that old-age disability in many aspects (but not all) is driven by life-style related factors, public health actions ought to be present throughout the life course [49] and at different levels of society [334]. And especial attention needs to be given to life-style related behaviours [335] . The urgency of the health status of the older population is well recognized and there are many well-developed strategies for promoting healthy aging and creating age-friendly environments [45, 84, 336]. Despite many optimistic scenarios of improving health in the old population, and an educational expansion, which to some extent is thought to midget the increase of disability in the population in the upcoming decades [293, 337, 338], the increase in life expectancy, and the increase of the numbers of older adults in the population, will most likely result in an increased pressure for the need of long-term care [337, 339-341]. Thus, to keep measuring and monitoring health trends in the older population will continue to be of great importance in decades to come [49].

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9 APPENDIX

Dissertations from the Aging Research Center and Stockholm Gerontology Research Center, 1991-2021

1991

Herlitz, Agneta. Remembering in Alzheimer's disease. Utilization of cognitive support.

(Umeå University)

1992

Borell, Lena. The activity life of persons with a dementia disease.

1993

Fratiglioni, Laura. Epidemiology of Alzheimer's disease. Issues of etiology and validity.

Almkvist, Ove. Alzheimer's disease and related dementia disorders: Neuropsychological identification, differentiation, and progression.

Basun, Hans. Biological markers in Alzheimer's disease. Diagnostic implications.

1994

Grafström, Margareta. The experience of burden in care of elderly persons with dementia.

(Karolinska Institutet and Umeå University)

Holmén, Karin. Loneliness among elderly - Implications for those with cognitive impairment.

Josephsson, Staffan. Everyday activities as meeting-places in dementia.

Stigsdotter-Neely, Anna. Memory training in late adulthood: Issues of maintenance, transfer and individual differences.

Forsell, Yvonne. Depression and dementia in the elderly.

1995

Mattiasson, Anne-Cathrine. Autonomy in nursing home settings.

Grut, Michaela. Clinical aspects of cognitive functioning in aging and dementia: Data from a population-based study of very old adults.

1996

Wahlin, Åke. Episodic memory functioning in very old age: Individual differences and utilization of cognitive support.

Wills, Philippa. Drug use in the elderly: Who? What? & Why? (Licentiate thesis)

Lipinska Terzis, Beata. Memory and knowledge in mild Alzheimer's disease.

1997

Larsson, Maria. Odor and source remembering in adulthood and aging: Influences of semantic activation and item richness.

Almberg, Britt. Family caregivers experiences of strain in caring for a demented elderly person. (Licentiate thesis)

1998

Agüero-Eklund, Hedda. Natural history of Alzheimer's disease and other dementias. Findings from a population survey.

Guo, Zhenchao. Blood pressure and dementia in the very old. An epidemiologic study.

Björk Hassing, Linda. Episodic memory functioning in nonagenarians. Effects of demographic factors, vitamin status, depression and dementia. (In collaboration with the Department of Psychology, University of Gothenburg, Sweden)

Hillerås, Pernilla. Well-being among the very old. A survey on a sample aged 90 years and above. (Licentiate thesis)

1999

Almberg, Britt. Family caregivers caring for relatives with dementia – Pre- and post-death experiences.

Robins Wahlin, Tarja-Brita. Cognitive functioning in late senescence. Influences of age and health.

Zhu, Li. Cerebrovascular disease and dementia. A population-based study.

2000

Hillerås, Pernilla. Well-being among the very old. A survey on a sample aged 90 years and above. (In collaboration with H. M. Queen Sophia University College of Nursing, Stockholm, Sweden)

von Strauss, Eva. Being old in our society: Health, functional status, and effects of research.

2001

Jansson, Wallis. Family-based dementia care. Experiences from the perspective of spouses and adult children.

Kabir, Nahar Zarina. The emerging elderly population in Bangladesh: Aspects of their health and social situation.

Wang, Hui-Xin. The impact of lifestyles on the occurrence of dementia.

2002

Fahlander, Kjell. Cognitive functioning in aging and dementia: The role of psychiatric and somatic factors.

Giron, Maria Stella. The rational use of drugs in a population of very old persons.

2003

Jönsson, Linus. Economic evaluation of treatments for Alzheimer's disease.

2004

Berger, Anna-Karin. Old age depression: Occurrence and influence on cognitive functioning in aging and Alzheimer's disease.

Cornelius, Christel. Drug use in the elderly - Risk or protection? Findings from the Kungsholmen project.

Qiu, Chengxuan. The relation of blood pressure to dementia in the elderly: A communitybased longitudinal study.

Palmer, Katie. Early detection of Alzheimer's disease and dementia in the general population. Results from the Kungsholmen Project.

Larsson, Kristina. According to need? Predicting use of formal and informal care in a Swedish urban elderly population.

2005

Derwinger, Anna. Develop your memory strategies! Self-generated versus mnemonic strategy training in old age: Maintenance, forgetting, transfer, and age differences.

De Ronchi, Diana. Education and dementing disorders. The role of schooling in dementia and cognitive impairment.

Passare, Galina. Drug use and side effects in the elderly. Findings from the Kungsholmen Project.

Jones, Sari. Cognitive functioning in the preclinical stages of Alzheimer's disease and vascular dementia.

Karp, Anita. Psychosocial factors in relation to development of dementia in latelife: a life course approach within the Kungsholmen Project.

Nilsson Jan. Understanding health-related quality of life in old age. A crosssectional study of elderly people in rural Bangladesh.

2006

Klarin, Inga. Drug use in the elderly – are quantity and quality compatible.

Nilsson, Erik. Diabetes and cognitive functioning: The role of age and comorbidity.

Ngandu, Tiia. Lifestyle-related risk factors in dementia and mild cognitive impairment: A population-based study.

Jonsson Laukka, Erika. Cognitive functioning during the transition from normal aging to dementia.

2007

Ferdous, Tamanna. Prevalence of malnutrition and determinants of nutritional status among elderly people. A population-based study of rural Bangladesh. (Licentiate thesis)

Westerbotn, Margareta. Drug use among the very old living in ordinary householdsAspects on well-being, cognitive and functional ability.

Rehnman, Jenny. The role of gender in face recognition. (Stockholm University)

Nordberg, Gunilla. Formal and informal care in an urban and a rural population. Who? When? What?

Beckman, Gyllenstrand Anna. Medication management and patient compliance in old age.

2008

Gavazzeni, Joachim. Age differences in arousal, perception of affective pictures, and emotional memory enhancement.

Marengoni, Alessandra. Prevalence and impact of chronic diseases and multimorbidity in the aging population: A clinical and epidemiological approach.

Rovio, Suvi. The effect of physical activity and other lifestyle factors on dementia, Alzheimer's disease and structural brain changes.

Xu, Weili. Diabetes mellitus and the risk of dementia. A population-based study.

Meinow, Bettina. Capturing health in the elderly population – complex health problems, mortality, and the allocation of home help services.

Agahi, Neda. Leisure in late life. Patterns of participation and relationship with health.

Haider, Syed Imran. Socioeconomic differences in drug use among older people. Trends, polypharmacy, quality and new drugs.

2009

Thilers, Petra. The association between steroid hormones and cognitive performance in adulthood.

Masud, Rana AKM. The impact of health promotion on health in old age: results from community-based studies in rural Bangladesh.

Paillard-Borg, Stéphanie. Leisure activities at old age and their influence on dementia development.

Livner, Åsa. Prospective and retrospective memory in normal and pathological aging.

Atti, Anna-Rita. The effect of somatic disorders on brain aging and dementia: Findings from population-based studies.

2010

Fors, Stefan. Blood on the tracks. Life-course perspectives on health inequalities in later life.

Keller, Lina. Genetics in dementia. Impact in sequence variations for families and populations.

2011

Schön, Pär. Gender matters. Differences and changes in disability and health among our oldest women and men.

Caracciolo, Barbara. Cognitive impairment in the non-demented elderly: Occurrence, risk factors, progression.

Rieckmann, Anna. Human aging, dopamine, and cognition. Molecular and functional imaging of executive functions and implicit learning.

2012

Haasum, Ylva. Drug use in institutionalized and home-dwelling elderly persons.

Mangialasche, Francesca. Exploring the role of vitamin E in Alzheimer's disease. An epidemiological and clinical perspective.

Lovén, Johanna. Mechanism of women's own-gender bias and sex differences in memory for faces.

2013

Hooshmand, Babak. The impact of homocysteine and B vitamins on Alzheimer's disease, cognitive performance and structural brain changes.

Rizzuto, Debora. Living longer than expected: protective and risk factors related to human longevity.

2014

Sjölund, Britt-Marie. Physical functioning in old age: Temporal trends and geographical variation in Sweden.

Wastesson, Jonas. Unequal drug treatment: age and educational differences among older adults.

2015

Sköldunger, Anders. Dementia and use of drugs: Economic modelling and population-based studies.

Gransjön Craftman, Åsa. Medicine management in municipal home care; delegating, administrating and receiving.

Svärd, Joakim. Emotional facial processing in younger and older adults.

Wang, Rui. Cardiovascular risk factors, brain structure, and cognitive decline in old age.

Pantzar, Alexandra. Cognitive performance in old-age depression.

2016

Kelfve, Susanne. Gotta survey somebody: methodological challenges in population surveys of older people.

Heap, Josephine. Living conditions in old age: Coexisting disadvantages across life domains.

Håkansson, Krister. The role of socio-emotional factors for cognitive health in later life.

Shakersain, Behnaz. Impact of nutritional status and diet on cognitive decline and survival.

Bellander, Martin. Plasticity of memory functioning: genetic predictors and brain changes.

2017

Ferencz, Beata. Genetic and lifestyle influences on memory, brain structure, and dementia.

Köhncke, Ylva. Lifestyle, cognitive aging, and brain correlates.

Santoni, Giola. How well are we aging? Capturing the complexity of health trajectories of older adults.

Becker, Nina. Inter-individual differences in associative memory: Structural and functional brain correlates and genetic modulators.

2018

Nilsen, Charlotta. Do psychosocial working conditions contribute to healthy and active aging? Studies of mortality, late-life health, and leisure.

Darin-Mattsson, Alexander. Set for life? Socioeconomic conditions, occupational complexity, and later life health.

Marseglia, Anna. The Impact of diabetes on cognitive aging and dementia.

Heiland, Emerald. Cardiovascular risk factor profiles in the development and progression of physical limitation in old age: A population-based study.

Sjöberg, Linnea. Using a life-course approach to better understand depression in older age.

Samrani, George. Interference control in working memory: neurobehavioral properties and age differences.

2019

Seblova, Dominika. Causal effects of education on cognition – How do we generate evidence?

Berggren, Rasmus. Cognitive development and educational attainment across the life span.

Vetrano, Davide Liborio. Impact of cardiovascular and neuropsychiatric multimorbidity on older adults' health.

Rehnberg, Johan. Inequalities in life and death: income and mortality in an aging population.

Pan, Kuan-Yu. Impact of psychosocial working conditions on health in older age.

Avelar Pereira, Bárbara. Multimodal imaging: Functional, structural, and molecular brain correlates of cognitive aging

Morin, Lucas. Too much, too late? Drug prescribing for older people near the end of life.

de Boer, Lieke. Dopamine, decision-making, and aging: Neural and behavioural correlates.

Ek, Stina. Predictors and consequences of injurious falls among older adults: A holistic approach.

Ding, Mozhu. The Role of Atrial Fibrillation in Cognitive Aging: A population-based study.

2020

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