Acta Universitatis Tamperensis 2335

LINDA ENROTH

Social Inequality in the Health of the Oldest Old

Socioeconomic differences in health, functioning, mortality and long-term care use in the population aged 90+

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ACADEMIC DISSERTATION
To be presented, with the permission of
the Faculty Council of Social Sciences
of the University of Tampere, for public discussion
in the auditorium F114 of the Arvo building,
Arvo Ylpön katu 34, Tampere,
on 1 December 2017, at 12 o'clock.

UNIVERSITY OF TAMPERE

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Acta Universitatis Tamperensis 2335
Tampere University Press
Tampere 2017

UNIVERSITY
OF TAMPERE

ACADEMIC DISSERTATION
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Finland

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The originality of this thesis has been checked using the Turnitin OriginalityCheck service in accordance with the quality management system of the University of Tampere.

Cover design by
Mikko Reinikka

Acta Universitatis Tamperensis 2335
ISBN 978-952-03-0598-7 (print)
ISSN-L 1455-1616
ISSN 1455-1616

Acta Electronica Universitatis Tamperensis 1840
ISBN 978-952-03-0599-4 (pdf)
ISSN 1456-954X
http://tampub.uta.fi

Suomen Yliopistopaino Oy – Juvenes Print
Tampere 2017

YMPÄRISTÖMERKKI
MILJÖMÄRKT
441 729
Painotuote

Abstract

Socioeconomic health inequalities are a consistent finding worldwide. People with higher socioeconomic status (SES) are healthier and live longer than people with lower SES. Socioeconomic health inequalities are well established for the middle-aged and young old (40-75 years old) in developed countries. However, for the oldest old (85+ years old) research is scarce, and it is not clear whether inequalities exist in very old ages. The number of the oldest old has increased rapidly. Round-the-clock LTC use is higher for the oldest old than for the younger old due to an age-related health decline. Socioeconomic inequalities in LTC use have, however, not been studied among the oldest old.

This study aimed to explore associations between SES and health in a Finnish population aged 90+. The study took advantage of two SES indicators, occupational class and education, and of several health indicators, including functioning, morbidity (multimorbidity), self-rated health (SRH), biomarkers (cardiometabolic and inflammatory), mortality (all-cause, dementia, and cardiovascular disease (CVD)), and LTC (total, publicly, and privately provided).

The study used data from the Vitality 90+ Study, which includes population-based data targeting all 90 years and older inhabitants in the city of Tampere in Finland. A cross-sectional survey from the year 2010 (n=1,276, response rate 79%), four surveys combined from the years 2001, 2003, 2007, and 2010 (n=2,862, response rate 80%), and health-examination data from the year 2000 (n=262, response rate 61%) were used in the study. National register data on mortality and LTC use were linked with survey data. SES association with functioning, morbidity, SRH and with biomarkers was analyzed in a cross-sectional setting by using logistic and ordered regression methods of analysis. SES association with mortality and LTC use was analyzed during three years of follow-up by using survival analyses. In addition to relative analyses, absolute differences were assessed for several health outcomes.

In terms of absolute inequalities, a social gradient was found in functioning, multimorbidity and SRH with both SES indicators for both genders, but not for women according to education level. The differences were not statistically significant in all cases but showed gradually better health for those with higher SES. In terms of relative inequalities, those with the highest occupational class or education had better health than other groups. The only exceptions where differences between occupational classes were not statistically significant were multimorbidity among women and SRH among men. People with lower education had a higher burden of cardiometabolic biomarkers than those who had the highest education level but there were no significant differences in inflammatory biomarkers. All-cause mortality and mortality from dementias were higher for those with lower SES in comparison with the reference groups. There were no statistically significant differences in CVD mortality and overall differences in mortality were milder when education was used as a SES indicator. LTC use in total was rather similar for all occupational classes. However, those with the highest occupational class were in privately provided LTC facilities more often in 2001, 2003, and 2007 but not in 2010 than the other occupational classes.

In conclusion, this study suggests that socioeconomic health inequalities exist in the population aged 90+. Health inequalities were found with both socioeconomic status indicators for both genders, even though the magnitude of inequalities varied. Socially produced life circumstances affect health throughout the life span. Thus, policy implications to reduce health inequalities in old age should focus on reducing social inequality in the society in general. Social inequality in health, especially in old age, emphasizes the importance of organizing health and social care services so that people in all socioeconomic groups have access to services based on their needs.

Keywords: occupational class, education, functioning, morbidity, self-rated health, biomarkers, mortality, long-term care, nonagenarians

Tiivistelmä

Sosioekonomiset terveyserot on hyvin tunnistettu maailmanlaajuisesti. Korkeamman sosioekonomisen aseman omaavilla on parempi terveys ja he elävät pidempään kuin matalammassa asemassa olevat. Sosioekonomiseen asemaan yhteydessä olevista terveyseroista on paljon näyttöä keski-ikäisessä väestössä sekä nuoremmilla vanhoilla (40-75-vuotiaat) kehittyneissä maissa mutta vanhoista vanhimpien (85+ -vuotiaat) osalta tutkimustieto on vähäistä, eikä ole selvää onko hyvin vanhoilla sosioekonomiseen asemaan yhteydessä olevia terveyseroja. Vanhoista vanhimpien määrä kasvaa nopeasti. Ympärivuorokautisen pitkäaikaishoidon käyttö on yleisempää vanhoista vanhimmilla kuin nuoremmilla vanhoilla koska ongelmat terveydessä ja toimintakyvyssä lisääntyvät iän myötä. Sosioekonomisia eroja pitkäaikaishoidon käytössä ei ole kuitenkaan tutkittu vanhoista vanhimmilla.

Tämän tutkimuksen tavoitteena on selvittää sosioekonomisen aseman yhteyttä terveyteen 90-vuotiailla ja sitä vanhemmilla. Tutkimuksessa käytetään kahta sosioekonomisen aseman osoitinta, ammattiasemaa ja koulutusta sekä useita terveyden osoittimia, toimintakykyä, sairastavuutta (monisairastavuus), itse arvioitua terveyttä, biomarkkereita (kardiometaboliset ja tulehdukselliset), kuolleisuutta (kokonaiskuolleisuus, dementia ja sydän- ja verisuonitauti kuolleisuus) sekä ympärivuorokautisen pitkäaikaishoidon käyttöä (kokonaiskäyttö sekä erikseen julkisesti ja yksityisesti tuotettu).

Tutkimuksessa käytetään Tervaskannot 90+ tutkimusaineistoa, jonka kohdeväestönä ovat kaikki 90-vuotiaat ja sitä vanhemmat tamperelaiset. Tutkimus koostuu poikkileikkausaineistoista: postikysely vuodelta 2010 (n=1,276, vastausprosentti 79), neljä postikyselyä yhdistettynä vuosilta 2001, 2003, 2007 ja 2010 (n=2,861, vastausprosentti 80) sekä terveystarkastusaineisto vuodelta 2000 (n=262, vastausprosentti 61). Tiedot kuolleisuudesta ja pitkäaikaishoidon käytöstä poimittiin Tilastokeskuksen rekistereistä sekä sosiaali- ja terveydenhuollon hoitoilmoitusrekistereistä ja tiedot yhdistettiin postikyselyaineistojen kanssa. Sosioekonomisen aseman yhteyttä toimintakykyyn, sairastavuuteen, itse arvioituun terveyteen ja biomarkkereihin tarkasteltiin poikkileikkausasetelmassa logistisen ja ordinaalisen regressioanalyysin avulla. Sosioekonomisen aseman yhteyttä kuolleisuuteen ja pitkäaikaishoidon käyttöön tarkasteltiin kolmen vuoden seurannassa suhteellisen vaaran regressioanalyyseillä. Suhteellisia terveyseroja tarkastelevien analyysien lisäksi tutkittiin myös absoluuttisia eroja terveydessä.

Toimintakyvyssä, monisairastavuudessa ja itse arvioidussa terveydessä absoluuttiset erot noudattivat terveyden sosiaalista gradienttia molemmilla sosioekonomisen aseman osoittimilla tarkasteltuna miehillä ja naisilla. Erot eivät olleet kaikissa tapauksissa tilastollisesti merkitseviä mutta osoittivat, että terveys oli asteittain parempi mitä korkeampi sosioekonominen asema oli. Naisilla kaikilla terveyden osoittimilla selvää terveyden gradienttia ei kuitenkaan havaittu koulutuksen mukaan. Suhteellisia eroja mittaavissa analyyseissä vertailuryhmänä olivat korkeimman ammattiaseman tai koulutuksen omaavat. Korkeimmassa sosioekonomisessa asemassa olevilla oli parempi toimintakyky ja itse arvioitu terveys sekä harvemmin 2 tai useampia sairauksia kuin muilla ryhmillä. Poikkeuksena olivat naisten monisairastavuus ja miesten itse-arvioitu terveys ammattiaseman mukaan, sillä niissä ei havaittu tilastollisesti merkitseviä eroja. Matalamman koulutuksen ryhmillä oli suhteellisesti huonommat tasot kardiometabolisissa biomarkkereissa mutta eroja ei havaittu tulehduksellisissa biomarkkereissa. Kokonaiskuolleisuus ja kuolleisuus dementiaan olivat korkeampia matalammassa sosioekonomisessa asemassa olevilla kuin vertailuryhmillä. Sydän- ja verisuonitautikuolleisuudessa ei havaittu tilastollisesti merkitseviä eroja ja yleisesti ottaen erot olivat pienempiä, kun koulutus oli sosioekonomisen aseman osoitin. Pitkäaikaishoidon kokonaiskäyttö oli melko samankaltaista kaikissa ammattiryhmissä. Korkeimmassa ammattiasemassa olevat olivat kuitenkin useammin yksityisesti tuotetussa pitkäaikaishoidon yksikössä kuin muut ammattiryhmät vuosina 2001, 2003 ja 2007 mutta eivät vuonna 2010.

Tämä tutkimus osoittaa, että vanhoista vanhimmilla on sosioekonomiseen asemaan yhteydessä olevia terveyseroja. Terveyseroja havaittiin molemmilla sosioekonomisen aseman osoittimilla sekä miehillä että naisilla vaikka erojen voimakkuus vaihteli. Sosiaalisen eriarvoisuuden tuottamiin terveyseroihin vaikuttavat erilaiset elämäntilanteet läpi elämän. Hyvin vanhojen sosioekonomisten terveyserojen kaventamisen tulisi siksi kohdistua yleisesti sosiaalisen eriarvoisuuden vähentämiseen kaikenikäisillä. Koska sosioekonomisia terveyseroja on myös hyvin vanhoilla, sosiaali- ja terveyspalvelut tulisi järjestää siten, että kaikkien sosiaaliryhmien tarpeisiin pystytään vastaamaan.

Avainsanat: Ammattiasema, koulutus, toimintakyky, sairastavuus, itse arvioitu terveys, biomarkkerit, kuolleisuus, ympärivuorokautinen pitkäaikaishoito, vanhoista vanhimmat

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II Enroth L, Raitanen J, Hervonen A, Lehtimäki T, Jylhävä J, Hurme M, Jylhä M (2016): Cardiometabolic and inflammatory biomarkers as mediators between educational level and functioning at the age of 90 years. The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences 71 (3), 412-419. doi.org/10.1093/gerona/glv105

III Enroth L, Raitanen J, Hervonen A, Nosraty L, Jylhä M (2015): Is socioeconomic status a predictor of mortality in nonagenarians? The Vitality 90+ Study. Age and Ageing 44 (1), 123-129. doi.org/10.1093/ageing/afu092

IV Enroth L, Aaltonen M, Raitanen J, Nosraty L, Jylhä M (2017): Does use of long-term care differ between occupational classes among the oldest old? The Vitality 90+ Study. European Journal of Ageing. doi.10.1007/s10433-017-0445-0

Abbreviations

AME	Average Marginal Effect
BI	Barthel Index
BMI	Body mass index
CI	Confidence interval
CRP	C-reactive protein
CVD	Cardiovascular disease
HDL	High-density lipoprotein
HR	Hazard ratio
ICD-10	International Classification of Diseases, 10th revision
IL-6	Interleukin 6
IL1-Ra	Interleukin 1 receptor antagonist
LTC	Long-term care
OR	Odds ratio
RR	Rate ratio
SES	Socioeconomic status
SHR	Subhazard ratio
SRH	Self-rated health

1 Introduction

Socioeconomic health inequalities are described as systematic, socially produced and unfair differences in health between socioeconomic groups (Whitehead & Dahlgren, 2006). Social structures, such as occupational class and education, shape life chances. People with higher socioeconomic status (SES), high occupational class or high education have more material and social resources as well as healthier life styles than people with lower SES. High SES protects from negative health events and when health problems occur, there are more resources for recovery.

Causal mechanisms and social selection are the two most common pathways through which health inequalities are thought to develop. Causal mechanisms refer to a situation where SES predates selection to good or poor health. Social selection suggests that health status determines individuals' occupational class or the level of education. Both mechanisms are likely to contribute to observed health inequalities. When health inequalities are socially produced, they are considered unfair and modifiable. In Finland, health policy has aimed at decreasing health inequalities since the 1980s. However, this aim has not been reached and the health gap between SES groups has even increased.

Socioeconomic health inequalities are witnessed globally. In general, people with higher socioeconomic status are healthier and live longer than people with lower socioeconomic status (Commission on Social Determinants of Health, 2008). Health inequalities are not found only between those with the highest and the lowest SES but they appear gradually, and in developed countries are mostly relative in nature. Literature provides strong evidence of persisting health inequalities for the middle-aged and younger old people (40-75) (Stringhini et al., 2017) in developed countries however, for the oldest old research and knowledge about their health inequalities is scarce.

The number of very old people has increased rapidly in Finland (Official Statistics of Finland, 2016d) and in other developed countries. In very old age, health problems are complex and the need for care services increases. Thus, socioeconomic inequality in health in old age is of great importance. The extent of health inequalities is a major public health concern because inequalities cause suffering for individuals and costs for society.

This study aims to assess social inequality in health and long-term care use among the oldest old. The study used two different socioeconomic status indicators, occupational class and level of education. Socioeconomic inequalities in health and biomarkers, and the role of biomarkers in the association between socioeconomic status and functioning, were examined with survey data in the cross-sectional studies. Socioeconomic inequalities in mortality and in long-term care use were studied with follow-up analyses by combining survey data with national registers. The study employed several health indicators, functioning, morbidity, self-rated health, biomarkers, mortality and the use of long-term care to demonstrate the association between socioeconomic status and health in a population 90+ years in age.

2 Longevity and health

2.1 Life expectancy and the emergence of the oldest old

The population structure dynamics and population ageing are described with the concepts of demographic and epidemiologic transitions. Notestein (1945) presented the demographic transitions for three populations, which were at different stages of transition. In the now developed countries, a change in the population structure was seen as a transition from high birth and death rates to low birth and death rates. The concept of epidemiological transition termed by Omran (1971) described changes in the occurrence and patterns of diseases and causes of death in addition to changes in mortality and fertility. In developed countries, the process of transition started with the declines in infectious diseases and mortality, especially among children. These changes were driven by modernization and improvements in living conditions. Lower mortality was followed by lower fertility, which changed the population structure towards ageing populations (Notestein, 1945; Omran, 1971). In the second half of the 20th century, chronic diseases became the predominant causes of death and targets of the medical and public health interventions (Defo, 2014; Omran, 1971). Mortality from heart diseases declined enormously between 1970 and 2000, and at the same time, medical procedures (e.g. surgeries and drugs) developed, postponing mortality to older ages (Beltran-Sanchez, Preston, & Canudas-Romo, 2008; Crimmins & Beltrán-Sánchez, 2011; Crimmins, 2015). Life expectancy increased with an accelerated pace during this period in most developed countries (Wilmoth et al., 2000). Even though there is some evidence of a slower rate of increase in life expectancy e.g. in the US, most projections suggest that maximum life expectancy is not reached yet (Crimmins, 2015; Glei, Meslé, & Vallin, 2010).

In the literature, longevity often refers to life expectancy at a certain age (Lan Karen Cheung & Robine, 2007). It may also refer to people who live beyond the average life expectancy, to exceptionally old age or to the age at death (Ash et al., 2015; Christensen et al., 2008; Lan Karen Cheung & Robine, 2007). Life expectancy is a statistical measure which is defined as "the number of years that a person of a given age would live provided that the rate of mortality remains unchanged" by Statistics Finland (2016) and others with similar wording (Eurostat, 2014). The definition includes that life expectancy is dependent on the birth cohort. Thus, longevity may refer to different chronological age at different historical times. Life span is also used in the literature when describing the length of life. It may refer to the maximum life span in one context, e.g. in one country, or to the longest life span in human history. Wilmoth et al. (2000) have studied the development of maximum life span in Sweden. They found that the maximum life span rose from approximately 101 to 108 during 1861-1999. By far, the longest-lived human being was a French woman, Jeanne Calment, who passed away at the age of 122 (Robine & Allard, 1998).

There has been a tremendous increase in life expectancy in developed countries during the last century (Crimmins, 2015). In Finland, after the famine and epidemics in 1867-68, the average life expectancy started to increase, being 40.3 years for men and 43.2 years for women in 1900 (Human Mortality Database, 2015). With the exception of the Civil War in 1918 and World War II, development has been steadily reaching the average life expectancy at birth of 78.5 years for men and 84.1 years for women in 2015 (Official Statistics of Finland, 2016c). Life expectancy nearly doubled in a century, indicating that most people live to old age.

The longer time lived in old age has brought many definitions for that period of life. One division that is made describes old age with three categories: the young old (65-74), the old old (75-84) and the oldest old (85+) (Cannon, 2015). In addition, definitions for these categories vary between studies since the oldest old refers to 77+ in the SWEOLD study (Lennartsson et al., 2014), 80+ in another (Guilley et al., 2010; Martelin, Koskinen, & Valkonen, 1998), and 85+ in another (Pocock et al., 2016). In the current study, "oldest old" refers to the people who turn 90 years or more during the year of participation of the study.

In Finland, women who survived to age 90 in 1970 were expected to live three more years, which increased to 4.4 years in 2015. For men, life expectancy at the age of 90 increased from 2.9 to 3.8 years during the same period. (Human Mortality Database, 2015; Official Statistics of Finland (OSF), 2016a.) Of the 1920 birth cohort, 18.9% of women and 5.6% of men celebrated their 90th birthday (Human Mortality Database, 2015). The majority of the oldest old population are women since more women live up to 90 years old and they have longer life expectancy at the age of 90. In a comparative study between Denmark, Japan and US, the absolute difference in male-female ratio increased in all countries in age-specific death rates until the age of 90. However, in Denmark, a steady increase in differences continued while in the US the male-female ratio stabilized in the age group of 90-94 and in Japan differences started to decrease at the age of 100+. (Oksuzyan et al., 2010.)

The increase in the oldest part of the population, 90+, has been unprecedented. In Finland (Figure 1), since 1980s, when the number of people who were 90+ year old was 6107 (0.12% of the total population), the 90+ population increased to nearly six fold 34 303 (0.64% of the total population) in 2010 and is projected to increase to four fold again until 2040, 140 632 (2.4% of the total population). The development of the 90+ population in terms of number and the proportion of the total population was similar in the city of Tampere where the current study took place. (Official Statistics of Finland, 2015b; Official Statistics of Finland, 2016d.)

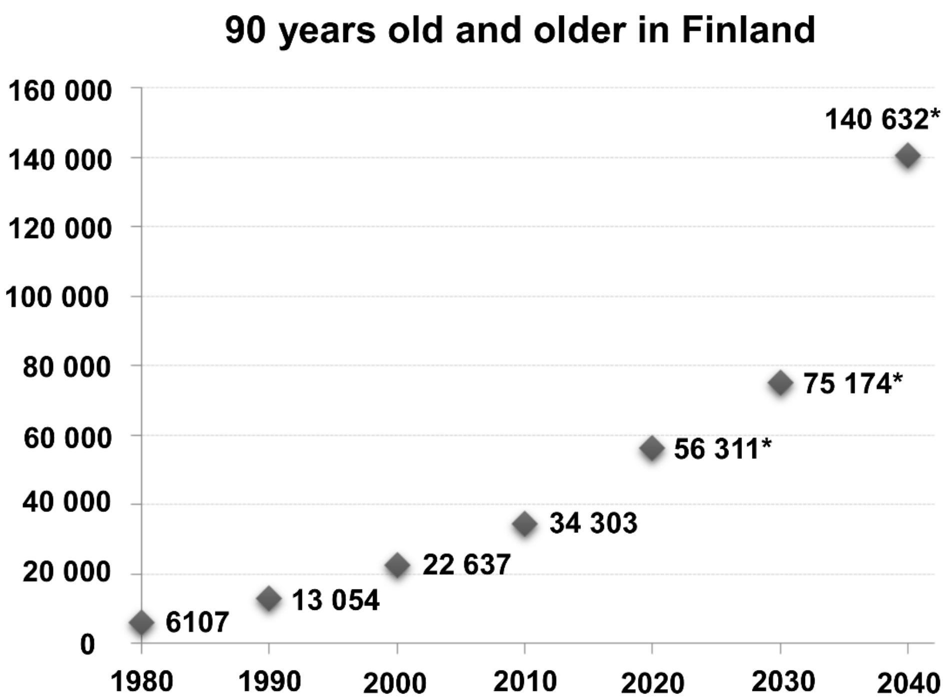

Figure 1. 90 years old and older in Finland 1980-2010 and projections* for 2020-2040 (Official Statistics of Finland, 2015b; Official Statistics of Finland, 2016d).

2.2 Basic concepts of health, functioning and long-term care

Multimorbidity

Several studies show that the number of diseases increases with ageing (Stenholm et al., 2015; van den Akker et al., 1998). Literature describes this co-occurrence of distinct diseases in various ways. Valderas and colleagues (2009) reviewed the terms used for having several diseases, finding that the concepts of comorbidity and multimorbidity are often used similarly when referring to the presence of more than one disease in an individual. However, they differentiate these concepts from each other. According to their, and for example van den Akker et al.'s (1998), definition, comorbidity refers to additional diseases in relation to one index disease, while multimorbidity refers to the coexistence of multiple diseases without expectations of the ordering of the diseases or their relation to each other. The current study prefers to use the concept of multimorbidity because the relationships between diseases are not taken into account and because literature increasingly distinguishes multimorbidity from comorbidity.

Biomarkers

The NIA working group* defined a biomarker as "a characteristic of objectively measured and evaluated as indicator of normal biological processes, pathogenic processes or pharmacologic responses to a therapeutic intervention" (Colburn et al., 2001). Sprott (2010) also differentiated biomarkers of ageing (normal biological processes) from the biomarkers of ageing-related diseases (pathogenic processes). However, how much of the observed changes in health are due to basic processes and how much are due to disease processes is under continuous discussion (Sprott, 2010). Butler et al. (2004) describe functional biomarkers of ageing as age-related biomarkers that predict physiological, cognitive and physical functioning better than chronological age.

Kirkwood and Austad (2000) state that "Ageing is not programmed but results largely from accumulation of somatic damage, owing to limited investments in maintenance and repair". They described ageing as a progressive loss of function in several organ systems. According to Sprott (2010), this definition implies that ageing is a result of more than one ongoing process, which is why a single biomarker that would be specific to the ageing process has not been found. Studies have, however,

*National Institutes of Health Director's Initiative on Biomarkers and Surrogate Endpoints attempted to find biomarkers that are associated with survival or age-related morbidity and functioning (Martin-Ruiz et al., 2011). The commonly used functional biomarkers of ageing include physiological tests (cholesterol level, high-density lipoprotein (HDL), glycosylated hemoglobin), anthropometric tests (body mass index (BMI) and body composition, bone density), inflammation (interleukin 6 (IL-6), C-reactive protein (CRP)), endocrine function, micronutrient status, and genomic and proteomic tests (Butler et al., 2004; Martin-Ruiz et al., 2011).

Fox and Growdon (2004) describe applicable biomarkers as laboratory substitutes that are clinically meaningful and are directly in the causal pathway linking biomarker to the outcome. Several applications where biomarkers can be used have been suggested: 1) indicators of disease trait (the risk of developing a disease, a risk marker), 2) indicators of disease state (subclinical or clinical), 3) disease rate (progression of disease or disease severity) or 4) prognostic biomarkers (predicting future disease course) (Colburn et al., 2001; Fox & Growdon, 2004). The development of morbidities and decline in functioning are considered as gradual processes. Thus, biomarkers that capture small physiological changes can improve risk assessment (Karlamangla, Gruenewald, & Seeman, 2012). Biomarkers may be defined in different ways depending on their use.

Functioning

Functioning has been explored with several measures and with different evaluation methods for older people. Guralnik and Lacroix (1992) state that the most common method for assessing functioning is self-report. Other methods such as direct observation or performance tests are also often used in clinical and research practices. The method of data collection is important in terms of interpreting the findings (Guralnik et al., 1992). Functioning was first assessed among people with severe diseases and particularly in institutional settings (Guralnik, Fried, & Salive, 1996). One frequently used concept of functioning, Activities of Daily Living (ADL), was developed to measure functioning among the chronically ill and older people (Katz et al., 1963). The original index included six activities, namely, bathing, dressing, toileting, transfer, continence and feeding. The information about participants' ability to perform these activities was utilized in assessments of the need for care and in the evaluations of the effectiveness of the treatment. The concept was developed further in 1970 when the index of independence in ADL was created (Katz et al., 1970). In this index, the original three alternative answers were distinguished into two, one reflecting independence and the other dependence (need for help) in performing the activity. The index of independence in ADL summarizes six activities in which people are independent or dependent, and operationalizes the degree of independence in functioning. Need for help in ADLs is generally based on self-reports or evaluations given by a nurse or relatives. The concept of ADL and its variations are widely used concepts in studies that are interested in examining independence in functioning (Jagger et al., 2001).

Another, commonly used summary measure of functioning is the Barthel Index (BI). The ten-item index was originally developed for the evaluation of improvement in rehabilitation (Mahoney & Barthel, 1965). Nurses commonly carry out this evaluation. The individual items in the index are feeding, transfers from bed to chair and back, grooming, toilet use, bathing, mobility, stair climbing, dressing, controlling the bowel and controlling the bladder. The Barthel Index forms a score where the minimum is 0 and the maximum is 100. The score indicates the degree of independence in functioning. The higher the score the higher the degree of independence (Appendix table 1).

Self-rated health

Self-rated health (SRH), also called self-assessed health, subjective health, and perceived health among others, is a commonly used measure of general health status (Idler & Benyamini, 1997). One advantage of this measure is that the information on SRH is easy to collect. The most important reason for its wide use is, however, the consistent finding that it predicts well-being, functioning and mortality across the countries in all age groups, also in old age (Idler & Benyamini, 1997; Jylhä, 2009; Nybo et al., 2003).

Perception of one's own health is very much related to the understanding of what health encompasses and with whom it is compared; whether the comparison is done with other people or with one's own previous health status. Therefore, SRH may be reflected upon differently depending on age, culture or time. (Jylhä, 2009). SRH is often assessed with questions such as how would you evaluate your present health? (Huisman, Kunst, & Mackenbach, 2003; Jylhä, Enroth, & Luukkaala, 2013) or how does your health compare with your age peers? (Deeg & Kriegsman, 2003). The beauty of the measure is that it captures not only observable health related information such as a decline in functioning but also individual sensations of pain and fatigue. SRH is usually analyzed only for those study participants who are able to rate their health by themselves because of the subjective nature of this measure. (Knäuper & Turner, 2003).

Ferraro (1980) suggests that when very old people have similar health status to younger old people they tend to rate their health more positively. The reasons for this may be related to the lowered expectations of health in old age and to the very old adapting to declining health by adjusting the goals suitable for the present situation (Tornstam, 1975). Studies also suggest that older people maintain their positive view of health by comparing their health to their age peers (Cheng, Fung, & Chan, 2007; Tornstam, 1975). The social comparison strategy could explain why self-rated health is evaluated positively even when morbidity increases (Festinger, 1954). It has been suggested that the discrepancy between SRH and objective health ratings become larger in very old age because of the adaptation strategies. Galenkamp et al. (2013) studied longitudinal changes in SRH and its sensitivity to reflect changes in chronic diseases and functioning among nonagenarians. They found that SRH declined in the nine years of follow-up, and that SRH was modified by the increase in number of chronic conditions and decline in functioning. Thus, the study suggested that increasing morbidity was reflected in the oldest olds' evaluation of SRH.

Long-term care

In Finland, long-term care (LTC) refers to round-the-clock care that is offered in three kinds of facilities, residential homes, inpatient wards in health centers and hospitals, and in service homes with 24-hour assistance. The two facilities mentioned first are categorized as institutional LTC and service homes with 24-hour assistance are categorized as community-based living. (Johansson, 2010). Even though LTC facilities are categorized differently, they all provide formal round-the-clock LTC. Another less intensive form of care, home care, is not regarded as LTC in the current study.

The use of round-the-clock LTC is a cultural and socio-political phenomenon and should be interpreted in the context of society. Finland adheres to the Nordic welfare state tradition where LTC for older adults is provided according to the universal principle; it is available for all citizens regardless of their financial situation (Johansson, 2010). Generally, people access all LTC facilities through the functional capacity assessment carried out by the municipal authorities since privately paid and acquired LTC use is very rare in Finland. There were 311 municipalities in 2017 in Finland, all of which had the responsibility of organizing LTC provision for their residents (Official Statistics of Finland, 2017).

Municipalities provide LTC services themselves or organize them through private LTC providers, which can be for-profit or not-for-profit service providers (Johansson, 2010). When the municipality admits people to LTC through the functional capacity assessment, the costs for the individual are dependent on disposable income, but not on whether the service provider is a public or private instance. The mechanisms of assessment of functional capacity and the heavily subsidized costs of LTC are expected to guarantee that LTC use is based on the need for care rather than the ability to pay for it.

2.3 Health, functioning and long-term care among the oldest old

In general, the number of chronic diseases increases with ageing and this difference is evident even between the age groups of 80-89 and 90+ (Salminen et al., 2012; Stenholm et al., 2015). In the Vitality 90+ Study in Finland, drawn from medical records, the highest prevalence for chronic diseases, measured as a lifetime accumulation, were cardiovascular diseases 78%, (coronary heart disease 45%, chronic heart failure 37%, hypertension 36%, stroke 17%) and dementias 26.7% (memory problems from forgetfulness to dementia in 35.9%). The prevalence of musculoskeletal diseases and fractures was also high (osteoarthritis 23%, hip fracture 17%) as was the prevalence of cancers 18%. (Goebeler, Jylhä, & Hervonen, 2003.) The Newcastle 85+ Study found a high prevalence for the same diseases in the UK despite slight differences in numbers. The disease prevalence, drawn from the general practice records, showed high percentages of cardiovascular diseases (ischaemic heart disease 31%, heart failure 11%, cerebrovascular disease 20%, hypertension 58%). The prevalence of moderate to severe cognitive impairment was 12%, however, researchers suggest some underestimation in the records. The prevalence for osteoarthritis was 52% and for cancers 15% (non-melanoma skin cancer excluded). (Collerton et al., 2009.) Since the number of diseases increases in advanced age, multimorbidity increases (Marengoni et al., 2011).

Besides doctor-diagnosed diseases, subclinical pathologies become prevalent in older people. One example of age-associated changes is chronic low-grade inflammation. Whether it is ageing or morbidity-driven dysfunction in the immune system, studies report a 2-4 fold increase in circulating cytokines (IL-6 and TNFα), acute phase proteins (CRP) and in anti-inflammatory mediators (IL-1Ra) in older populations. (Krabbe, Pedersen, & Bruunsgaard, 2004.) Other generally known biological age-related changes include declines in hormone levels such as growth hormone and dehydroepiandrosterone (DHEA) (Baulieu, 1996; Rudman et al., 1981). There is also evidence of changes in body composition, increase in body fat and decrease in lean mass (Schutz, Kyle, & Pichard, 2002).

The most common causes of death in 90+ population in Finland, as in many other developed countries, are cardiovascular diseases, dementias and cancer (Official Statistics of Finland, 2015a). However, in part, different diseases such as arthritis, pulmonary diseases and depressive symptoms are associated with limitations in functioning (Stenholm et al., 2015).

Studies across the world report increasing prevalence of ADL limitations with ageing (Chatterji et al., 2015). People in their 90s have more limitations in ADL functioning than people in their 80s. This difference is also found among people who do not suffer from chronic diseases. (Stenholm et al., 2015.) Angleman and colleagues (2015) reported a 3-fold increase in the prevalence of ADL limitations for nonagenarians compared with 81-84 year-olds. A Swedish study showed that the prevalence of ADL limitations in Katz ADL index (bathing, dressing, going to the toilet, transfer, continence and feeding) varied between 18 and 36% and 7 and 20% among women and men aged 90+ respectively. The prevalence was highest in bathing and lowest in continence for both genders. Overall, the percentage of those who needed help in 0-1 of the activities was 70% among women and 86% among men. (von Strauss et al., 2003.) A Danish study showed a similar summary prevalence of needing help in 0-1 activities of daily living according to the Katz index, however, this index did not include continence. The researchers reported that among the 94-95 years old, 40% of men and 59% of women needed help in 0-1 activities. (Christensen et al., 2013.) A study from the US assessed ADL functioning for 85+ years old. The study showed that 48% of men and 57% of women reported limitations in ADL. (Minkler, Fuller-Thomson, & Guralnik, 2006.)

There are some time trends in the development of ADL functioning among the oldest old. A Swedish study showed a slight decrease in the prevalence of ADL limitations for nonagenarians during 1991-2010 but no change in incident ADL limitations (Angleman et al., 2015). A Finnish study also showed slight improvement in ADL functioning but no change in mobility activities for nonagenarians during 2001-2010 (Jylhä et al., 2013). A Danish study that compared the health of nonagenarians in two birth cohorts, 1905 and 1915, found that ADL disability was lower for the later born cohort even though they were two years older at the time of the health evaluation than the participants in 1905 cohort were. There was no improvement in physical performance, which is why researchers suggest that better ADL is a cause of improved cognitive functioning, living conditions and better aids to support independence. (Christensen et al., 2013.) Little change is seen in ADL functioning for the oldest old in Nordic countries despite the rapid increase in life expectancy.

Huisman et al. (2003) demonstrated the increase in the prevalence of poor SRH in the age groups from 60-69 and 70-79 to 80+ years of age. In this study that included 11 European countries, researchers found that 73% of men and 75% of women reported less than good SRH among the 80+ age group. The level of SRH among the oldest old is described also in other studies. Nybo et al. (2001) studied 92-93 years old people in Denmark, and found that 45% of women and 43% of men reported less than good SRH. Similarly to the Danish study, a study including 60-85 year-olds in the Netherlands found lower levels of less than good SRH than what was found in the multinational study. The study showed that only 34-39% of the participants reported less than good SRH during 1992-2009. (Galenkamp et al., 2013.) The Vitality 90+ Study, where SRH was studied from the opposite view, reported that the level of good self-rated health varied between 25% and 35% among the oldest old during 2001-2010 (Jylhä et al., 2013).

There is a well-known gender difference in the number of diseases and in ADL functioning in the 90+ population. Shown by the Vitality 90+ Study, women have more diseases and more limitations in ADL and mobility than men do (Jylhä et al., 2013; Tiainen et al., 2015). Similarly, in the UK, 85+ years old women have more diseases and higher disability than men (Collerton et al., 2009), and ADL limitations are more prevalent in the 90+ population for women than for men in Denmark, US, and Japan (Nybo et al., 2001; Oksuzyan et al., 2010). It is also shown that women suffer from multimorbidity more often than men (Marengoni et al., 2011). Gender differences are pronounced in physical performance in the very old age, too. For example, men perform better in handgrip strength (Nybo et al., 2001; Oksuzyan et al., 2010), and have higher walking speed than women do (Nybo et al., 2001). Despite the gender differences in morbidity and functioning, some studies suggest that men and women report rather similar levels of good SRH. This could mean that women tolerate more health problems for good SRH than men do. (Jylhä et al., 2013; Nybo et al., 2001; Oksuzyan et al., 2010.)

The health of the oldest old is not simply a question of personal well-being, it has consequences at the societal level, too. At the end of life, most, but not all, people need to be cared for, and the time of dependence on other people becomes important for example from the point of view of long-term care organization and economics. Long-term care use increases with ageing because of an age-related decline in functioning (Luppa et al., 2010; Martikainen et al., 2012). In Finland as in other countries, the use of LTC clearly increases after the age of 85. In total, 4.9% and 18.7% of the 75-84 years old and 85+ years old respectively were LTC users at the end of the year 2014. The average age for people in round-the-clock LTC was 83.6. (Väyrynen & Kuronen, 2015.) As described above, health problems increase with ageing. Declines in physical and cognitive functioning are strong predictors for entering LTC (Gaugler et al., 2007; Yang et al., 2013). Other examples of well-known LTC use predictors are living arrangements and availability of informal care (Breeze, Sloggett, & Fletcher, 1999; Grundy & Jitlal, 2007; Nihtilä & Martikainen, 2008; Pot et al., 2009). In general, a higher proportion of women than men use LTC. The gender difference found in LTC use is suggested to be a result of women's higher morbidity and widowhood, and its consequences such as living alone. (Grundy & Jitlal, 2007; Luppa et al., 2009; Martikainen et al., 2009.) Tiainen and colleagues (2013) showed that also among the 90+ years old, women live longer than men with a similar level of ADL disabilities.

The increase in life expectancy in old age has raised questions of whether the years gained have increased or decreased the years lived with disabilities and poor health. The most well-known hypothesis, introduced by Fries (1980) is a theory of the compression of morbidity. Fries presented a positive scenario where the occurrence of morbidity is postponed more than life expectancy increases, thus, the time lived with morbidity would be shorter. Later on, Fries (2003) introduced other alternative scenarios for the health development in the context of increasing life expectancy. First, if the length of life increases and the onset of the occurrence of morbidity remains the same, time lived with morbidity would increase. Second, if both time of death and the onset of morbidity are postponed at a similar rate, the time lived with morbidity would remain the same. Other researchers have also theorized the occurrence of morbidity and the length of life. Gruenberg (1977) presented the thought of the failure of success. He proposed that while mortality is postponed to older ages, the onset of chronic diseases is not. The reasons for the decline in mortality were suggested as medical innovations and better management of diseases that used to be lethal. Thus, people who earlier died from medical conditions were kept alive and consequently, people live longer with diseases and disability. Manton (1982) introduced the concept of dynamic equilibrium, where similar to Gruenberg (1977), the time lived with diseases increases as mortality declines. However, in Manton's concept, the decline in mortality was due to the slower rate of progression of chronic disease processes.

Thus far, there have been some attempts to shed light into these multidimensional relations between trends in morbidity and mortality. The literature shows that life expectancy is increasing (Glei et al., 2010; Wilmoth et al., 2000). However, findings of the trends in morbidity are more complex since the result is dependent e.g. on the morbidity indicator and the age group studied. A review article that included results from the US and Europe, provided evidence of increasing disease morbidity but a decrease in ADL disability (Chatterji et al., 2015). Another study showed also improvement in ADLs among the very old population, however, the researchers suggest that the driving force for the improved functioning was improved cognitive functioning and living conditions that support mobility and independence (Christensen et al., 2013). Hossin et al. (2017) tested the dynamic equilibrium hypothesis among older people in Sweden. They found an increase in chronic conditions and a decrease in disabilities between 1992 and 2011. In addition, the researchers showed that CVD's and other conditions' association with disability weakened over time. Thus, the study supported the original hypothesis of longer lives with higher prevalence of chronic conditions but less severe conditions and less disability. Crimmins and Beltrán-Sánchez (2011) studied the compression of morbidity hypothesis in the US population. They found that the prevalence of diseases (heart disease, stroke, cancer, and diabetes) increased and functioning declined during 1998-2008. In general, this result was the same for all age groups and for both genders. Thus, the study suggests that the time lived with diseases and loss of functioning increased during the study period. Glei et al. (2010) elaborated on the reasons for declining mortality. They suggested that higher age at death may be related to people not getting diseases or that they get them later, slower progression of diseases, or better management of very sick people. According to the US study, people fall ill and much effort is put on the consequences of diseases. As a result, diseases may be less lethal, less disabling and perhaps less progressive. One achievement mentioned in the study is that survival from heart diseases and cancer has improved. Researchers point out, however, that if mortality declines because people survive with morbidity and not because of the decline in the prevalence of morbidity, morbidity will expand. (Crimmins & Beltrán-Sánchez, 2011.)

3 Socioeconomic status and health inequalities

3.1 Basic concepts

Social stratification

It has been suggested that throughout the human history social structures have differentiated groups from each other based on the valued characteristics in society (Lynch & Kaplan, 2000). Measures of socioeconomic circumstances aim at indicating the relative positions or structural locations within the society (Liberatos, Link, & Kelsey, 1988; Lynch & Kaplan, 2000). Theories of social stratification stems from sociological research, especially from the works of Karl Marx and Max Weber (Liberatos et al., 1988). One attempt to describe social stratification is based on the view of Lynch and Kaplan (2000), which owes elements of the aforementioned works: "… effective control of material, economic, social, political, symbolic and cultural resources is differentially distributed within society, so those who are exploited, dominated, or excluded have less resources and less control over them". In their generalization of the complex framework, the relationship between socioeconomic circumstances and health operates through health damaging exposures and protective resources. In health inequality research, socioeconomic status (SES) is a frequently used measure of social stratification (Adler & Newman, 2002; Huisman et al., 2004; Lahelma et al., 2004). In addition, several other concepts have been used to refer to social stratification, such as social class, social status, socioeconomic position and socioeconomic group (Geyer et al., 2006). According to Lynch and Kaplan (2000), the variety of concepts is likely to reflect different historical, conceptual and disciplinary roots.

Operationalization of socioeconomic status

A wide range of studies have used the level of education (Nybo et al., 2003; Rostad, Schei, & Lund Nilsen, 2009), occupational class (Arber & Cooper, 1999; Marmot et al., 1997; Martelin et al., 1998) and income (Hoffmann, 2011b; Huisman et al., 2003) as SES indicators. As discussed for example by Lahelma et al. (2004) and Liberatos et al. (1988) in the current study, the indicators of SES are thought to reflect society's hierarchical ranking. The often used SES indicators, education, occupation and income, are strongly interrelated but are also shown to have their own specific mechanisms in how they affect health. (Geyer et al., 2006; Lahelma et al., 2004.)

Socioeconomic status is most commonly operationalized by education, occupation or income, however other measures, such as area-based and composite measures, are also applied (Liberatos et al., 1988). The SES indicators are thought to represent partly different conceptual backgrounds. Grundy and Holt (2001) list three main mechanisms that are expressed in SES indicators: behavioral and lifestyle factors, psychosocial factors, and materialistic factors. Education is gained early in life and because of that, family resources may have an important role in determining it (Galobardes et al., 2006). Education is related to access to information and cognitive skills, which in turn, affect behavior and lifestyle such as physical activity, diet, smoking and alcohol consumption (Grundy & Holt, 2001; Mirowsky & Ross, 2005). Education also influences future employment and income (Galobardes et al., 2006; Mirowsky & Ross, 2005). Occupational class is suggested to be related to psychosocial factors. The working environment may reflect mental and physical exposures to stress including low status relative to others, low autonomy, toxic environment or physical strain. (Galobardes et al., 2006.) Income is most directly related to materialistic mechanisms. It affects housing, nutrition, the living environment, access to health services, and for example possibilities for leisure activities (Galobardes et al., 2006; Grundy & Holt, 2001).

During recent decades, research on SES related health inequalities has increasingly focused on older people. However, SES indicators were originally developed to describe the socioeconomic situation of the working age population. This has raised questions about the suitability of SES indicators for older people who completed their education several decades ago, who left the labor force years ago, and whose income is mainly based on pensions and benefits. Education is widely used as a SES indicator for older people (Huisman et al., 2004; Schöllgen, Huxhold, & Tesch-Römer, 2010) even though among the current oldest old population most have a low education level. The skewed educational distribution may complicate the interpretation of inequalities (Grundy & Holt, 2001). There are various ways in which previous occupation is used as a SES indicator for the retired. It has been used in studies based on the longest held occupation, the last position before retirement, position with the highest status or as an average of all held jobs (Liberatos 1988). Occupational class is a frequently used SES indicator for older people, also for women (Arber & Cooper, 1999; Martelin et al., 1998; Rostad, Deeg, & Schei, 2009).

Income is also a common SES indicator among older people (Hoffmann, 2011a). However, researchers suggest that income may not give a full view of the standard of living since it changes with age. Income follows a curvilinear trajectory being highest in the middle age and lowest in childhood and in old age (Galobardes et al., 2006). For older people, wealth is suggested to reflect the standard of living better than income. For example, home ownership may give a hint of the lifetime accumulation of resources. However, home-related SES indicators would exclude institutionalized individuals, which again would affect the SES-health association. (Grundy & Holt, 2001.)

One important dimension in the occupation-based indicators, especially for older generations, is the classification of women. Traditionally, women were classified into an occupational class based on their husband or father's SES. This was justified with women's lower labor force participation, common part-time employments and lower education levels. (Liberatos et al., 1988.) When women started to participate increasingly in the labor force, the ways of classifying individual and household occupation classes diversified (Krieger, Chen, & Selby, 1999). Currently, women also from the older generation are classified into SES based on their own occupations (Grundy & Holt, 2001). There is, however, an ongoing discussion of whether the occupational categories, rooted from the men's work arenas, are applicable to women (Krieger et al., 1999). In a Finnish context, Martikainen (1995) assessed occupational class differences in mortality by using two different classifications for women, one based on their own and the other based on the spouse's occupation. He found that differences in mortality were notably similar regardless of whether the woman's own occupational class or that of the spouse was applied (Martikainen, 1995). The individual occupational classification for those women who were not in the labor force outside the home may be problematic. Some studies (e.g. Rostad et al., 2009) have analyzed this group separately even though it is not clear what kind of activities are undertaken by this group. In Finland, for example, a housewife, a homemaker or a person not working outside the household may refer to the lady of the house or to a woman participating in farming and housework.

There is no gold standard for choosing a SES indicator for the evaluation of health inequalities among older people. Only a few studies have attempted to identify suitable or the best SES indicators. In a nationally representative study of people between 55-75 years old in the UK Grundy and Holt (2001) assessed the sensitivity of seven (occupational class, education, income, household resources, deprivation, housing tenure, and car access) SES indicators to identify graded differences in health. They evaluated the indicators based on their linkage to theory, ease of collection, sensitivity to identify gradients and disadvantage groups and the possibility to avoid social selection where health affects SES. As a result, all SES indicators suggested that self-rated health was better for the better off. Researchers, however, pointed out that none of the indicators alone could meet the aforementioned criteria. Based on the statistics (the fit of the models), researchers came up with the most promising combination of SES indicators, which were education or occupational class paired with a deprivation indicator. Other suggestions for the best SES indicator have been put forward based on other criteria. For example, Knesebeck and colleagues (2003) suggested that income is the best indicator for health inequalities among older people since it showed the strongest effect after adjustment for other SES indicators (occupational class, education, assets and home ownership).

Health inequality, health inequity, health difference and social inequality in health

Studies that aim to show the average level of health in one socioeconomic group in comparison to another use concepts such as health inequality, health inequity, health difference and social inequality in health. These concepts may refer to the same issue but they have distinct underlying meaning, which is why the basis for using health inequality in the current study is clarified here. Whitehead (1992) conceptualizes equity in health in the discussion paper provided by the World Health Organizations (WHO) Regional Office for Europe. The principles of when health difference can be considered as health inequity were written in the context of Health for All policy in 1984. Whitehead does not differentiate health inequality from health inequity but describes both with the term inequity. In the discussion paper, health inequity refers to the health differences that are unnecessary and avoidable as well as unfair or unjust (Whitehead, 1992). Based on this definition, both health inequity and health inequality embrace the elements of fairness (Whitehead, 1992). However, sometimes the word inequality is used in a descriptive manner without the assumptions of the fairness of the inequalities (Kunst & Mackenbach, 1995). Thus, in this kind of case, inequality would actually refer to the more neutral concept of health difference.

Braveman and Gruskin (2003) differentiate health inequality and health inequity from each other. According to them, "health equity has focus on distribution of resources and other processes that drive a particular kind of health inequality". They point out that not all health differences arise from circumstances considered unjust. For them, health inequity refers to the systematic inequality in health or in the social determinants of health between more and less advantaged social groups. Braveman and Gruskin (2003) as well as Whitehead (1992) brought up the moral and ethical dimensions related to health inequity. According to Whitehead (1992), there are equitable and inequitable health differences. If differences in health originate from natural variation (e.g. genes), are dependent on age, or relate to freely chosen high-risk sports, in general they are considered equitable. However, if the causes for health differences are based on the exposure to stressful living and working environment or to inadequate access to health care, the differences would be considered inequities. Another example of the inequitable cause of health differences listed in the WHO report is health behavior in cases where the degree of choice is severely restricted. (Whitehead, 1992). Braveman and Gruskin (2003) differentiated inequalities from inequities in a similar manner, based on the causes behind the health differences. In a later WHO report, Whitehead and Dahlgren (2006), clarify that even though WHO reports prefer to use the term health inequity, the term inequality is used with the same connotation referring to unjust health differences in the public health context in Britain and in other European countries (Whitehead & Dahlgren, 2006).

The concept of inequity is considered normative (Braveman & Gruskin, 2003; Whitehead, 1992) that is, value based. Inequality may however, refer to health differences that exist due to natural causes such as gender or age differences. The term inequality is also used when describing inequity in health, which then implies that health differences exist due to unfair processes in the distribution of resources (Braveman & Gruskin, 2003). Braveman and Gruskin (2003) continue by adding another term, social inequality in health, to the discussion. They consider that social inequality in health is a more succinct way of describing inequalities in health between more and less advantaged social groups than health inequalities are, as the latter can refer to other health differences, too.

Based on these definitions, the decision of whether health differences are inequities or inequalities needs the assessment of causes of differences, and the causes need to be judged unfair (Whitehead, 1992). A comprehensive analysis of whether the causes of health differences are fair or not is not at the core of this study. However, the concept of health inequality is used here in order to refer to health differences as systematic, originating from socially produced unfair differences in health (Adler & Ostrove, 1999; Berkman & Glass, 2000; Marmot, 1999).

The Black Report (Townsend & Davidson, 1982), a report of the British working group (more about Black Report 3.2), elaborated the existence and explanations for health inequalities. The working group introduced three approaches known as 1) artefact, 2) natural or social selection, and 3) causal pathways including materialist or structural, and cultural or behavior explanations (Townsend & Davidson, 1982). Macintyre (1997) further elaborated on these explanations by providing "hard" and "soft" versions of them. According to her interpretation, a hard version of the explanations can explain away health inequalities and thus, different explanations were seen as competing with each other. A soft version of the explanations acknowledges that all of them contribute in generating and maintaining health inequalities.

The artefactual explanation as referred to in the Black Report, which concerns measurement errors and problems in identifying socioeconomic groups that falsely create or diminish health inequalities, is thought to have a minor effect in explaining health inequalities (Smith, Bartley, & Blane, 1990). Thus, the main debate concerns the importance and magnitude of selection and causal mechanisms. Selection is described with social selection, reverse causation or for example with health-related social mobility. In general, selection refers to the situation where poor health may lead to reduced SES and good health to higher SES. (Blane, Smith, & Bartley, 1993; Goldman, 2001.) Two kinds of mechanisms have been suggested for selection: direct and indirect. Examples of direct selection would be situations were poor health or disabilities limit educational attendance (children) or employment (adults), both of which are known to have longstanding effects on income (Blane et al., 1993; Goldman, 2001; Macintyre, 1997). In indirect selection, characteristics that are related to both SES and health, such as height or coping abilities, affect a person's SES (Goldman, 2001; Peck & Vagero, 1989). In general, the role of selection is acknowledged but its contribution to overall association between SES and health is thought to be smaller than in causal mechanisms (Bartley & Plewis, 1997; Blane et al., 1993).

Causal mechanisms refer to a situation where SES has an influence on health. Marmot (1999) and many other researchers suggest that health inequalities originate from a complex set of causal mechanisms. The causality of social circumstances, predating the change in health, has been proven in several longitudinal studies (Goldman, 2001; Macintyre, 1997). A wide range of studies suggest that the most common causal pathways from low socioeconomic status to poor health works through unequal distribution of material and social resources as well as differences in health-related behavior (Marmot, 1999).

Figure 2 presents the main causal pathways of how SES is suggested to have an influence on health. *Social structure*, represented with education, occupational class or income, describes an individual's position and thus, the material circumstances and the social environment (Lynch & Kaplan, 2000). *Material circumstances* determine the assets, standard of living, nutrition and leisure activities. Differences in the material circumstances are suggested to be mainly due to relative deprivation, at least in developed countries (Marmot, 1999). However, the relative advantage is seen in several areas of life, such as in the possibility to use private health care and in opportunities for participating in society. Material circumstances are also seen as working conditions. People have exposure to different health risks, toxic working environments, and physical strain. (Galobardes et al., 2006.) Based on Berkman and Glass (2000), the *social environment* refers e.g. to the prevailing norms and values, and thus to shared culture. It can also refer to the social network, which is suggested as an important factor in the health-related causal chain. The link from the social networks to health is proposed to operate through psychosocial factors such as social support, social influence, social engagement, and access to resources. (Berkman & Glass, 2000.) The health care service itself is suggested to have an impact on health inequalities, however, in this model it is regarded as a possible mediator of health inequalities.

The *psychosocial factors* influence the *health-related behavior* and the *psychological factors*. For example, social support may affect care seeking behavior or enable access to health care, and social engagement is likely to reinforce self-esteem and coping. (Berkman & Glass, 2000.) Health behaviors such as smoking, excessive alcohol consumption, unhealthy diet and low physical activity are known risk factors for several morbidities. They are considered as a major pathway to poorer health in lower socioeconomic statuses. (Lynch, Kaplan, & Salonen, 1997.) The *work environment* has consequences on health also through psychosocial processes. Jobs vary according to the degree of control over work as well as in terms of security and stability (Macintyre, 1997; Marmot, 1999). Health-related behavior and psychological factors are interrelated and their effects on morbidity are thought to operate through *physiological factors* (Brunner & Marmot, 2006).

Stress is considered one of the pathways of how SES "gets under the skin" (Kelly, Hertzman, & Daniels, 1997; Schneiderman, Ironson, & Siegel, 2005). Brunner and Marmot (2006) describe the physiological stress response with the term

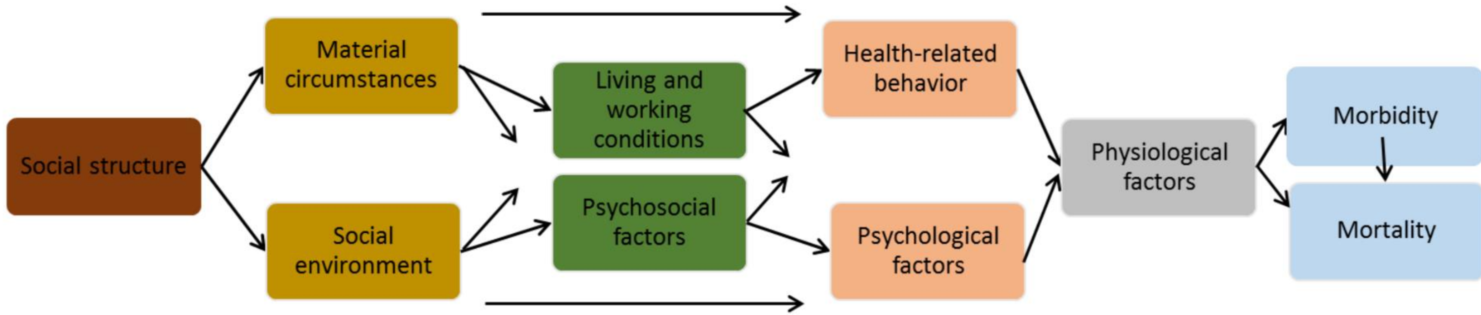

Figure 2. Schematic presentation of the causal pathways, based on Berkman & Glass (2000), Brunner & Marmot (2006), and Marmot (1999).

fight-or-flight response. It refers to the automatic response to physical, psychological, or biological threats. The stress response, activation of the nervous system and increased secretion of adrenalin and cortisol, cause e.g. accelerated heart rate and increase in blood glucose levels, which are beneficial traits in the face of a threat. However, as a long-standing condition, the stress response may lead to deterioration of health. McEwen and Seeman (1999) proposed that perceived stress starts physiological and behavioral responses that lead to allostasis (ability to achieve stability through change) and adaptation. The allostatic load refers to a situation where adaptation to cumulative or long-standing external exposure to psychosocial stress changes the optimal physiological operating ranges (neuroendocrine, immunological, and sympathetic nervous system). Elevated levels of the stress mediators and strain on organs and tissues may lead to chronic diseases such as coronary heart disease, diabetes, depression and musculoskeletal disorders.

As described, SES affects exposure to stressful life events but also affects coping mechanisms to overcome such events (Lynch & Kaplan, 2000). The allostatic load is for example, considered an appropriate measure for examining the health effects of SES because "exposure" to socioeconomic status is long-standing and creates strain on several biological regulatory systems through multidimensional causal pathways (Goldman, 2001; McEwen & Seeman, 1999).

3.2 Current understanding of socioeconomic health inequalities

Socioeconomic health inequalities are described as systematic, socially produced and unfair differences in health between socioeconomic groups (Whitehead & Dahlgren, 2006). Socioeconomic circumstances are strong determinants of health. They are reproduced in the conditions in which people are born, grow, live, work, and age. (Marmot et al., 2010.) The social patterning of health is a global phenomenon (Whitehead & Dahlgren, 2006) and in general, people with a high SES are healthier and live longer than people with a low SES no matter the indicator of SES or health (Commission on Social Determinants of Health, 2008). However, the magnitude of inequalities and underlying mechanisms vary (Mackenbach et al., 2008). The extent of health inequalities is a major public health concern because inequalities cause suffering for individuals and costs for the society. According to Marmot and colleagues (2010), premature death and ill health have several consequences for the economy. Individuals' reduced productivity is seen, for example, in a decrease in tax revenue, higher welfare payments and increased treatment costs.

Observations of health inequalities date back to ancient Greece, Egypt and China (Krieger, Williams, & Moss, 1997). However, systematic, documented studies on socioeconomic health inequalities originate from the 19th century (Liberatos et al., 1988; Macintyre, 1997). In Britain, already in the 19th century, a link between the labor market position and mortality was found (Macintyre, 1997) and the association between economic deprivation and poor health was shown in the US 100 years ago (Krieger et al., 1997). The link between poverty and poor health was reasoned about with two diverging explanations. One suggested that inherited poor health and behavioral factors caused health differences, and another blamed poor living and working conditions. (Macintyre, 1997.) Despite the growing body of research in the mid-20th century, the basis for the contemporary research tradition arises from the report of the British Working Group known as the Black Report (Townsend & Davidson, 1982).

The Black report continued the long tradition of studies on occupational class differences in mortality in Great Britain, and the discussion about the reasons for the differences (Macintyre, 1997). The report attempted to review knowledge about social class inequalities in health and to discuss the possible explanations and policy implications (Townsend & Davidson, 1982). The report revealed a wide range of mortality inequalities that were present among men and women in all age groups. In most causes of death, mortality was gradually higher the lower the social class. This was seen especially in respiratory, infective and parasitic diseases, which owe the fundamental causes in the socioeconomic environment. The literature on morbidity was not as comprehensive but it implied the same. Self-reported morbidity, especially of chronic diseases, were more common among low social classes than among the high social classes. Time trends in mortality inequalities showed the persistence of inequalities during 1949-1972. The Black report raised awareness of the health and mortality inequalities but also shed light on the theoretical approaches of how to explain social inequalities in health. (Townsend & Davidson, 1982.)

After the release of the Black report, research on socioeconomic inequalities in health and mortality expanded. Hundreds of studies showed the persistence of inequalities in developed countries, also in those countries representing the generous welfare states. (Adler & Ostrove, 1999; Mackenbach, 2012.) The Whitehall studies were the landmarks of establishing the social gradient in health and mortality (Marmot, Shipley, & Rose, 1984; Marmot et al., 1978; Marmot et al., 1991). The Whitehall studies were initiated in Britain in 1967, where more than 17 000 civil servant men aged 40-64 in London were screened. In 1978, Marmot and colleagues (1978) showed that among the office workers who worked in the same region, those holding the lowest employment grade in status (messengers) had 3.6 times the coronary heart disease mortality compared with those with administrative statuses during the 7.5 years of follow-up. The differences in mortality were not only between these extreme ends but followed a step-wise relation between the grade of employment and mortality. This meant that mortality differences were not due to one group of people with poor health but mortality was gradually higher the lower the employment grade. This is referred to as the social gradient in health. In 1984, similar gradients were found in mortality from coronary heart disease, respiratory diseases, and from all causes combined in ten years of follow-up (Marmot et al., 1984). The Whitehall Study II was launched in 1985 to study the social gradient in morbidity and to enlarge the study to women. Over 10 000 civil servants aged between 35-55 were included in this study that revealed the existence of the social gradient in several morbidities, such as in angina, in the symptoms of chronic bronchitis and in self-perceived health status. (Marmot et al., 1991.)

Socioeconomic inequalities in mortality, showing higher survival for people with a higher SES than for people with a lower SES, have been widely reported during the last 40 years for the middle-aged and in some studies also for older adults. Mortality inequalities are witnessed with several SES indicators, for both men and women, in European countries (Huisman et al., 2013; Mackenbach et al., 2008; Marmot & Shipley, 1996) as well as in the US (Bassuk, Berkman, & Amick, 2002; Lantz et al., 2010; Nandi, Glymour, & Subramanian, 2014) and Japan (Ito et al., 2008). Most of the differences in all-cause mortality in Finland are explained by higher mortality from cardiovascular and alcohol related diseases, and cancer among those with a lower SES (Martikainen, Valkonen, & Martelin, 2001; Tarkiainen et al., 2012). Lower socioeconomic groups have higher mortality of all causes, except for breast cancer mortality among women, where high socioeconomic status can be considered a risk factor (Huisman et al., 2005; Steenland, Hu, & Walker, 2004). The majority of the studies providing strong evidence of socioeconomic inequalities in mortality are conducted in North and Western Europe. This is mainly because of the tradition of administrating population-based registers of mortality, which can be linked to people with personal identity codes.

Socioeconomic inequalities in health are also well established. Self-assessed health, whether referring to the self-reported longstanding illnesses or to the general measure of self-rated health, is shown to differ by SES, self-assessed health being poorer for those with a lower SES. (Eikemo et al., 2008; Huisman et al., 2003; Kunst et al., 2005; Mackenbach et al., 2008.) Self-reported limitations in upper and lower body functioning and in ADL and mobility are suggested to be more prevalent among people with a lower socioeconomic status (Huisman et al., 2003; Minkler et al., 2006; Murray et al., 2011; Schöllgen et al., 2010). Differences are also found in physical performance, for example in balance and chair rise times, showing a disadvantage for people in lower socioeconomic groups (Kuh et al., 2005).

Socioeconomic inequalities in health and mortality have turned out to be persistent despite the welfare model or changing economic situation (Valkonen et al., 2000). During the last three decades, research has mainly provided evidence of stable or increasing inequalities. Mackenbach and colleagues (2003) suggest that from 1981 to 1995 relative inequalities in mortality increased among the 30-74 years old in six European countries studied. Steenland et al. (2004) reported that mortality inequalities sustained and even increased among men in US during the same period (1984-1997). In Finland, during 1970-1995, the development of life expectancy in the occupational classes suggested a widening gap in mortality among the population aged 35+ (Martikainen et al., 2001). In addition, a more recent study from Finland addresses a similar trend in life expectancy where inequalities increased in the general population during 1988-2007 (Tarkiainen et al., 2012).

Studies from Finland and Sweden showed that socioeconomic inequalities in ADL and mobility remained rather stable for older adults over the period 1991-2003 (Fors, Lennartsson, & Lundberg, 2008; Sulander et al., 2006). Research from Sweden covers a longer period (1992-2011), and the finding for 77+ years old population is similar stating stability in inequalities (Fors & Thorslund, 2015). A study from the Netherlands assessed inequalities in ADL among the 55-65 years old. Researchers found that inequalities remained stable for men during 1991-2002 but increased for women. (Hoogendijk et al., 2008.) A study from the US suggested increasing inequalities in ADL for the 70+ years old during 1982-2002 (Schoeni et al., 2005). Socioeconomic inequalities in SRH seem to be in line with the other health indicators suggesting stability or a slight increase in inequalities over the last decades (Kunst et al., 2005; Min, 2014). Research from Finland shows the same, stable inequalities in SRH among the 65-84 years old during 1993-2003 (Sulander et al., 2009).

Research on socioeconomic inequalities in biomarker levels that reflect subclinical pathologies and predicts decline in health has a shorter history. Most studies have focused on cardiovascular risk factors such as blood pressure, high-density lipoprotein (HDL) cholesterol, body mass index (BMI), glucose level, insulin level, or metabolic syndrome with the age scope ranging from the middle-aged to age 79. The pattern in cardiovascular risk factors is similar to health and mortality inequalities; lower SES exposures to higher risk (Elovainio et al., 2011; Koster et al., 2005; Muennig, Sohler, & Mahato, 2007; Prescott et al., 2007; Wardle, Waller, &

Jarvis, 2002). Some studies have found that inflammation, measured with C-reactive protein (CRP) and interleukin-6 (IL-6), is higher for people with a low SES (Koster et al., 2005; Koster et al., 2006; Loucks et al., 2010). However, socioeconomic inequalities are not consistent in all cardiovascular or inflammatory biomarkers and the association is suggested to be weaker at older ages (Loucks et al., 2007; Loucks et al., 2010; Seeman et al., 2008).

Socioeconomic inequalities in biomarkers are also studied with composite measures, which reflect the functioning of several organ systems. These studies originate from the concept of allostatic load (AL) that describes the cumulative biological burden. The theoretical background and operationalization of AL mostly stems from the studies of Seeman and McEwen (McEwen & Seeman, 1999; Seeman et al., 1997; Seeman et al., 2004; Seeman et al., 2010). Ten biomarkers (systolic and diastolic blood pressure, waist-hip ratio, HDL and total cholesterol, glycosylated hemoglobin, dehydroepiandrosterone (DHEA), cortisol, norepinephrine and epinephrine) reflecting the biological regulatory systems (cardiovascular, metabolism, hypothalamic-pituitary-adrenal (HPA) axis, autonomic nervous system and inflammation) were first operationalized with the data from The MacArthur Studies of Successful Aging (Seeman et al., 2001). Some studies suggest that socioeconomic inequalities are larger when studied with the composite measures of AL than with the individual biomarkers (Gruenewald et al., 2012; Seeman et al., 2008; Seeman et al., 2004).

The research tradition on socioeconomic inequalities in the use of institutional LTC is thin. LTC use increases with age and previous studies have mainly concentrated on the 65+ population as a whole. Whether the focus in the study was the use of, or entering into, LTC, the most consistent finding is that home occupiers enter LTC less frequently than those who rent their home (Breeze et al., 1999; Gaugler et al., 2007; Grundy & Glaser, 1997; McCann, Grundy, & O'Reilly, 2012; Nihtilä & Martikainen, 2007; Tomiak et al., 2000). Only a few studies have showed similar results with other socioeconomic indicators. Mustard and colleagues (1999) showed that people with higher income and higher education entered LTC less often than those worse off, and Nihtilä & Martikainen (2007) showed that people with higher income and higher occupational class entered LTC less than the worse off. However, there are also studies (Gaugler et al., 2007) with diverging results, and some of the aforementioned studies showed no socioeconomic inequalities in the use of LTC with different SES indicators (Breeze et al., 1999).

3.3 Socioeconomic health inequalities among the oldest old

Health and mortality inequalities are well acknowledged among the younger old and the old old but for the oldest old research is scarce. It is not clear whether inequalities continue to very old ages. Hypotheses have been put forward about the increase or decrease in inequalities. Increasing inequalities during ageing supports thinking of the cumulative advantage or disadvantage in material and social resources. A cumulative advantage throughout the life course is suggested to lead to inequalities also among the oldest old. (Mirowsky & Ross, 2005; Ross & Wu, 1996.) Mirowsky and Ross (2005) demonstrate the accumulation of health inequalities with the growth-curve model. They suggest that the prevalence of physical impairment is higher for the 20-30 years old with less than high school degree than for those with a college degree. In addition, the development of physical impairment is faster among the group with lower education. This leads to an increase in inequalities in old age. Researchers suggest that after the age of 65, the trajectory of health decline becomes more similar between the educational groups but inequalities still continue to grow. Kim and Durden (2007) also provide empirical evidence for the cumulative advantage hypothesis; however, they suggest that age-related health trajectories may vary by SES and health indicators.

The age-as-leveler hypothesis supports thinking that socioeconomic health inequalities decrease with age. House and colleagues (1994) suggest that exposure to psychosocial risk factors differs according to age. Thus, for example the influence of working conditions, a major cause of health inequalities, becomes weaker after retirement and may cause convergence in health inequalities. Herd (2006) and others (Beckett, 2000; McMunn, Nazroo, & Breeze, 2009) have found evidence of decreasing inequalities with ageing. The research suggests that people with higher SES may be able to postpone health decline to later life than people with lower SES, resulting in a convergence of inequalities in old age. This is related to the thought that the processes of frailty are biologically programmed. It would mean unavoidable frailty in very old age, which would decrease inequalities between socioeconomic groups. Dupre (2007), among others, discusses mortality selection, which is thought to be one of the drivers for the observed decrease in inequalities with ageing. This mechanism refers to people with lower SES having higher mortality at all ages. Because of that, in the very old population, the proportion of worse off people would be relatively lower leading to a decrease in inequalities. (Dupre, 2007.) Kaplan and colleagues (1999) brought the ceiling effect into the discussion. In the context of decreasing health inequalities, the ceiling effect could refer to a situation where very high morbidity among all study participants (the oldest old) would complicate the identification of excess risk in one group relative to another (Kaplan, Haan, & Wallace, 1999). As a result, in the very old population absolute measures (%) could show higher inequalities than the relative measures.

The empirical evidence of health and mortality inequalities is still rare among the oldest old. Two register studies based on the total population in the country have examined mortality inequalities among the 90+ years old and one register study has examined mortality inequalities among the 85+ years old. Martelin (1996) found that among Finns aged between 90-94 mortality was lower for those with a high occupational class and among highly educated men when compared with those who were worse off. The study included all deaths in Finland between 1971 and 1990. (Martelin, 1996.) Hoffman (2011) studied mortality inequalities in Denmark during 1980-2002. He reported lower mortality for 90-99-year-old-men who belonged to higher income deciles when compared with those in the lowest income decile. (Hoffmann, 2011b.) Moe and colleagues (2012) made a similar finding in Norway during the years 1961-2009. Among the 85-94 years old, mortality was lower for the highly educated than for those with low education levels. (Moe et al., 2012.)

A Norwegian register-based study focused on the remaining life expectancy at the ages of 85, 90, and 95 (Kinge et al., 2015). Measured with absolute differences, the researchers found higher life expectancy for those who had a tertiary education when compared to those who had a primary education. This was seen in all age groups and for both genders during the study period 1990-2009. The only exception, where differences were not significant, was the group of women aged 95. (Kinge et al., 2015.) Huisman et al. (2004) conducted pooled mortality analyses for 90+ year-olds in 11 European countries or areas during 1990-1997. In their study, which was also based on register data, the higher educated had lower mortality than those with a primary education. The result was similar with absolute and relative measures and for both genders. The differences were, however, not significant when housing tenure was used as a SES indicator. (Huisman et al., 2004.)

A Danish population based survey and two other survey studies with smaller samples have examined mortality inequalities among nonagenarians. A large Danish survey including 2,249 participants found no differences in mortality in the 15 months of follow-up according to years of education. The study had response rate of 63% and it included institutionalized and proxy respondents. (Nybo et al., 2003.) A similar result was found in a Spanish study where mortality in educational groups was followed for 5 years among nonagenarians (Formiga et al., 2011). A Chinese study assessed mortality inequalities between educated people who live in urban areas, and people with no education who live in rural areas in the age groups of 90 and 100. In four years of follow-up, mortality was shown to be lower for educated urban people than for uneducated rural people. (Zhu & Xie, 2007.) The two latter studies suffer in quality since in the aforementioned study mortality information was based on interview records, and thus the study is vulnerable for misreporting, and the latter study was based on a very small study sample and presents only descriptive results.

Only a few studies have examined socioeconomic inequalities in health and functioning among people 80+ years old and none have done so among nonagenarians. Rostad et al. (2009) studied SRH and long-standing illnesses that limit daily activities in a Norwegian population-based survey that focused on women. They found that among the age groups of 80-84 and 85+, those with a high education assessed their health more often as good than those with a low education; however, there were no differences in limiting long-standing illnesses. Based on the other SES indicator, occupational class, there were no health differences among the oldest age groups. (Rostad et al., 2009.) Arber and Cooper (1999) studied SRH and disability for the same age groups in a survey in Great Britain. Contrary to previous findings, they reported that people with a higher occupational class assess their health more often as good and are less frequently disabled than people with a lower occupational class. (Arber & Cooper, 1999.) A European multinational study, including populations aged 80+, also assessed inequalities in SRH and long-term disabilities. The study showed that men with a high education or high income level assess their health better and suffer less often from long-term disabilities than those who are worse off. For women, differences were found only in SRH based on the level of education. Differences in the measure of cut down of daily activities were not found either for men or for women. (Huisman et al., 2003.) The two latter studies differ from the first one since they did not include institutionalized individuals.

The aforementioned studies on mortality and health inequalities among the oldest old are presented in Appendix table 2, including SES and health indicators, study population, age groups, and the main results. Currently, there is no research on socioeconomic inequalities in biomarkers levels or in the use of long-term care for the oldest old.

4 Conclusions regarding earlier studies

Overall, there is a convincing volume of evidence that socioeconomic inequalities in health outcomes are real, are witnessed in all developed countries, and are persistent. It has been suggested that health inequalities mostly originate from the societal structures where people live, work, and grow old (Marmot et al., 2010). However, the impact of the mechanisms, material and social environment, may change with ageing. Thus, different hypotheses of whether health inequalities increase or decrease with ageing have been put forward. The empirical evidence mostly supports the thinking that health inequalities exist among the younger old age groups (65-80). Earlier research shows that health inequalities do not exist only between the extreme ends, between the highest and lowest socioeconomic statuses, but that they follow the social hierarchy. On average, the highly educated have better health than the middle educated, and middle educated have better health than those with low education level. Health inequalities are thus considered relative by nature rather than a cause of absolute deprivation.

There are only a few studies where inequalities in health-related outcomes are assessed for the oldest old. Where the oldest old are explored as a separate group, most studies have focused on mortality and are mainly based on register data. Earlier findings on mortality inequalities are contradictory and give a different view of social inequalities depending on the research method; register-based studies suggest that there are inequalities in mortality while survey studies mostly suggest the opposite. Only a few earlier studies have assessed health inequalities among the 80+ population. There is no gold standard for choosing the SES indicator for older people; however, the results seem inconsistent even between the studies that used the same SES and health indicators. Overall, of previous studies on health and mortality inequalities among the oldest old, a minority are population based surveys and most exclude institutionalized individuals. As the decline in health and functioning as well as the increase in institutionalization are common among the oldest old, these factors have an impact on the representativeness of the study. In addition, only a few of the previous studies report results from recent years.

Since the number of previous studies is low, the use of different SES and health indicators, different inclusion criteria (birth cohorts, gender, institutionalized), different methods, different response rates, and populations studied in different countries complicates the interpretation of the results as a whole. Inconsistent results prevent the creation of a general view of whether health and mortality inequalities exist among the oldest old. There are no studies for the oldest old regarding inequalities in biomarker levels or the use of institutional long-term care.

Social inequality in health cause suffering for individuals and is considered morally indefensible. From the public health perspective, inequality in health and care service use becomes increasingly important as the number of the oldest old rapidly increases. Social inequality can be burdensome especially in old age because of the increasing morbidity and functional disability as well as the higher need for care services. Based on previous theoretical considerations and empirical findings, it is not clear whether social inequalities in health-related matters continue to exist in the oldest age group.

5 Aims of the study

The overall aim of the study was to assess social inequality in the health of the oldest old. The study used two socioeconomic status indicators, occupational class and level of education. Socioeconomic inequalities in health and in biomarkers, and the role of biomarkers in the association between socioeconomic status and functioning, were examined with survey data in a cross-sectional setting. Socioeconomic inequalities in mortality and in long-term care use were studied with follow-up analyses by combining survey data with national registers. The study employed several health indicators, functioning, morbidity, self-rated health, biomarkers, mortality and the use of long-term care to demonstrate the association between socioeconomic status and health in the 90+ population.

The specific research questions were:

1. What is the association between socioeconomic status and functioning, morbidity or self-rated health in the 90+ population? (sub-study I)

2. To what extent is educational attainment associated with cardiometabolic or inflammatory biomarkers, and what is the role of biomarkers in the association between education and functioning among 90-year-olds? (sub-study II)

3. Is socioeconomic status a predictor of mortality in the 90+ population? (sub-study III)

4. Does the use of long-term care differ between occupational classes in the 90+ population? (sub-study IV)

6 Materials and methods

6.1 Data

The data came from three different sources; from The Vitality 90+ research project from the Statistics Finland and from the national administrative health and social care registers. Register data were linked with the data from the Vitality 90+ Study by using unique personal identity codes.

The Vitality 90+ Study

The Vitality 90+ Study is an ongoing multidisciplinary research project focusing on longevity. The study was initiated in Tampere in 1995, which is the third largest city in Finland with around 226 000 inhabitants in 2016. The project focuses on the research themes, such as the predictors of health, functioning and longevity, the biological basis of ageing, need for and use of care and services, and ageing as an individual experience. The driving force for the project is the rapid increase in the oldest old population.

The project consists of mailed survey data, health-examinations and life story interviews (Figure 3). Mailed survey data collections were carried out eight times (1995, 1996, 1998, 2001, 2003, 2007, 2010, and 2014) since the start of the study. In the first three waves of data collection, the target population included inhabitants who were 90 years old or over in the city of Tampere living in the community. The institutionalized were also invited to participate from 2001 onwards. The sample size varied from 366 (1995) to 1637 (2014) and the response rates between study years varied from 78 to 86 percent. Most of the study participants answered the questionnaires by themselves. However, around 20% received help from someone else in filling out the questionnaire, and for less than 20% the answers were given by family members or relatives, friends, home care personnel, or staff in LTC institutions. The latter is referred to as a proxy answer in the current study.

Health-examinations, including interviews, anthropometric measurements, physical performance tests, and blood tests were carried out in 2000, 2010 and 2014. The same protocol without blood tests was carried out in 2003. All individuals in

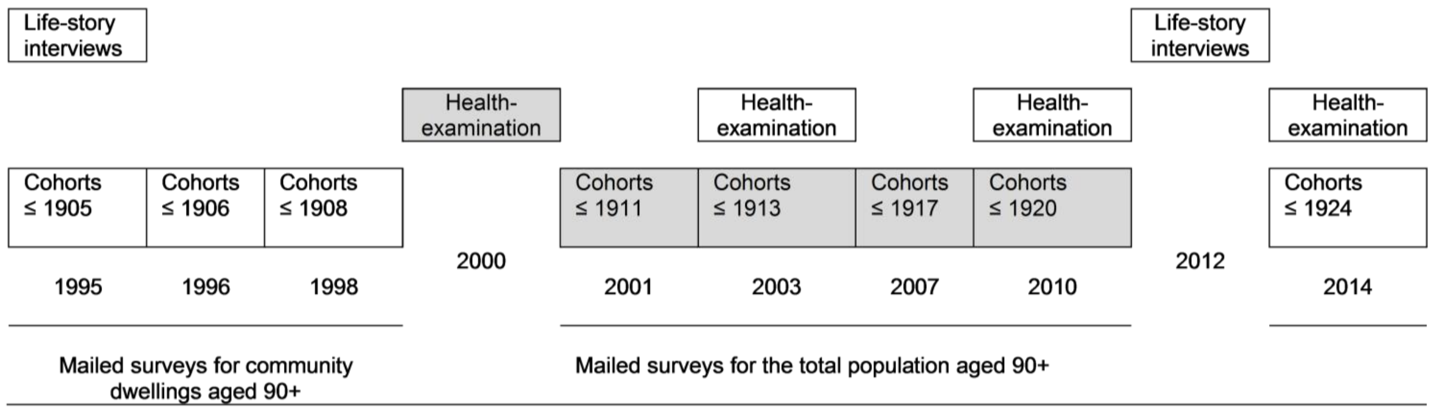

Figure 3. The Vitality 90+ Study data chart. The data used in this study are marked with gray boxes.

the city of Tampere aged 90 to 91 years old were invited to participate in 2000 (535) and in 2003 (528). In 2010, only 90-year-olds (439) were invited. Among the eligible population, the response rate for those who went through the interview, anthropometric measurements, physical performance test, and blood tests was 61% in 2000 and 54% in 2010. The response rate was 56% in 2003. In 2014, 99 of those who participated in 2010 were invited for a follow-up examination with the same protocol, and 67 people were re-examined. Life story interviews were carried out in 1995 with 200 people aged 90 or over, and in 2012, 45 people were interviewed.

Data from the Vitality 90+ Study was utilized in all four sub-studies. Sub-studies I and III used survey data from the year 2010 since it was the first survey that included two socioeconomic status indicators, occupational class and education level. It was also the latest wave of data collection and included the highest number of participants at the time of sub-study I. For sub-study III, this particular data gave a long enough follow-up for studying mortality. In between conducting the sub-studies I and III data were cross-checked, and a few individuals who could not be linked to other waves of data collection were removed. Thus, the number of the participants vary slightly between the two sub-studies. In addition, the exact number of people in the different occupational classes varies. This is because the occupational class was not known for 74 people who participated in the 2010 data collection. However, some participants in the 2010 data collection had participated in the earlier waves of data collection, too. For some of those whose occupational class was not known in 2010, occupation was later found from earlier data.

For sub-study II, the decision to use health-examination data from the year 2000 was based on the size of the data and availability of the variables. In the sub-study IV, data from 2001, 2003, 2007, and 2010 surveys were pooled to increase study power. Since there was a possibility that a person had participated in the Vitality 90+ Study in several waves, only the first entry was taken into account.

The analytic data for all sub-studies are presented in Table 1. The number of participants varied from 262 to 2,862 between the sub-studies and the gender distribution was heavily skewed towards women in each study. The response rate varied in the mailed surveys from 79 to 86, and was 61 in the health-examination data. The age ranges were 90-107 in the surveys and 90-91 in the health-examination data. The percentage of proxy respondents was 18 in the sub-studies I and III, and 8 in the sub-study IV. There were no proxy respondents in the health-examination data. More than 30% and less than 20% of the survey participants and health-examination participants respectively were in round-the-clock long-term care.

Table 1. Analytic data by the sub-studies. The Vitality 90+ Study.

	Sub-study I	Sub-study II	Sub-study III	Sub-study IV
Data set	Mailed survey 2010	Health-examination 2000	Mailed survey 2010	Mailed survey 2001 Mailed survey 2003 Mailed survey 2007 Mailed survey 2010
Participants (N)	1,283	262	1,276	2,862
Response rate (%)	80	61	79	80
Women (%)	81	74	81	80
Age (min-max)	90-107	90-91	90-107	90-107
Proxy respondents (%)	18	-	18	8
Round-the-clock long-term care (%)	37	19	37	32

Statistics Finland

Data for mortality came from Statistics Finland, which is a public authority that produces the vast majority of the Finnish official statistics. The Causes of Death Register maintained by Statistics Finland provided the mortality data, date of death and the cause of death. Mortality data is based on the death certificates that are compiled with the information from the Central Population Register. (Official Statistics of Finland, 2011.) This study took advantage of mortality information for all causes of death and separately for cardiovascular and dementia related causes of death (sub-study III). The information of the causes of death are displayed as immediate, underlying, intermediate and contributing causes of death (Official Statistics of Finland, 2015c). The cause of death in this study was the underlying cause of death, which is described as a disease that starts the series of health processes, which directly leads to death. In the death certificates, the underlying cause of death is given by a physician. (Official Statistics of Finland, 2015c.) The underlying cause of death is used as a cause of death in several other studies e.g. (Huisman et al., 2005; Rosvall, Chaix, Lynch, Lindstrom, & Merlo, 2006), and was coded according to the 10th revision of International Classification of Diseases (ICD-10) in this study.

National care registers and ethical approvals

Data for the use of institutional LTC came from The Care Register for Health Care and The Care Register for Social Welfare administrated by the National Institute for Health and Welfare. The Care Register for Health Care provides information on hospital and health center use including admissions, discharges and received care. (National Institute for Health and Welfare, 2016a). The Care register for Social Welfare provides the same information of the long-term care use given in residential homes and in service homes with 24-hour assistance (National Institute for Health and Welfare, 2016b). In addition, information of the service provider was available from both registers. LTC providers are divided to public and private actors.

The study protocols for The Vitality 90+ Study, mailed surveys and health-examinations, were approved by the *Ethics Committee of the City of Tampere or the Pirkanmaa Hospital District* depending of the year of the study. The information regarding names, addresses, and the places of residence, were derived from the Tampere City Population Register. If a person filled out the questionnaire and returned it or participated in the interviews, it was considered as a permission to use the data for research purposes. The register data was linked with the survey data in collaboration with National Institute for Health and Welfare (THL/1553/5.05.00/2011) and Statistics Finland (TK-53-623-09). The permissions to use the anonymized data were received before the data were given for the research purposes. For the use of care information, informed consent was requested from the participants or their legal representatives.

6.2 Socioeconomic status

The two socioeconomic status indicators used in the study were occupational class and the level of education. Occupational class was based on the question, "what is your longest held occupation?" Former, personal occupational class was coded according to the Occupational and Industrial Classification of Statistics Finland (Official Statistics of Finland, 1976) (Appendix table 3). This study categorized individual occupations according to the 1976 classification since it describes the occupations and their relations at the time when study participants belonged to the work force. Individual occupations were coded hierarchically to reflect social stratification. In Finland, also the self-employed and farmers were categorized as part of the social hierarchy. This kind of categorization made it possible to include these relatively small groups in this study. The four hierarchical occupational classes formed were upper non-manual class, lower non-manual class, skilled manual class and unskilled manual class (Table 2), as listed by the Statistics Finland (1976), and as also used in other studies in the research field e.g. (Geyer et al., 2006). The classification was based on work tasks and responsibilities but also on the information of having or not having employees for the self-employed. The classification elaborated by the Statistics Finland was widely used for national demographic statistics at the time of its release.

Housewives were not mentioned in the original classification but because the group was quite large and did not fit into other groups, it was included as a separate group. Persons who were recorded as assisting family members were first combined with housewives (sub-study I and III) since they all were women with unspecified job descriptions. In the sub-study IV, they were combined with unskilled manual workers since many of the assisting family members participated in farming. In addition, one group was formed of those whose occupational class was not known (sub-studies I, III and IV). In this group, the number of proxy respondents was high, which implies that the socioeconomic status was not known for them due to poor health.

In the survey data, the level of education was assessed by the question, "what is your education?" The alternative answers were primary school, lower secondary education, vocational education, folk high school, upper secondary education, college-level training, and academic education. If several options were chosen, the highest educational attainment was taken into account. Three hierarchical indicators of the level of education were formed. First, low level of education (primary and lower secondary, maximum 6 years), second, middle level of education (vocational education, folk high schools, 7-9 years), and third, high level of education (upper secondary, college-level training, academic education, at least 9 years) (sub-study I). In the sub-study III, those with lower secondary education were categorized as having a middle level of education. Information about education was missing for approximately 4% of the sample. These were categorized as having unknown education. They represented the fourth educational group (sub-studies I and III). The number of proxy respondents was also high in this group.

Table 2. Hierarchical coding for occupations in the Vitality 90+ Study (sub-studies I, III and IV)

Codes from the Occupational and Industrial Classification of Statistics Finland (1976)	**Sub-study I**	**Sub-study III**	**Sub-study IV**
	n	n	n
Upper non-manual class			
employers (11) and entrepreneurs (21) comparable to upper non-manuals	9	9	13
business directors (30) and other upper non-manuals (31)	82	83	217
Lower non-manual class			
employers (12) and entrepreneurs (22) comparable to lower non-manuals	58	58	88
salesmen, office staff, insurance agents (40)	6	6	5
shop assistants and sellers (41)	72	75	146
other comparable to lower non-manuals (42)	301	302	562
Skilled manual class			
entrepreneurs in agriculture (20)	20	21	52
employees in agriculture, forestry and fishing (50)	18	18	30
other professionals or specialized employees (51)	441	448	937
Unskilled manual class			
other unprofessional or unspecialized employees (52)	80	83	205 [a]27
Housewives	103	105	254
employer's (60) and entrepreneur's (70) assisting family members	19	19	
Occupation unknown	74	49	326
Total, N	1,283	1,276	2,862

[a]In the sub-study IV, codes 60 and 70 (27 people) were included in the unskilled manual workers.

Because there were fewer participants in the health examination data and the question of education level had different answer options from the survey, educational attainment was categorized differently. The answer options of less than primary, primary school, lower secondary, upper secondary, college-level training, or academic education were categorized into three groups 1) low (less than primary), 2) middle (primary school or lower secondary), and 3) high (upper secondary, college-level training or academic education) in sub-study II.

6.3 Other independent variables

In addition to socioeconomic status indicators, several other independent variables were included in the analyses. Men and women were studied separately in sub-study I but in the other sub-studies sex was included as an independent variable. Age was included as a continuous variable in all sub-studies except for sub-study II where participants were born in 1909 or 1910. The study year was included as a variable in sub-study IV, where the four survey waves were combined. Living arrangements and having children were independent variables in sub-study IV. Living arrangements were collected from those living in the community by asking the question "who do you live with". The answer options were alone, with spouse, with a child, with grandchildren, or with others. For community dwelling individuals, living arrangements were coded as living alone or living with someone. Having children was assessed from the question "when was the last time you met your children". The answer options were a) I do not have children, b) today or yesterday, c) a couple of days ago, d) a week or two ago, e) several weeks ago, f) several months ago, or g) years ago. The variable was coded as yes, if answer was b-g, and no if the answers was a.

Smoking and alcohol use and medical diagnoses were independent variables from the health-examination data (sub-study II). Smoking status was assessed at three levels: current, former or never a smoker, and alcohol use at four levels: more than 2 times a week, 2 or less times a week, rarely or never. For the health-examination data, medical diagnoses were collected from the medical records of the city of Tampere (Goebeler, 2009). Medical diagnoses were coded according to the International Classification of Diseases, 10th Revision including heart diseases (I0-50), infectious disease (A00-99 and B00-99), diabetes (E10-14), dementia (F00-03, G30) and arthritis (M15-19). If a participant had at least one disease in the diagnosis category, it was coded as 1, thus the number of the diagnoses varied between 0 and 5.

Multimorbidity and the level of functioning were independent variables in the sub-studies III and IV but since they were outcomes in the sub-study I, they are described in the next chapter.

6.4 Outcome variables: health, functioning, mortality and long-term care

Several health outcomes, self-reported and measured, were included in the study. From the survey data, functioning was assessed through the five following questions: Are you able to 1) dress and undress, 2) get in and out of bed, 3) move indoors, 4) walk 400 meters, or 5) use stairs? The alternative answers were a) without difficulty, b) with difficulty, c) if someone helps or d) not at all. The first two options, a and b, addressed independence in functioning and the two latter options, c and d, addressed dependency in functioning. In sub-study I, all five indicators of functioning were combined and functioning as an outcome variable included six categories, 1) independent in five activities, 2) dependent in one, 3) dependent in two, 4) dependent in three, 5) dependent in four, and 6) dependent in five activities. In addition, a dichotomized variable of functioning was used in the sub-studies I and IV. It was categorized as independent in five activities versus dependent in at least one of the activities. The latter category represented poor functioning. In sub-study III, functioning was independent variable with six categories.

From the health-examination data, another measure of functioning, namely the Barthel Index, was used as an outcome (Mahoney & Barthel, 1965). The index consisted of ten items: feeding, bathing, grooming, dressing, bowel and bladder control, toilet use, transfers bed to chair and back, mobility and stair-climbing. The score given from the index of ten items ranged between 0 and 100. Higher points show a higher degree of independence in functioning (sub-study II). See Appendix table 1.

Morbidity and multimorbidity were assessed with self-reported diseases that were diagnosed by a doctor. Participants were asked whether they had (yes/no) 1) cardiovascular diseases (CVD), 2) diabetes, 3) arthritis, 4) hip fracture, 5) depression, 6) dementia (included Alzheimer's disease, other dementias and a decline in cognition), 7) stroke, 8) blood pressure, 9) cancer, or 10) Parkinson's disease. In sub-study I, where morbidity and multimorbidity were used as outcomes, morbidity was studied with the six first mentioned diseases (results shown only in the original article). Multimorbidity was studied with the same six diseases, of which five categories were formed, 1) no diseases, 2) one disease, 3) two diseases, 4) three diseases, and 5) 4-6 diseases. In addition, a dichotomized variable was formed of the same six diseases comparing those with 0-1 diseases to those with 2-6 diseases. The latter category represented multimorbidity. In the sub-study III, multimorbidity was an independent variable. It included CVDs, diabetes, stroke, hip fracture and dementia because they are risk factors for old age mortality. In the sub-study IV, multimorbidity was also as an independent variable. It included CVDs, diabetes, hip fracture, depression, and dementia since they are known risk factors for entering LTC. Both summary multimorbidity variables included from 0 to 5 diseases.

Self-rated health (SRH) was assessed by asking: "How would you evaluate your present health?" Answer options were 1) very good, 2) fairly good, 3) average, 4) fairly poor, or 5) poor. In sub-study I, SRH was studied as an ordinal variable that ranged from very good to poor health. It was also used as a binary variable where 1) good SRH, included first the three answer options, and 2) poor SRH, the last two answer options. Because of the subjective nature of SRH, proxy answers were excluded from the analyses.

The eight biomarkers were leptin, high-density lipoprotein (HDL) cholesterol, triglycerides, a ratio of HDL and total cholesterol, body mass index (BMI), interleukin 6 (IL-6), C-reactive protein (CRP) and interleukin 1 receptor antagonist (IL-1Ra) (sub-study II). An anthropometric measure of BMI was measured at the home visit and was calculated as weight in kilograms divided by height in meters squared. Other biomarkers were analyzed from the blood samples that were collected in the morning after an overnight fast. Leptin concentrations were analyzed from serum with a Luminex-based multiplex analysis system (Bio-Plex 200 System, Bio-Rad Laboratories, Inc., Hercules, CA, USA) using a Human Serum Adipokine (Panel B) kit, catalog no. HADK2–61K-B, LINCOplex (Linco Research, Inc., St Charles, MO, USA). Other biomarkers were analyzed from plasma. High-sensitivity CRP, total cholesterol, HDL-cholesterol, and triglyceride concentrations were analyzed by using an automatic analyzer, Cobas Integra 700, with reagents and calibrators as recommended by the manufacturer (Hoffmann-La Roche Ltd., Basel, Switzerland). IL-1Ra and IL-6 concentrations were analyzed using commercial enzyme-linked immunosorbent assays, Quantikine; R&D Systems, Minneapolis, MN, for IL-1ra, and Pelikine Compact human IL-6 ELISA kit; CLB, Amsterdam, The Netherlands, for IL-6.

Only a few of the biomarkers were normally distributed, which is why biomarker readings were first categorized as tertiles, after which the variables were dichotomized. The highest third of the values signified a high risk tertile and was coded as 1, and the two lowest thirds were categorized as 0. For HDL-cholesterol and for the ratio of HDL to total cholesterol, the lowest third of values signified the high risk tertile. Cut-off values that indicate the levels for belonging to the high risk tertile in each biomarker are shown in Table 3. The cut-off values were the same for men and women.

Table 3. Cut-off points for high risk tertile in individual biomarkers, IQR = interquartile range

	Cut-point	Median (IQR)
Cardiometabolic biomarkers		
Body mass index (kg/m^2)	≥ 25.6	24.2 (22.1-26.4)
Leptin (ng/mL)	≥ 16.9	11.7 (5.9-21.8)
High-density lipoprotein (HDL) cholesterol (mmol/L)	≤ 1.20	1.38 (1.11-1.67)
Ratio of HDL and total cholesterol	≤ 0.22	0.25 (0.20-0.31)
Triglycerides (mmol/L)	≥ 1.81	1.44 (1.14-1.99)
Inflammatory biomarkers		
Interleukin-6 (pg/mL)	≥ 3.84	2.64 (1.63-5.07)
C-reactive protein (mg/L)	≥ 2.90	1.70 (0.50-4.20)
Interleukin-1 receptor antagonist (pg/mL)	≥ 444	372 (276-487)

All eight biomarkers were analyzed individually with binary variables (1/0) where 1 indicated belonging to high risk tertile. In addition, biomarkers were analyzed as cardiometabolic and inflammatory scores. Cardiometabolic score included leptin, HDL-cholesterol, triglycerides, a ratio of HDL and total cholesterol, and BMI. Inflammatory score included IL-6, CRP, and IL-1Ra. The two scores indicated the number of biomarkers where the values were in the high risk tertile. The cardiometabolic score ranged between 0-5 and the inflammatory score between 0-3.

Mortality was studied for all causes and separately for two most common causes of death, CVDs (I00-I99) and dementias. Dementia was a combined category of Alzheimer's disease (G30) and other dementias (F01-03). The cause of death in this study was the underlying cause of death (sub-study III).

In the sub-study IV, LTC use was defined as staying 90 days or more in a residential home, in service home with 24-hour assistance or in the inpatient ward of health center or hospital. The 90 days criteria for the stay was met if a person stayed in one institution or had successive periods in different institutions. In addition, those who had a confirmed LTC decision from the municipality authorities were identified as LTC users even if the length of stay was less than 90 days. The definition stems from the Act on Client Fees in Social Welfare and Health Care (734/1992) that describes a long-term care user as a person who stays in institutional round-the-clock care for more than three months (Finlex, 2003). A similar LTC use definition as in the current study, is also used in other Finnish studies (Nihtilä & Martikainen, 2007). In the present study, public and private LTC refers to the LTC provider. In general, the municipalities organize LTC, and the costs are mainly covered with tax revenues. Privately-paid LTC use is very rare in Finland and its potential use was here included in private LTC use because it could not be separated from privately provided LTC.

6.5 Analyses and statistical methods

The study was based on quantitative research methods. The distribution of the variables used in the study was described with frequencies and percentages. In order to show the average levels and dispersion of the health outcomes, means, medians and interquartile range were applied. Cross-tabulation analysis (also known as contingency table analysis) is generally used to analyze relationships between categorical variables (Metsämuuronen, 2003). In the current study, cross-tabulation was utilized in showing the frequencies of poor functioning, multimorbidity, poor self-rated health and the use of LTC in socioeconomic groups. The method for testing whether health varied statistically significantly between socioeconomic groups was Pearson's chi-square test, and if the conditions were not met, Fisher's exact test was used (McDonald, 2009). If the chi-square test showed significant differences in health outcomes between socioeconomic groups, post hoc analyses were conducted to find out in which group or groups the observed frequencies differed from the expected. The differences between observed and expected values can be evaluated with adjusted residuals. The greater the residual the larger the discrepancy. Adjusted residuals +/- 2 are considered significant at p-level 0.05 (Nummenmaa, Konttinen, Kuusinen, & Leskinen, 1997). However, for large contingency tables, the Bonferroni adjustment is recommended (Sharpe, 2015). Thus, in sub-study I the Bonferroni correction was applied for the adjusted residuals, which gave the level of statistical significance to residuals higher than +/- 3 (Beasly & Schumacker (1995).

The Kruskal-Wallis Test is a rank-based nonparametric test that is used for analyzing one dependent categorical variable and one independent continuous or ordinal variable. There are no assumptions about normality for the continuous variable. (McDonald, 2009.) In this study, the Kruskal-Wallis Test was used for testing whether the distributions of the biomarker readings differed statistically significantly at different education levels (sub-study II). Pairwise comparisons were conducted with the Dunn-Bonferroni test (results are shown in the original article).

The logistic regression method is applied for categorical dependent variables (McDonald, 2009). Binary logistic regression, where both the independent and the dependent variables were categorical, and the dependent variable was dichotomized, was used in the current study to predict the probability of having a biomarker reading in the high risk category or using LTC in socioeconomic groups (sub-studies II and IV). When occupational class or the level of education was an independent variable, the reference category was the highest occupational class or the highest education.

Odds ratios and their 95% confidence intervals (CIs) were reported. Ordered logistic regression, where the dependent variable was ordinal, was used to utilize the full variation in the health outcomes. The appropriate link functions were chosen based on the distribution of the health outcomes. A probit link function was used for normally distributed multimorbidity and SRH, and a complementary log-log link for functioning because the distribution was heavily skewed towards higher categories (sub-study I). A log link was applied to assess coefficients for the biomarker scores since the categories in these variables were at equal size (sub-study II). The parallel lines assumptions were tested and if not reached, the irregularity was taken into account in Stata with the hetero option for the ordinal generalized linear model (Williams, 2009). Coefficients and their 95% CIs intervals were reported.

After the ordered logistic regression analyses, Average Marginal Effects (AMEs) were computed as a post-estimation analysis (sub-study I). Marginal effects were computed for each case, and the effects in one SES group were then averaged. Thus, the difference in the average probability of a health outcome was analyzed in SES categories. For categorical variables with more than two possible values, the marginal effects show the difference in the predicted probabilities for cases in one category relative to the reference category. (Torres-Reyna, 2014.)

Negative binomial regression analyses were applied for the count outcome in sub-study II. The method was chosen since the outcome, Barthel Index, did not include negative numbers, the conditional variance exceeded the conditional mean (over-dispersed data) and the likelihood ratio test showed a better fit for the negative binomial regression method than for the Poisson regression method (Introduction to SAS, 2016). Rate ratios with 95% CIs were reported.

In the mortality analyses, the Kaplan–Meier method was applied to calculate the mean survival times in the different socioeconomic groups. The participants were followed from the beginning of the study until the event or endpoint. Those who reached the endpoint without failure were coded as censored (Kleinbaum & Klein, 2006). The mean survival times and statistically significant differences in comparison to the reference groups were reported. The follow-up period for all-cause mortality was from 23rd February 2010 to 31st January 2013, approximately 36 months, and for cause-specific mortality from 23rd February 2010 to 19th November 2012, approximately 33 months. The follow-up periods were based on the availability of mortality information. Cox-regression was applied to compare the survival curves between socioeconomic groups while taking into account possible risk factors for survival. Proportional hazards assumption, checking that the ratio of the hazards comparing socioeconomic groups is constant over time, was tested with Schoenfeld residuals. If the assumptions were not fulfilled, an extended Cox model with the time-covariate interaction term was used (Kleinbaum & Klein, 2006). Hazard ratios (HR) and their 95% CIs were reported (sub-study III). Entering LTC was followed from the baseline of the study until entering LTC, until death or until the end of follow-up (max 34 months). The competing-risks regression method (Stata command stcrreg) enables survival analyses in the case of more than one event. Mortality was considered as a competing event for entering LTC. The Fine & Gray (1999) method was used in order to assess the incidence of entering LTC in the presence of a competing event (Fine & Gray, 1999). Assumptions for proportional subhazards were tested by adding time interactions for all of the covariates. Subhazard ratios (SHR) and their 95% CIs were reported (sub-study IV).

The data were analyzed using SPSS for Windows version 20.0 for IBM Statistics. Another statistical package, Stata for windows and its versions 12.1 and 14.0, was also used in the analyses. Table 4 summarizes the data sets, main methods and variables that were used in the four sub-studies.

Table 4. The data set and data source, main methods and variables by the sub-studies. CVD=cardiovascular diseases, CRP=C-reactive protein, IL-6=interleukin 6, IL-1Ra=interleukin 1 receptor antagonist, HDL=high-density lipoprotein, BMI=body mass index, LTC=long-term care.

	SUB-STUDY I	SUB-STUDY II	SUB-STUDY III	SUB-STUDY IV
Data	2010 mailed survey Vitality 90+ Study	2000 health-examination data Vitality 90+ Study	2010 mailed survey Vitality 90+ Study Causes of Death Register	2001, 2003, 2007, 2010 mailed surveys Vitality 90+ Study Care Registers for Health Care and for Social Welfare Central Population Register
Statistical methods	Ordered logistic regression	Negative binomial regression	Kaplan-Meier Cox regression	Competing-risks regression
Indepen-dent variables	**Occupational class** Upper non-manual Lower non-manual Skilled manual Unskilled manual Housewives Occupation not known **Education** High Middle Low	**Education** High Middle Low	**Occupational class** Upper non-manual Lower non-manual Skilled manual Unskilled manual Housewives Occupation not known **Education** High Mid-level Low	**Occupational class** Upper non-manual Lower non-manual Skilled manual Unskilled manual Housewives Occupation not known
Outcome variables	**Functioning** Get in and out of the bed Dress and undress Move indoors Walk 400 meters Use stairs **Multimorbidity** CVD Diabetes Stroke Arthritis Hip fracture Depression Dementia **Self-rated health** Very good Fairly good Average Fairly poor Poor	**Biomarkers** Inflammatory: CRP IL-6 IL-1Ra Cardiometabolic: HDL-cholesterol Triglycerides Total cholesterol Leptin BMI **Barthel Index**	**Mortality** All-cause CVD Dementias	**Use of LTC** 90 days or more: Residential homes, Service home with 24 h assistance, Inpatient ward of health centers or hospitals or A confirmed LTC decision **Enter in LTC** **LTC provider** Public Private

7 Results

7.1 Distribution of socioeconomic status

Socioeconomic status was the main independent variable in all sub-studies. Distributions of the occupational class and education level are presented based on their use in the sub-studies (Table 5). Among the occupational classes, altogether, less than 10% belonged to upper non-manual class, more than 30% belonged to lower non-manual class and skilled manual class, respectively, and less than 10% belonged to unskilled manual class. The proportions for the two categories that were not considered as hierarchical occupational classes, were 11% for housewives and 8% for those with unknown occupation. Since education was categorized differently in mailed surveys and in the health-examination, they are not completely comparable. In the sub-studies I and III (survey data), highly educated represented 13% of the population, while 29% were middle educated, and the majority, 54%, had a low education level. The education level was not known for 4%. In the sub-study II (health-examination data), 15% were highly educated, most, 70%, were middle educated, and 15% had a low education level. Overall, men were higher educated and outnumbered women in the upper non-manual group. The category of housewives included only women.

Table 5. Socioeconomic status by sex in the sub-study I and both genders together in sub-studies II-IV.

	Women	Men	All	All	All
	Sub-study I		Sub-study II	Sub-study III	Sub-study IV
	1,041	242	262	1,276	2,862
Occupational class	N (%)	N (%)	N (%)	N (%)	N (%)
Upper non-manual	48 (5)	43 (18)		92 (7)	230 (8)
Lower non-manual	359 (35)	78 (32)		441 (35)	801 (28)
Skilled manual	378 (36)	101 (42)		487 (38)	1,019 (36)
Unskilled manual	69 (7)	11 (5)		83 (7)	232 (8)
Housewives	122 (12)			124 (10)	254 (9)
Unknown	65 (6)	9 (4)		49 (4)	326 (11)
Education					
High	114 (11)	48 (20)	39 (15)	162 (13)	
Middle	181 (17)	73 (30)	182 (70)	373 (29)	
Low	704 (68)	113 (47)	39 (15)	694 (54)	
Unknown	42 (4)	8 (3)		47 (4)	

7.2 Association of socioeconomic status with functioning, multimorbidity and self-rated health (sub-study I)

The prevalence of poor health according to occupational class and education was first analyzed with binary variables, namely with poor functioning, multimorbidity and poor self-rated health (Table 6). The prevalence of poor functioning increased gradually from upper non-manual class to unskilled manual class among men. Similarly, according to education, those with a low education had highest prevalence of poor functioning and those with the highest education had the lowest prevalence of poor functioning. However, differences were not statistically significant. Among women, a corresponding gradient was seen in poor functioning according to occupational class. The chi-square test showed that poor functioning differed significantly between occupational classes. The more detailed analysis of the adjusted residuals showed that poor functioning was significantly lower for lower non-manual women than expected (Bonferroni corrected residuals at level +/- 3). According to education, those with a low education had the highest prevalence of poor functioning and the chi-square test showed that differences were significant also between the educational groups. Adjusted residuals showed that poor functioning was significantly lower for middle educated and higher for those with a low education than expected.

For multimorbidity, a social gradient was found with both SES indicators among men. It means that those who were lower in the social hierarchy had more frequently two or more diseases than those who were higher in the hierarchy. The result was significant according to education. Adjusted residuals showed that multimorbidity was lower for the high educated than expected. Among women, multimorbidity was highest for unskilled manual class and lowest for upper non-manual class but the differences were not significant. According to education, those with low education level had the highest prevalence of multimorbidity and the prevalence of multimorbidity was lowest for those with middle education; however, the differences were minor.

The prevalence of poor SRH fluctuated among men according to occupational class. Poor SRH was lowest among the upper non-manual class and for the unskilled manual class. A gradient was found in education showing the lowest prevalence of poor SRH for the highly educated. Among women, poor SRH followed the social hierarchy according to occupational class. According to education, the highly educated had the lowest prevalence of poor SRH. Absolute differences in poor SRH were not significant for men or for women. In general, housewives and those with an unknown occupational class or education had a relatively high prevalence of poor functioning, multimorbidity and poor SRH among men and women.

Table 6. The prevalence of poor functioning, multimorbidity and poor self-rated health according to occupational class and education. res. = adjusted residuals, Bon. = Bonferroni corrected p-values for adjusted residuals.

	Poor functioning			Multimorbidity			Poor self-rated health	
	%	res.	Bon.	%	res.	Bon.	%	res.
Men								
Occupational class								
Upper non-manual	24	-2.4		33	-1.9		10	-1.8
Lower non-manual	41	0.3		43	-0.8		27	1.5
Skilled manual	44	0.9		52	1.2		23	0.5
Unskilled manual	55	1.0		70	1.5		10	-0.9
Occupation unknown	50	0.6		71	1.3		17	-0.3
Chi-square test, p-value	0.17			0.09			0.26	
Education								
High	29	-1.7		25	-3.3	**0.0010**	12	-1.7
Middle	36	-0.8		49	0.3	0.7642	22	0.1
Low	48	2.3		54	2.0	0.0455	25	1.3
Education unknown	29	-0.6		67	1.0	0.3173	20	-0.1
Chi-square test, p-value	0.12			**0.008**			0.35	
Women								
Occupational class								
Upper non-manual	50	-2.1	0.0394	55	-0.9		18	-1.5
Lower non-manual	58	-3.2	**0.0015**	59	-1.1		24	-1.9
Skilled manual	69	2.2	0.0285	59	-0.8		30	1.0
Unskilled manual	74	1.7	0.0930	73	2.1		37	1.5
Housewives	68	1.0	0.3173	64	0.8		34	1.5
Occupation unknown	68	0.7	0.4965	69	1.2		25	-0.4
Chi-square test, p-value	**0.004**			0.16			0.10	
Education								
High	55	-2.2	0.0278	60	-0.2		18	-2.3
Middle	53	-3.6	**0.0003**	57	-1.2		30	0.7
Low	68	3.8	**0.0001**	62	1.0		29	0.8
Education unknown	77	1.5	0.1336	65	0.5		32	0.4
Chi-square test, p-value	**< 0.001**			0.61			0.13	

Chi-square test: statistical significance at p-value 0.05.
If chi-square test was < 0.05, Bonferroni corrected p-values for adjusted residuals were run.
Bonferroni corrected adjusted residuals: statistical significance at p-value 0.00625 for education (0.05 / 8, where 8 is the number of tests, 4 categories for education and a dichotomized outcome) and at p-value 0.0042 for occupation among women (0.05 / 12).

Relative differences in functioning, multimorbidity and SRH between socioeconomic groups were studied with ordered logistic regression analyses (Table 7). Among men, those from skilled manual class and unskilled manual class had significantly higher coefficients in functioning than upper non-manual class indicating poorer functioning in these groups in comparison to the reference group. According to education, those with low education level had poorer functioning than those with high education level. Among women, the skilled manual class, the unskilled manual class and housewives had poorer functioning than the upper non-manual class. According to education, only those with an unknown education had significantly poorer functioning than those with a high education. Multimorbidity was higher for unskilled manual class than for upper non-manual class among men. According to education, those with a low education level had higher multimorbidity than those with a high education. Among women, there were no statistically significant differences in multimorbidity between occupational or educational groups. Self-rated health did not differ significantly between occupational classes among men; however, those with a low education level reported to have poorer SRH than those with a high education level. Among women, skilled manual class, unskilled manual class and housewives had poorer SRH than the upper non-manual class. Self-rated health was also poorer for those with a low or middle education when compared with those with a high education level.

Table 7. Poor functioning, multimorbidity and poor self-rated health according to occupational class and education. Age-adjusted coefficients (95% CIs) from the ordered logistic regression. Higher coefficient indicates worse health. * p-value ≤ 0.05; **p-value ≤ 0.01; ***p-value ≤ 0.001.

	Men			Women		
	Coefficient		95% CI	Coefficient		95% CI
Functioning						
Occupational class						
Upper non-manual, ref						
Lower non-manual	0.694		-0.02 to 1.41	0.303		-0.13 to 0.74
Skilled manual	0.784	*	0.09 to 1.48	0.499	*	0.07 to 0.93
Unskilled manual	1.02	*	0.01 to 2.04	0.704	**	0.20 to 1.20
Housewives				0.557	*	0.09 to 1.02
Occupation unknown	0.932		-0.23 to 2.10	0.712		-0.12 to 1.54
Education						
High, ref						
Middle	0.419		-0.25 to 1.10	-0.062		-0.37 to 0.24
Low	0.721	*	0.11 to 1.33	0.245		-0.02 to 0.51
Education unknown	-0.084		-1.58 to 1.41	0.956	*	0.00 to 1.91
Multimorbidity						
Occupational class						
Upper non-manual, ref						
Lower non-manual	-0.039		-0.45 to 0.37	0.027		-0.30 to 0.36
Skilled manual	0.111		-0.29 to 0.51	0.128		-0.20 to 0.46
Unskilled manual	0.998	**	0.25 to 1.74	0.338		-0.06 to 0.74
Housewives				0.166		-0.20 to 0.53
Occupation unknown	0.567		-0.27 to 1.41	0.302		-0.11 to 0.72
Education						
High, ref						
Middle	0.403		-0.01 to 0.82	0.015		-0.24 to 0.27
Low	0.500	**	0.12 to 0.88	0.128		-0.09 to 0.35
Education unknown	0.816		-0.07 to 1.71	0.19		-0.22 to 0.59
Self-rated health						
Occupational class						
Upper non-manual, ref						
Lower non-manual	0.280		-0.14 to 0.70	0.115		-0.24 to 0.47
Skilled manual	0.318		-0.09 to 0.73	0.349	*	-0.00 to 0.70
Unskilled manual	0.312		-0.44 to 1.06	0.456	*	0.02 to 0.90
Housewives				0.454	*	0.06 to 0.85
Occupation unknown	0.515		-0.42 to 1.45	0.177		-0.31 to 0.66
Education						
High, ref						
Middle	0.246		-0.17 to 0.66	0.357	**	0.08 to 0.63
Low	0.439	*	0.05 to 0.83	0.391	***	0.15 to 0.63
Education unknown	0.596		-0.41 to 1.60	0.403		-0.12 to 0.93

Average marginal effects with 95% CIs were conducted after ordered logistic regression analyses to show more detailed distribution of functioning (6 categories), multimorbidity (5 categories) and self-rated health (5 categories) according to occupational class and level of education. Marginal effects show the predicted probability (in percentages) of belonging to a certain health category in other socioeconomic groups in comparison with upper non-manual class or people with high education level. The marginal effects showed that when compared with upper non-manual class men, skilled manual class men were less often independent in functioning (24%) and more often dependent in one or two activities (7%, respectively). Compared to those with a high education, men with a low education level were less often independent (22%) and more often dependent in 1, 2, 4 or 5 activities (7%, 6%, 3%, 5%, respectively). Among women, skilled manual class (17%), unskilled manual class (23%) and housewives (19%) were less often independent in functioning and more often dependent in 2-5 activities (1-7%, 2-12%, 1-9%, respectively) than upper non-manual class women. Yet, women with a middle education were less often dependent in all five activities (8%) than those with a high education. Among women, the rather small groups with unknown occupational class or unknown education had poorer functioning and were clearly more often dependent in all five activities than the reference groups (occupation unknown 36%, education unknown 31%) (Figure 4).

Unskilled manual class men were less often free of diseases (12%) or had only one disease (24%), and more often three diseases (15%) than upper non-manual class men had. According to education, men with a low education had poorer outcomes throughout the multimorbidity scale (6-11%), and those with a middle education were less often free of the diseases (8%) and had more often two diseases (4%) than those with a high education. Among women, those from unskilled manual class were less often free of diseases (5%) than those from upper non-manual class (Figure 5). Among men, there were no significant differences in SRH according to occupational class but those with low education levels reported more fairly poor (10%) SRH, and less very good (4%) or fairly good (10%) SRH than those with a high education level. Among women, those from skilled and unskilled manual classes, as well as housewives reported more fairly poor (7%, 9%, 9%), and less very good (2%, 2%, 2%) or fairly good (9%, 11%, 11%) SRH than those from the upper non-manual class. In addition, women with low and middle education had more frequently poor (5%, 6%) or fairly poor (8%, 7%), and less often very good (3%, 2%) or fairly good (10%, 9%) SRH than those with a high education (Figure 6).

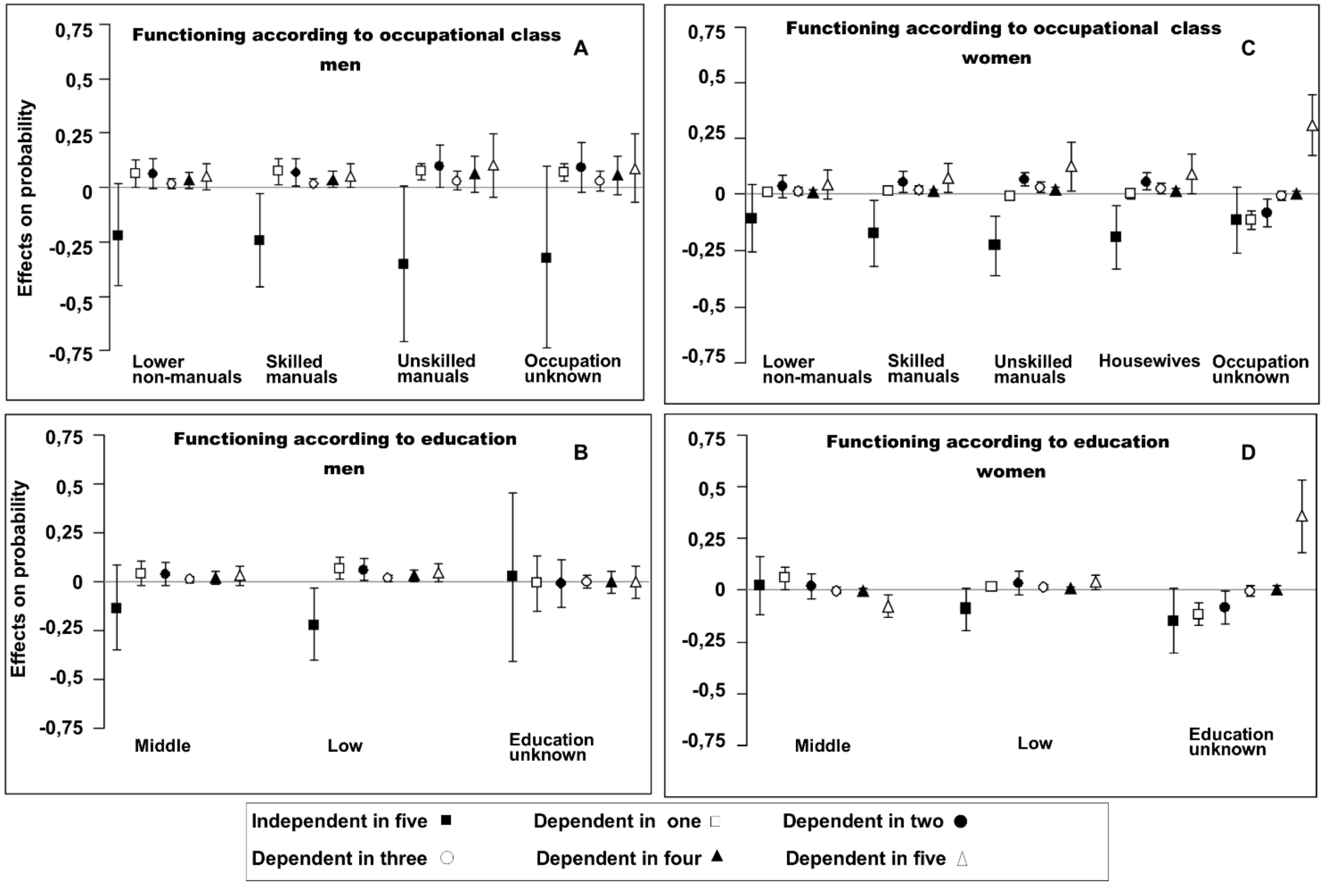

Figure 4. Functioning according to occupational class and education. Marginal effects after ordered logistic regression. Figures A and B show results for men, C and D for women. Reference groups are upper non-manual class and those with a high education level.

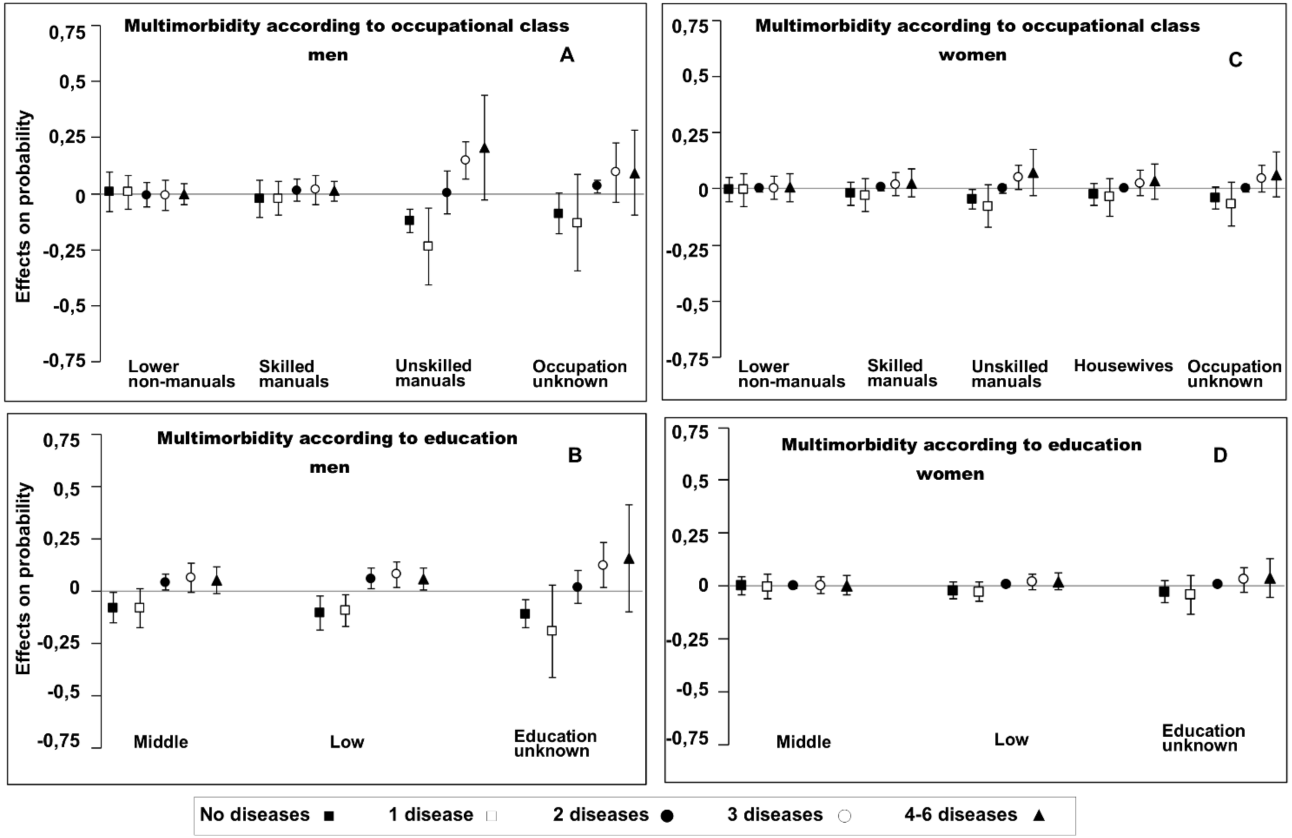

Figure 5. Multimorbidity according to occupational class and education. Marginal effects after ordered logistic regression. Figures A and B show results for men, C and D for women. Reference groups are upper non-manual class and those with a high education level.

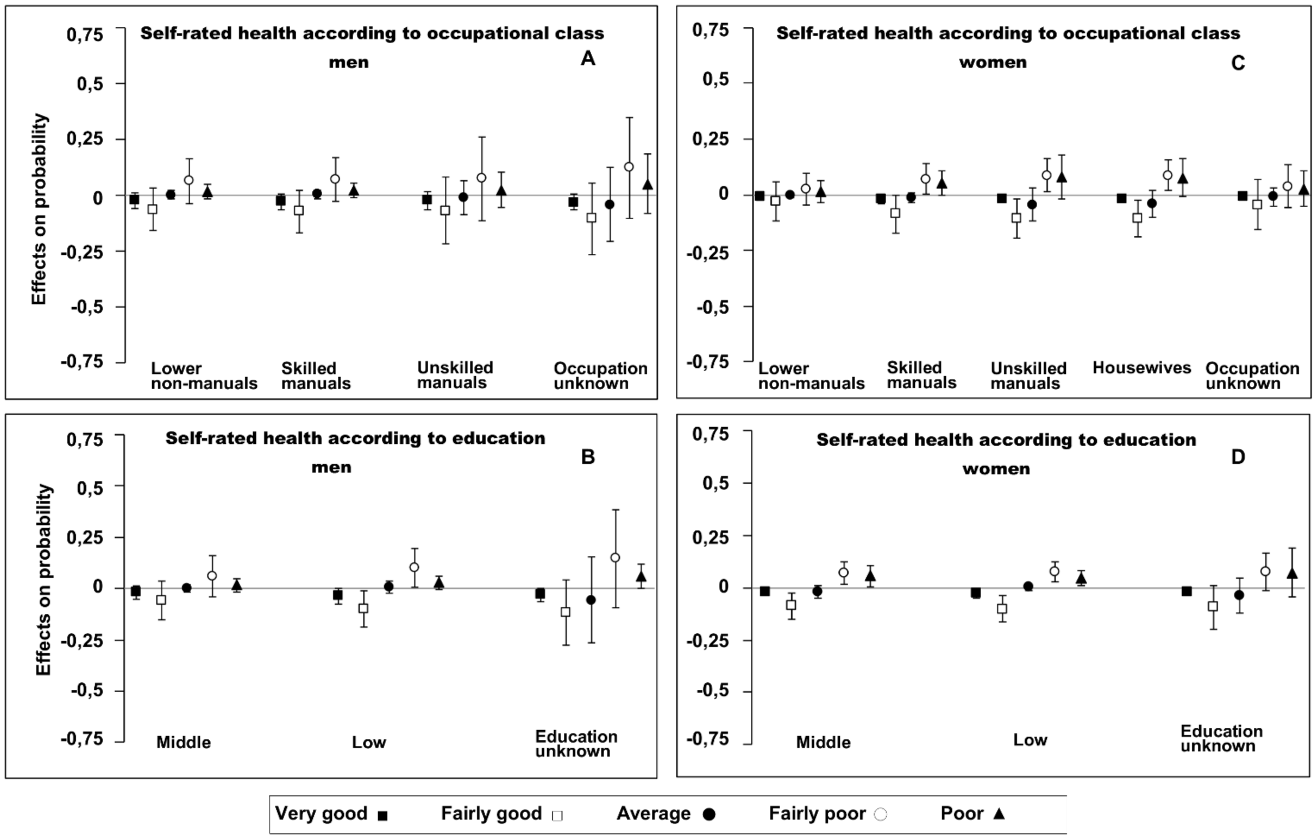

Figure 6. Self-rated health according to occupational class and education. Marginal effects after ordered logistic regression. Figures A and B show results for men, C and D for women. Reference groups are upper non-manual class and those with a high education level

7.3 Association of education with biomarkers (sub-study II)

The associations between the level of education and eight biomarkers were assessed in a cross-sectional setting. Chosen cardiometabolic (BMI, leptin, HDL-cholesterol, ratio of HDL and total cholesterol and triglycerides) and inflammatory (IL-6, CRP and IL-1Ra) biomarkers are predictors of decline in functioning and thus, their role as mediators between education and functioning was assessed. Women had higher levels of HDL-cholesterol and leptin than men did (p-values 0.04 and <0.001). However, the association between education and biomarkers was very similar for both genders and interaction terms showed no reason to stratify analyses by gender.

Those with a high education level had the best biomarker levels in all cardiometabolic biomarkers and overall differences between educational groups were significant in BMI and leptin. In the inflammatory biomarkers, those with a high education level had the lowest level of IL-1Ra and the highest in IL-6 but differences between educational groups were not significant (Table 8).

Table 8. Cardiometabolic and inflammatory biomarker levels by education, median, interquartile range, and p-value from the Kruskal-Wallis Test.

	Education			
	High	Middle	Low	
Population N (%)	39 (15)	182 (70)	39 (15)	
Cardiometabolic biomarkers				P-value
Body mass index, kg/m^2	22.9	23.9	25.8	0.004
	20.6-25.2	22.3-26.2	23.1-27.9	
Leptin, ng/mL	6.7	13.2	12.6	0.007
	4.2-12.9	6.2-24.4	8.1-21.5	
High-density lipoprotein cholesterol,	1.58	1.35	1.33	0.08
(HDL) mmol/L	1.27-1.84	1.09-1.66	1.09-1.62	
Ratio of HDL and total cholesterol	0.26	0.26	0.24	0.30
	0.22-0.33	0.20-0.31	0.19-0.30	
Triglycerides, mmol/L	1.34	1.43	1.74	0.18
	1.00-1.86	1.17-1.97	1.11-2.41	
Inflammatory biomarkers				
Interleukin-6, pg/mL	2.98	2.80	2.36	0.08
	1.69-6.95	1.65-5.30	1.36-4.15	
C-reactive protein, mg/L	1.40	1.70	1.20	0.17
	0.50-5.05	0.50-4.15	0.18-3.53	
Interleukin-1 receptor antagonist, pg/mL	348	356	364	0.17
	256-422	261-452	245-698	

Logistic regression analyses showed that in terms of individual cardiometabolic biomarkers, those with a low education had higher BMI (OR 5.76, 95% CI 2.00-16.60) than those with a high education. In addition, those with a middle education had higher leptin (2.75, 1.07-7.09) and lower HDL-cholesterol (2.46, 1.04-5.81) levels than those with a high education. There were no statistically significant differences in inflammatory biomarkers (Figure 7). Biomarkers were also analyzed in cardiometabolic and inflammatory scores. Descriptive statistics showed that the lower the education the higher the cardiometabolic score whereas in the inflammatory score, those with middle education levels had the highest score. Functioning had a graded association with both biomarker scores showing lower points in the Barthel Index for those with more high risk readings (Table 9). The ordered logistic regression analysis of the association between education and the biomarker scores showed that those with a low education level (coefficient 1.10, 95% CI 0.20-1.99) and those with middle education levels (coefficient 0.84, 95% CI 0.14-1.53) had more cardiometabolic biomarker readings in the high risk category than those with a high education but result was not significant in the inflammatory score (results not shown).

In order to assess the role of biomarkers in the association between educational level and functioning, negative binomial regression models were run. The first model with adjustment for sex showed that those with a high education had better functioning than those with a low and middle education levels. Second, biomarker scores were added to the analysis separately. When the cardiometabolic score was included in the model, the differences between educational levels in functioning attenuated but the inflammatory score did not change the association. Third, all biomarkers were scored and added to the model. The score of all studied biomarkers attenuated the association between education and functioning approximately as much as the cardiometabolic biomarkers score did alone. Fourth, smoking, alcohol use and diseases were added to the model. The differences in functioning attenuated but did not disappear totally. In the final model, including the combined biomarker score, smoking, alcohol use and diseases, the educational differences in functioning were no longer significant (Table 10).

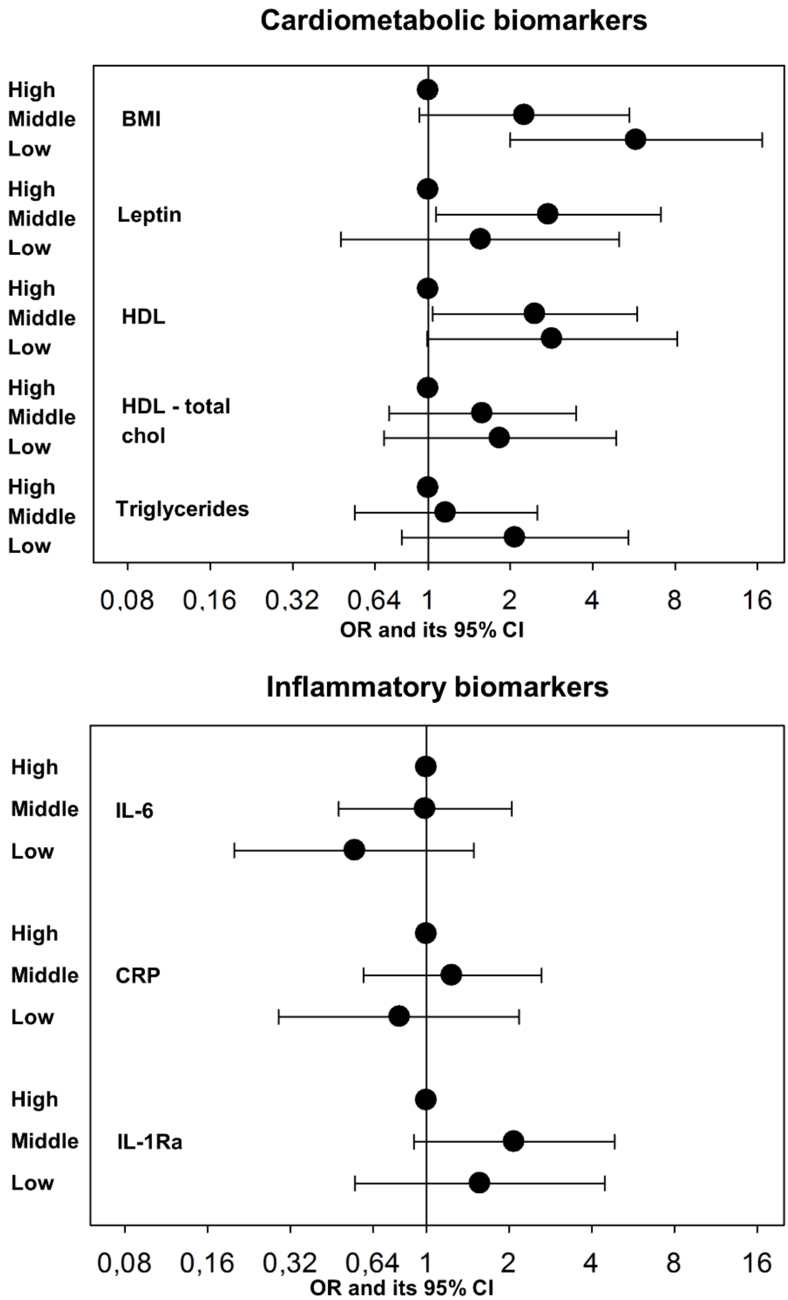

Figure 7. Odds ratios of having high risk readings in cardiometabolic and inflammatory biomarkers according to education. Sex adjusted logistic regression analyses.

Table 9. Mean number of cardiometabolic and inflammatory biomarkers in the high risk tertile according to the level of education and functioning.

	Cardiometabolic markers (BMI, leptin, HDL, ratio of HDL and total cholesterol, triglycerides) range 0-5	**Inflammatory markers** (IL-6, CRP, IL-1Ra) range 0-3
Education		
High	1.03	0.87
Middle	1.62	1.07
Low	1.82	0.79
p-value Kruskal-Wallis test	0.05	0.23
Functioning		
Barthel Index points		
100	1.33	0.83
61-99	1.73	0.90
0-60	1.86	1.63
p-value Kruskal-Wallis test	0.08	< 0.001

Table 10. Likelihood of good functioning according to education. Rate ratios (95% CIs) from Negative binomial regression models with a log link.
* p-value < 0.05, ** p-value < 0.01, *** p-value < 0.001

	Sex	Sex and cardiometabolic score	Sex and inflammatory score	Sex and score for all biomarkers	Sex, smoking, alcohol use and diseases	Sex, score for all biomarkers, smoking, alcohol use and diseases
Education						
High, ref	1.00	1.00	1.00	1.00	1.00	1.00
Midde	0.88 (0.83-0.93)***	0.91 (0.87-0.97)**	0.88 (0.82-0.95)***	0.92 (0.87-0.97)**	0.92 (0.86 to 0.99)*	0.95 (0.89-1.02)
Low	0.92 (0.84 - 1.00)*	0.93 (0.85 - 1.01)	0.90 (0.81 - 0.99)*	0.93 (0.85-1.01)	0.96 (0.87 to 1.05)	0.95 (0.87-1.04)

7.4 Socioeconomic status as a predictor of mortality (sub-study III)

Mortality from all-causes, CVDs and dementias were assessed separately according to occupational class and education level. In the analyses with 33-36 months follow-up, men and women were studied together because of the similarly patterned associations between socioeconomic status and mortality and because interaction terms of gender with occupational class or with education were not statistically significant.

The age adjusted probability of all-cause mortality varied from 37% to 56% between upper non-manual class and unskilled manual class in the 36-months follow-up, and mortality was highest for those with an unknown occupation (62%). Among housewives the mortality was 51%. Based on education, participants with a high education level had the lowest mortality (44%) while for those with a middle education level mortality was 49%, for those with a low education level 50% and for those with an unknown education 65%. Even though there was variation in all-cause mortality at an absolute level, the differences were not statistically significant.

Age and gender adjusted hazard ratios (HR) from the Cox regression analyses showed higher all-cause mortality for other occupational classes when compared with upper non-manual class (lower non-manual class HR 1.61, 95% CI 1.11-2.32; skilled manual class HR 1.56, 95% CI 1.09-2.25; unskilled manual class HR 1.88, 95% CI 1.20-2.94; housewives HR 1.77, 95% CI 1.15-2.71; and occupation unknown HR 2.33, 95% CI 1.41-3.85). An adjustment for multimorbidity decreased the hazards of mortality, yet, the differences remained significant. After adjustment for functioning the differences were no longer significant between occupational classes. When multimorbidity and functioning were analyzed in the same model, the hazard ratios decreased only marginally compared with the effects of functioning alone (Figure 8). According to education level, mortality was significantly higher for those with an unknown education level (HR 1.98, 95% CI 1.29-3.03) when compared with a high education level also after adjustments for multimorbidity and functioning (Figure 9).

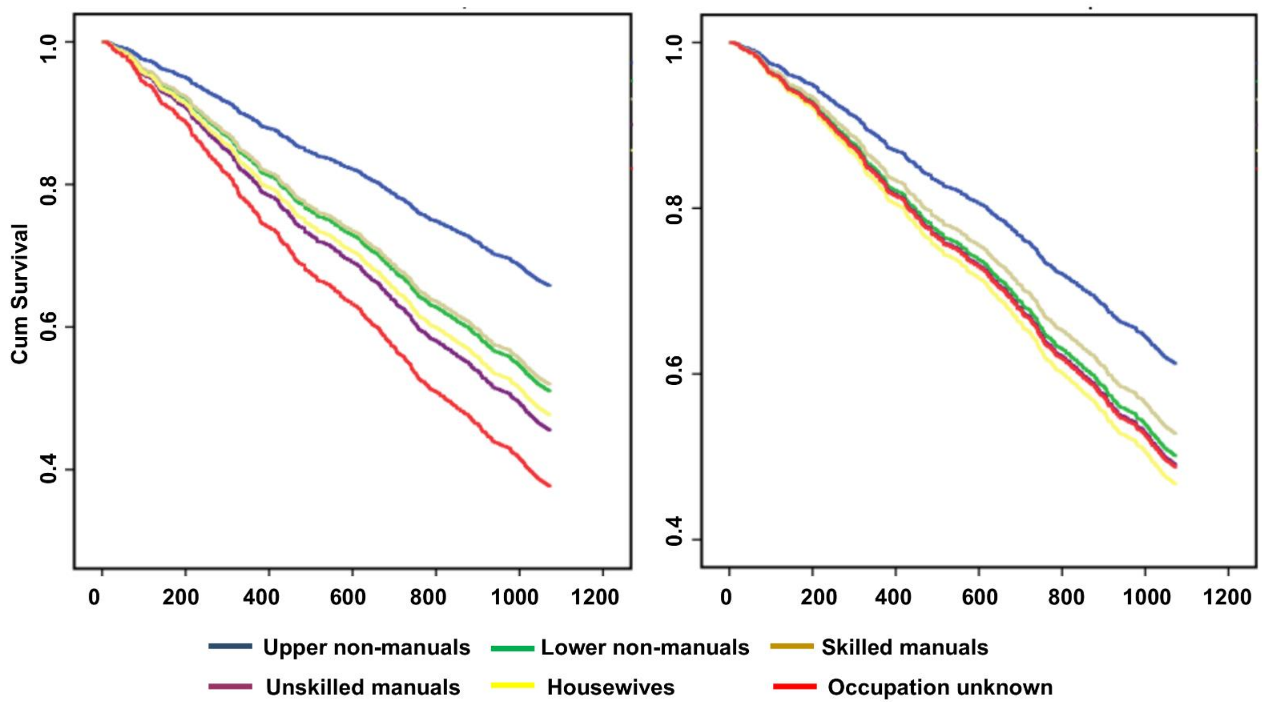

Figure 8. All-cause mortality according to occupational class. Follow-up from 23.2.2010 to 31.1.2013. Cox regression models adjusted for age and gender (left) and additionally for multimorbidity and functioning (right).

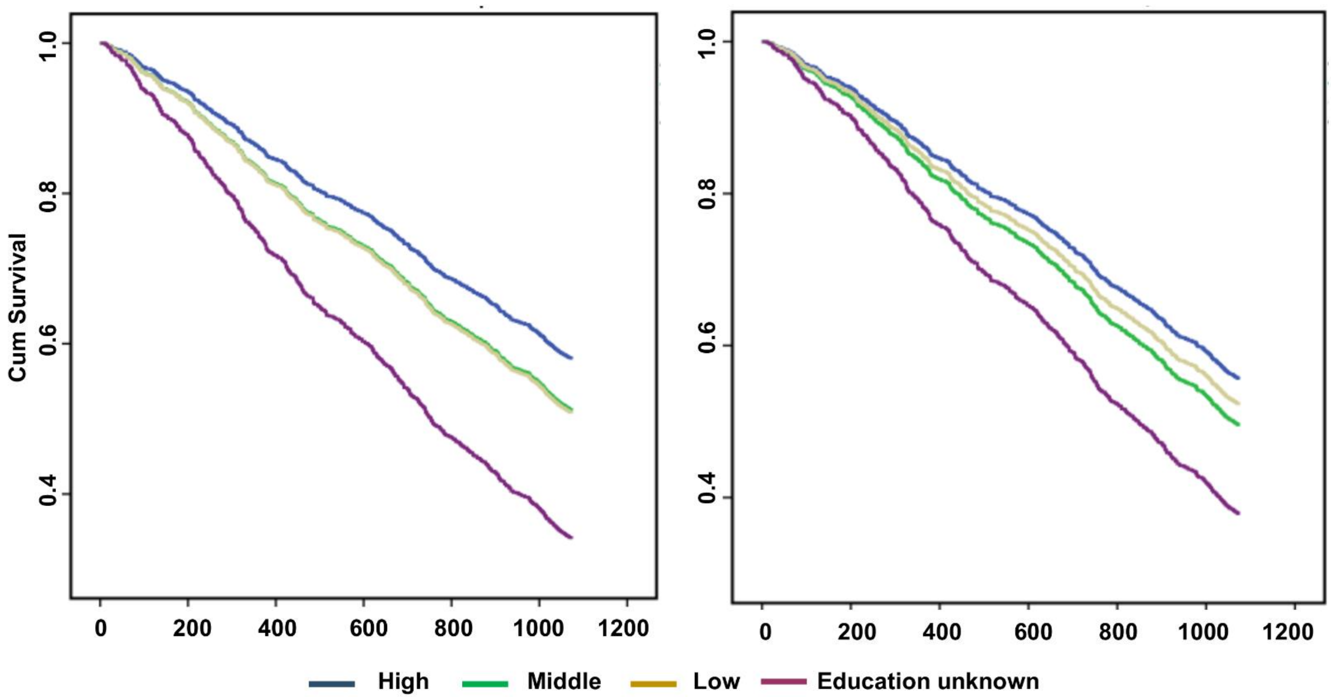

Figure 9. All-cause mortality according to education. Follow-up from 23.2.2010 to 31.1.2013. Cox regression models adjusted for age and gender (left) and additionally for multimorbidity and functioning (right).

Mortality from CVDs and dementias were assessed at 33 months of follow-up. Out of the 581 deceased, 191 (33%) died from dementias and 263 (45%) died from CVDs. When analyzing mortality from dementias according to occupational class, the mean survival decreased gradually from upper non-manual class (976 days) to unskilled manual class (895), to being the lowest for housewives (894) and for those with an unknown occupation (850). The pattern was similar in mortality from CVDs, with the exception that the unknown occupation group had the second longest survival after the upper non-manual group. According to the level of education, mean survival was highest for those with a high education. Survival decreased gradually towards those with a low education, to being shortest for the education unknown group (Table 11).

Age and gender adjusted HRs from the Cox regression analysis showed that mortality from dementias was higher among other occupational classes than among upper non-manual class (lower non-manual class HR 2.58, 95% CI 1.11-6.01; skilled manual workers HR 2.42, 95% CI 1.04-5.60; unskilled manual workers HR 2.95, 95% CI 1.13-7.70; housewives HR 2.77, 95% CI 1.10-7.00; and occupation unknown HR 5.16, 95% CI 1.91-13.91). According to education level, mortality from dementias was higher for the education unknown group (HR 3.23, 95% CI 1.62-6.45) when compared with upper non-manual class. Adjustment for functioning decreased differences between occupational classes. Despite the higher HRs in CVDs mortality in the other occupational classes, only housewives differed significantly (HR 1.91, 95% CI 1.03-3.54) from the upper non-manual class. Mortality from the CVDs did not differ significantly between the educational groups.

Table 11. Mortality from dementias and cardiovascular diseases (CVDs) according to occupational class and education. Hazard ratios (HR 95% CIs) from Cox regression models and mean survival time in days from Kaplan-Meier analysis with upper non-manual class and people with high education as the reference groups

	Cause of death dementias					Cause of death CVDs				
	Mean a	HR b	95% CI	HR c	95% CI	Mean a	HR b	95% CI	HR c	95% CI
Occupational class										
Upper non-manual	976	1				921	1			
Lower non-manual	912*	2.58*	(1.11-6.01)	1.81	(0.77-4.26)	889	1.36	(0.79-2.35)	1.29	(0.75-2.22)
Skilled manual	914*	2.42*	(1.04-5.60)	1.58	(0.68-3.71)	884	1.36	(0.80-2.33)	1.22	(0.71-2.10)
Unskilled manual	895*	2.95*	(1.13-7.70)	1.94	(0.74-5.10)	862	1.57	(0.80-3.08)	1.39	(0.70-2.76)
Housewives	894*	2.77*	(1.10-7.00)	1.98	(0.78-5.06)	855	1.91*	(1.03-3.54)	1.85	(1.00-3.43)
Occupation unknown	850*	5.16**	(1.91-13.9)	2.01	(0.72-5.60)	898	1.30	(0.55-3.06)	1.02	(0.41-2.51)
Education										
High	944	1				912	1			
Middle	934	1.06	(0.61-1.84)	1.11	(0.63-1.95)	882	1.25	(0.83-1.90)	1.22	(0.81-1.85)
Low	903	1.42	(0.86-2.35)	1.20	(0.72-2.01)	881	1.09	(0.73-1.61)	1.00	(0.68-1.49)
Education unknown	770*	3.23**	(1.62-6.45)	1.82	(0.88-3.75)	869	1.11	(0.51-2.42)	1.00	(0.44-2.28)

a = Mean survival time in days
b = Age and gender adjusted model
c = Age, gender and functioning adjusted model
* P-value < 0.05, ** P-value < 0.01

7.5 Occupational class as a predictor of long-term care use (sub-study IV)

Differences in LTC use between occupational classes were analyzed cross-sectionally at the baseline. Entering LTC was assessed in a 34-month follow-up for those who were not in LTC at the baseline. LTC use and entering LTC were analyzed in total and separately for public and private LTC facilities.

There were 2,862 study participants, of which 32% were in LTC at the baseline, 21% entered LTC during the follow-up, and 47% did not use LTC during the study (Table 12). Overall, almost half of the participants used public LTC facilities (46%) and around one-fifth (18%) used private LTC facilities. In addition, there were people who used both kinds of facilities, both public and private (11%).

Descriptive analyses showed that LTC use at baseline and during the follow up were higher among skilled and unskilled manual classes than among upper and lower non-manual classes. LTC use was lowest for housewives and highest for those with an unknown occupation at the baseline. However, entering LTC was lowest for those with an unknown occupation. The study utilized four waves of data collection. LTC use at baseline and entering LTC during the follow-up were gradually less frequent in the later study years (p-value < 0.001). Staying and entering LTC were more frequent for women than for men (p-value < 0.001). During the 34 months study period, overall, almost half (47%) of the participants died. In total, 68% of the 908 people who were in LTC at baseline died. Mortality for those 606 people who entered LTC during the follow-up was 46%.

Table 12. LTC users at baseline and during the follow-up and non-LTC users during the study by occupational class, study year and gender (P-values from the chi-square test).

	Baseline	LTC at the baseline	Entering LTC in 34-month follow-up	Non-LTC users
	N	%	%	%
Total population	2,862	31.7	21.2	47.1
Occupational class				
Upper non-manual	230	29.1	18.3	52.6
Lower non-manual	801	27.8	21.0	51.2
Skilled manual	1,019	29.5	22.9	47.6
Unskilled manual	232	39.7	24.6	35.8
Housewives	254	26.0	22.8	51.2
Unknown occupation	326	48.8	14.7	36.5
P-value		< 0.001	0.065	< 0.001
Study year				
2001	892	39.1	27.6	33.3
2003	476	31.3	19.5	49.2
2007	687	31.1	18.6	50.2
2010	807	24.3	17.2	58.5
P-value		< 0.001	< 0.001	< 0.001
Gender				
Women	2,276	34.6	21.8	43.6
Men	586	20.6	18.6	60.8
P-value		< 0.001	< 0.001	< 0.001

LTC use at baseline was studied with logistic regression analyses adjusted for age, gender, and study year (model 1), model 1 + functioning, and multimorbidity (model 2), model 1 + having children (model 3), and all covariates in one (model 4). The interaction terms in LTC use between occupational class and gender, and between occupational class and study year were tested for statistical significance. Statistically significant interaction terms were found between occupational class and gender in public LTC use (unknown occupation#women model 1) OR 3.92, 95% CI 1.48-10.38, model 2) OR 3.96, 95% CI 1.26-12.50, and model 3) OR 3.63, 95% CI 1.29-10.19). In addition, statistically significant interaction terms were found between occupational class and study year in private LTC (unknown occupation#2010 model 1) OR 3.80, 95% CI 1.02-14.15, model 2) OR 4.50, 95% CI 1.10-18.40, model 3) OR 4.27, 95% CI 1.08-16.80, and model 4) OR 4.24, 95% CI 1.01-17.81.

In general, the upper non-manual class had higher odds of using LTC in total than other hierarchical occupational classes but the differences were statistically significant only in one case. In a fully adjusted model, skilled manual class (OR 0.68, 95% CI 0.46–0.99, model 4) used less LTC than upper non-manual class. In addition, housewives (OR 0.53, 95% CI 0.33–0.87, model 4) stayed in LTC less frequently and those with an unknown occupation (OR 1.49, 95% CI 1.01–2.21, model 3) stayed in LTC more frequently than the upper non-manual class. However, among the unknown occupation group, the difference was found only in models one and three (Table 13).

Public LTC use was higher among unskilled manual class (OR 1.59, 95% CI 1.02–2.48, model 3) than among upper non-manual class when the adjustment included age, gender, study year, and having children. The interaction term showed that there was variation between occupational class and gender in public LTC use. Thus, the analysis was stratified by gender. The result revealed that women with an unknown occupation used more public LTC (OR 2.23, 95% CI 1.24–4.04, model 4) than upper non-manual class women; however, there were no significant differences among men.

Private LTC use was lower among lower non-manual class (OR 0.54, 95% CI 0.35–0.85, model 4), skilled manual class (OR 0.40, 95% CI 0.26–0.62, model 4), and housewives (OR 0.40, 95% CI 0.22–0.74, model 4) than among the upper non-manual class. As suggested by the significant interaction terms between occupational class and study year, the analysis was stratified by the study year for the unknown occupation group. There was variation in private LTC use between the study years among the unknown occupation group in relation to upper non-manual class. The unknown occupation group used less private LTC in 2001, 2003, 2007 than the upper non-manual class but more private LTC in 2010. The differences were, however, significant only in model 2 in 2001 (OR 0.41, 95% CI 0.17-0.99, model 2) and in all models in 2003 (OR 0.07, 95% CI 0.01-0.65, model 4). Thus, a significant interaction term indicated a change in the direction of the differences.

Entering LTC was studied with competing risks regression models adjusted for age, gender, and study year (model 1), model 1 + functioning, and multimorbidity (model 2), model 1 + living alone and having help at home (model 3), and all covariates in one (model 4). The same interactions were tested in the follow-up analyses as in the baseline analyses. Significant interaction terms were found between occupational class and study year (Table 14).

Table 13. LTC use in total and separately for public and private LTC facilities according to occupational class. Odds ratios and 95% confidence intervals from the logistic regression analyses. * Difference is statistically significant.

	LTC in total			
	Age, gender, and study year (Model 1)	Model 1 + functioning, and multimorbidity (Model 2)	Model 1 + having children (Model 3)	Model 2 + having children (Model 4)
Upper non-manual class (reference category)	1	1	1	1
Lower non-manual class	0.83 (0.59-1.16)	0.72 (0.48-1.06)	0.81 (0.57-1.15)	0.70 (0.47-1.04)
Skilled manual class	0.90 (0.65-1.25)	0.68 (0.47-1.00)	0.89 (0.64-1.25)	0.68 (0.46-0.99)*
Unskilled manual class	1.27 (0.85-1.91)	0.98 (0.62-1.57)	1.31 (0.87-1.98)	0.99 (0.62-1.59)
Housewives	0.59 (0.39-0.90)*	0.54 (0.33-0.87)*	0.58 (0.38-0.89)*	0.53 (0.33-0.87)*
Unknown occupation	1.76 (1.21-2.56)*	1.51 (0.97-2.34)	1.49 (1.01-2.21)*	1.29 (0.82-2.03)
	Public LTC			
	Age, gender, and study year (Model 1)	Model 1 + functioning, and multimorbidity (Model 2)	Model 1 + having children (Model 3)	Model 2 + having children (Model 4)
Upper non-manual class (reference category)	1	1	1	1
Lower non-manual class	1.01 (0.69-1.46)	0.88 (0.58-1.34)	0.99 (0.68-1.46)	0.86 (0.56-1.32)
Skilled manual class	1.14 (0.80-1.63)	0.89 (0.59-1.33)	1.15 (0.79-1.65)	0.88 (0.58-1.33)
Unskilled manual class	1.52 (0.98-2.36)	1.17 (0.71-1.92)	1.59 (1.02-2.48)*	1.19 (0.73-1.96)
Housewives	0.79 (0.50-1.24)	0.73 (0.44-1.22)	0.80 (0.50-1.27)	0.76 (0.45-1.28)
Unknown occupation				
Women	3.12 (1.90-5.11)*	2.74 (1.55-4.84)*	2.64 (1.56-4.46)*	2.23 (1.24-4.04)*
Men	0.84 (0.36-1.94)	0.64 (0.23-1.76)	0.74 (0.30-1.82)	0.67 (0.24-1.86)
	Private LTC			
	Age, gender, and study year (Model 1)	Model 1 + functioning, and multimorbidity (Model 2)	Model 1 + having children (Model 3)	Model 2 + having children (Model 4)
Upper non-manual class (reference category)	1	1	1	1
Lower non-manual class	0.56 (0.37-0.86)*	0.56 (0.36-0.87)*	0.54 (0.35-0.83)*	0.54 (0.35-0.85)*
Skilled manual class	0.44 (0.29-0.67)*	0.41 (0.26-0.63)*	0.44 (0.29-0.67)*	0.40 (0.26-0.62)*
Unskilled manual class	0.73 (0.43-1.23)	0.64 (0.37-1.11)	0.73 (0.43-1.24)	0.63 (0.36-1.09)
Housewives	0.42 (0.24-0.74)*	0.43 (0.23-0.77)*	0.40 (0.22-0.72)*	0.40 (0.22-0.74)*
Unknown occupation				
2001	0.47 (0.21-1.08)	0.41 (0.17-0.99)*	0.52 (0.24-1.15)	0.48 (0.20-1.20)
2003	0.05 (0.01-0.48)*	0.06 (0.01-0.56)*	0.06 (0.01-0.54)	0.07 (0.01-0.65)*
2007	0.64 (0.24-1.75)	0.54 (0.19-1.54)	0.68 (0.25-1.85)	0.56 (0.20-1.59)
2010	1.65 (0.58-4.69)	1.48 (0.46-4.75)	2.03 (0.68-6.02)	1.70 (0.52-5.49)

Table 14. Significant interaction terms between occupational class and study year in entering private LTC. The reference group is upper non-manual class.

	Model 1	Model 2	Model 3	Model 4
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Lower non-manual class#2010	6.45 (1.39-29.93)	7.10 (1.51-33.42)	6.51 (1.34-31.60)	6.89 (1.38-34.35)
Skilled manual class#2010	4.56 (1.05-19.79)	5.06 (1.16-22.11)	4.92 (1.09-22.24)	5.03 (1.10-22.88)
Unskilled manual class#2003	4.32e-08	4.58e-08	6.46e-08	6.35e-08
	(8.22e-09-2.27e-07)	(8.78e-09-2.39e-07	(9.47e09-4.40e-07)	(9.23e-09-4.37e-07)

Entering LTC in total was higher for the unskilled manual class (SHR 1.52, 95% CI 1.02–2.27, model 1) than for the upper non-manual class after adjusting for age, gender, and study year. After other adjustments, entering LTC in total did not differ statistically significantly between occupational classes. There were no statistically significant differences in entering public LTC. Entering private LTC was lower among the skilled manual class (SHR 0.58, 95% CI 0.35–0.97, model 2) than among the upper non-manual class. However, the difference was statistically significant only in model 2, which included adjustments for age, gender, study year, functioning, and multimorbidity.

Since significant interaction terms were found between occupational class and study year in entering private LTC, analyses were also conducted stratified by the study year. Result suggested that entering private LTC was lower for other occupational classes than for upper non-manual classes in 2001, 2003, and 2007. Lower non-manual class (SHR 0.31, 95% CI 0.10-0.94) and skilled manual class (SHR 0.36, 95% CI 0.14-0.94) differed significantly from the upper non-manual class in 2001 and the unskilled manual class in 2003 (SHR 1.56e-07, 95% CI 1.59e-08-1.52e-06). However, in 2010, entering private LTC was higher among the lower non-manual class, the skilled manual class, and among the unknown occupation group than among the upper non-manual class, though these differences were not statistically significant.

The findings from the competing risk regression analysis for entering LTC in total are shown in the Figure 10. In the figure, the light grey area indicates the cumulative incidence of entering LTC and the dark grey area indicates the cumulative incidence of dying without entering LTC. The white area in the figure indicates the probability of being free from the two events, so to say, being alive and living at home. The probability of entering LTC was highest for the unskilled manual class (41%), lowest for the upper non-manual class (26%), and approximately 30% for the other occupational classes. The probability of dying was highest for the unknown occupation group (28%), lowest for the unskilled manual class (18%), and around 20-23% for the other occupational classes. The probability of being event-free was highest for the upper non-manual class (55%) and lowest for the unskilled manual class (41%).

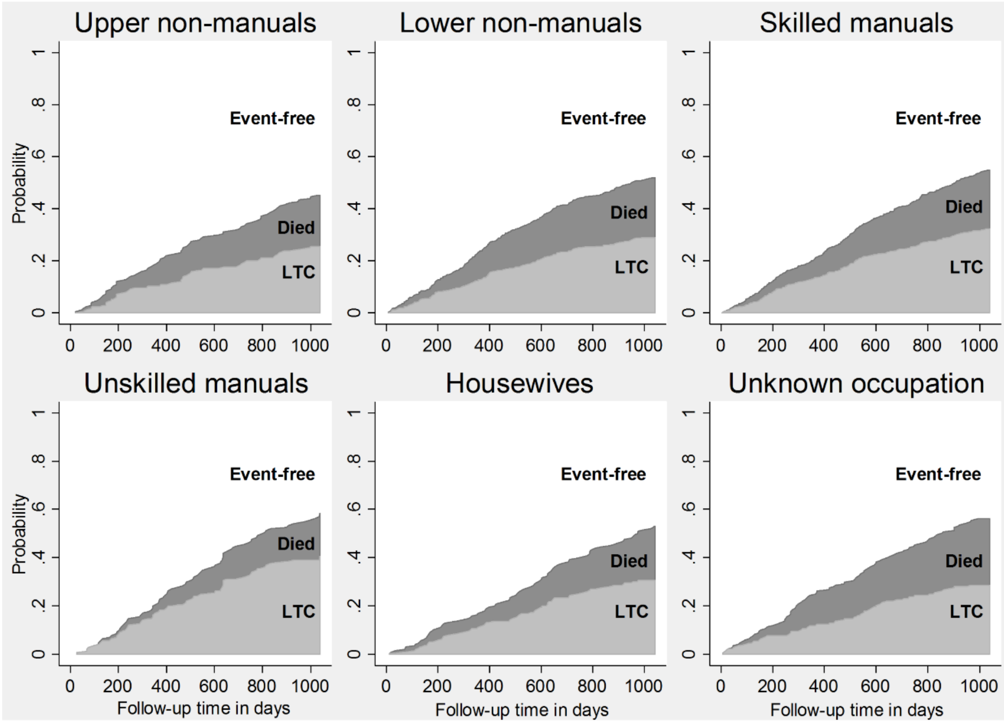

Figure 10. Stacked cumulative incidence of entering long-term care (LTC), dying, or being free from the two events in the 34-month follow-up according to occupational class. The figure shows the cumulative incidence for LTC use in total. The light grey area shows the probability of entering LTC, and the dark grey area shows the probability of dying without entering LTC. The white area, “event-free”, indicates people who did not enter LTC or die during the follow-up. (Enroth et al. 2017)

8 Discussion

8.1 Summary of the main findings

In terms of absolute differences, those with a higher socioeconomic status had better health when measured in terms of functioning, multimorbidity, and self-rated health than those with lower socioeconomic status. This was true for both men and women, and with both socioeconomic status indicators. Results between men and women varied slightly in the relative measures. Among women, manual classes had poorer functioning and self-rated health than those in the upper non-manual class, while among men similar differences were found in functioning and multimorbidity. Based on education level, women with middle and low education levels had poorer self-rated health than women with a high education level. Among men, those with a low education level had poorer health than those with a high education level when measured with all three health indicators.

The percentage of high risk readings in cardiometabolic biomarkers, (BMI, leptin, HDL-cholesterol, ratio of HDL and total cholesterol, and in triglycerides) was lowest for those with a high education level. With regard to the inflammatory biomarkers (IL-6, CRP, IL-1Ra) the biomarker levels fluctuated between educational groups. In terms of the relative differences, those with a low education level had higher BMI, those with a middle education level had higher leptin levels and lower HDL-cholesterol levels than those with a high education level. In addition, when biomarkers were analyzed as scores, those with low and middle education levels had more high risk readings in the cardiometabolic score than those with a high education. Cardiometabolic biomarkers explained a small part of the educational differences in functioning.

All-cause mortality as well as mortality from CVDs and dementias was gradually higher towards the lower socioeconomic groups. With the relative measurements, significant differences were found in all-cause and dementia mortality between occupational classes. Differences were not as pronounced in level of education as they were with occupational class. There were no statistically significant differences in CVDs mortality according to either of the socioeconomic status indicators even though the hazard ratios were the lowest for the upper non-manual class.

LTC use in total and in public LTC facilities did not differ substantially between occupational classes. Private LTC use, however, was lower for most of the other occupational classes in comparison with upper non-manual class, especially at baseline. Interaction terms between occupational class and study year suggested a change in the pattern of private LTC use. The upper non-manual class used more often private LTC than other occupational classes in the earlier study years but not in the last study year.

In order to take full advantage of the data sets, the two groups, housewives and those with an unknown socioeconomic status, were studied parallel to hierarchical socioeconomic groups. In general, housewives had poorer functioning and self-rated health and higher mortality than the upper non-manual class. However, they were less frequently LTC users than the upper non-manual class. Those with an unknown socioeconomic status had overall poorer health, higher mortality, and they used more LTC in total than the upper non-manual class.

8.2 Methodological considerations

The Vitality 90+ Study

All of the sub-studies were based on the Vitality 90+ Study. Both the mailed surveys and the health-examination were well defined population based data sets that included very old people living in the community and those living in round-the-clock long-term care. The response rate was very high for the mailed surveys and relatively high for the health-examination data. A strength related to the survey data is that the data were collected repeatedly by using mostly the same questions, which enabled combining data from different years. In addition, one particular advantage of the study was that the exhaustive register data on mortality, and the health and social care service use were linked to Vitality 90+ Study. It enabled follow-up analyses, which were conducted for mortality, and for entering LTC. The health-examination data also included measured health indicators. The information on biomarker levels was analyzed from blood samples and body mass index (BMI) was measured with height and weight.

Even though the data is special in the field of gerontology, there were some issues concerning data and methods that require further consideration. First, all the data sets were based on a population within the city of Tampere. Despite this the data corresponds well to the 90+ population in Finland in terms of the proportion (0.6%)

of 90+ years old people in the total population. The vast majority of the study participants were women (75-80%). However, a very similar gender distribution is seen in the total population in Finland and in this age group (in 2010, 27% of all of the 90+ year-old population were men) (Official Statistics of Finland, 2016d). In addition, there are both urban and rural areas in Tampere, which represents well the situation in Finland. Second, the study had a focus on the 90+ years old. Since only 19% of women and 6% of men from the 1920 birth cohort lived up to 90 years old in Finland (Human Mortality Database, 2015), the oldest old population is highly selected. The mortality selection is higher for men (there are fewer men among the oldest old), which in this study led to a rather small sample of men.

The oldest old as research participants differ from the younger age groups. Decline in physical and cognitive functioning, including problems in vision and hearing, may reduce study participation (Hardy, Allore, & Studenski, 2009). In addition, the use of round-the-clock LTC increases in old age. If elusive groups, such as those with difficulties in filling out the questionnaire or those who live in LTC, are left out of the study, it has consequences for the generalizability of the results. If the most vulnerable groups were systematically excluded from the study, it would lead to a healthy participant bias. Thus, results could be under- or overestimated. Kelfve (2017) showed with Swedish data that health inequalities were underestimated among 69-84 and among 85+years old when proxy respondents or the institutionalized were excluded from analysis. In the current study, the use of proxy respondents was allowed for the mailed surveys and the institutionalized were included in all data sets.

However, even with the inclusive data collection methods, the non-response was 21% for the 2010 mailed survey. If the non-response is not random, which it rarely is, it may cause bias to the results (Ferrie et al., 2009). It was possible to evaluate the non-response group (21% of the population, n = 332) in relation to study participants in the 2010 mailed survey. The comparison was possible in terms of age, sex, and mortality. The comparison showed that age and sex distributions were similar for both groups. However, mortality was higher (HR 1.47, 95% CI 1.25–1.73) among the non-response group than among those who participated in the study (3 years of follow-up). Similar findings are also reported in several other studies (Ferrie et al., 2009). Higher mortality is a sign of poorer health and functioning, and thus suggests that this study may give an overly positive view of the level of health in general.

Information on SES or health, besides mortality, was not available for the non-respondents in the mailed surveys. There is, however, literature of the associations between SES, health and survey non-response. Numerous studies show that people with lower SES have poorer health status than people with a higher SES. In addition, Galea & Tracy (2007) suggest that people with lower SES are less likely to participate in studies. There are, however, other studies showing that non-response is similar in all occupational classes. In the Whitehall II study where civil servants were categorized for three groups 1) high, 2) middle, and 3) low in terms of the employment grade, the non-response at baseline and in the follow-up surveys were similar in all three groups (Ferrie et al., 2009). In general, the level of poor health would be biased in a study only if those with lower SES have a lower response rate. However, the association of SES with the health outcome would be biased only if the non-response rate of those with poor health differs between higher and lower SES. A study from the US showed higher non-response for those with a low education when compared to those with high education level but they did not find substantial differences in disease prevalence between non-respondents and respondents (Shahar, Folsom, & Jackson, 1996). In the current study, it was not possible to estimate whether the non-response varied between socioeconomic groups. What we know is that the use of proxy respondents was higher among manual classes than among the non-manual class and among those with a low education level in comparison to those with high education level. This may suggest that despite lower SES groups' poorer functioning, they are not necessarily underrepresented in the study.

In the health-examination data, where proxy respondents were not allowed because of the biological and anthropometric measurements (blood samples, height, and weight), the non-response rate was 39%. The non-response group included 86 individuals who refused to participate because of their poor physical or cognitive condition, another 45 individuals refused to give a blood sample and seven individuals could not be reached. Since some of the individuals refused to participate in the study referring to poor health, it is probable that the sample in the health-examination represents the healthier end of the basic population. It was not possible to assess the non-response rates according to SES in the health-examination data.

Socioeconomic status

Each person's longest held occupation was used as a measure of occupation. This study used an occupational classification based on the Official Statistic of Finland (1976) first to categorize individual occupations, and second to form hierarchical occupational classes of the individual occupations. This particular classification was chosen to describe the occupational situation at the time when the study participants were at a working age. Determining occupational class for those who did not participate to the labor force may, however, be problematic. In Finland, many women born in the 1920s have a history of labor force participation even though, supposedly, it is more fragmented than that among men. In the current study, the personal longest held occupation was reported for more than 80% of women. A special "occupational" category for women was formed of those who answered in the questionnaire that they are housewives. Approximately 10% of the study population in the mailed surveys were categorized as housewives. Presumably, the group is heterogeneous including both those women taking care of the housework or working on a farm, and those more affluent women who do not have the burden of physical work. In addition, few women reported to be assisting family members in agricultural work. They were first combined with the housewives, however, later in sub-study IV, their work was considered as more comparable with unskilled manual class. The study also included a group of the self-employed. As Galobardes and colleagues (2006) underline, it is not always clear how a self-employed person in a field of manual work with 20 employees should be categorized, if they should be categorized as a manager or a skilled manual worker. The current study categorized entrepreneurs in agriculture as skilled manual workers. Other entrepreneurs were categorized into upper or lower non-manual classes depending on the group that the occupation was closer to. Education as a SES indicator also has some limitations even though it is a very broadly used measure. In the cohorts born in the 1920s, the level of education is quite low. Thus, it is not a perfect measure for differentiating groups from each other. The study included also groups with unknown occupation or education levels. Participants in these groups had high morbidity and mortality, and they were in LTC more often than the other groups. In the unknown occupation or education groups, the percentage of proxy respondents was almost 50, clearly higher than in other socioeconomic groups. These facts are likely to reflect not only the poor health condition in these groups but also the reason why their socioeconomic status is not known.

The analyses were conducted separately according to occupational class and education since they reflect the same issue in general, the person's social status in the hierarchy. The overlap of these measures was, however, cross-tabulated. The chi-square test showed a significant association between occupational class and education (p-value < 0.001). Among the upper non-manual class, 74% had high education level while among the unskilled manual class, 83% had a low education level. The other way round the figures show that of those with a high education almost 90% belonged to non-manual occupations and of those with a low education almost 60% belonged to manual occupations.

In this study, the reference groups in the analyses of relative health inequalities were the upper non-manual class and those with a high education level. The reference groups were relatively small in comparison to other occupational or educational groups. All groups were rather similar in terms of age. The median age was 92 in other occupational classes but 92.5 among the group where occupation was unknown. In educational levels, the median age for those with a high education and those with middle education levels was 91, and for those with a low education and unknown education level it was 92. Men had higher SES. They outnumbered women among the upper non-manual class and among those with a high education. It is also generally known that women have more diseases and poorer functioning than men. These issues together could potentially bias the results showing greater health inequalities in the combined analyses than in the gender specific ones. To avoid this bias, the interaction terms between gender and SES were tested regarding the health outcomes in the combined analyses. In addition, the study reported results from both absolute and relative analyses, and the results were highly similar.

Reliability of self-reported health outcomes

The study was mainly based on self-reported health outcomes. Since approximately 40% of the participants reported dementia, it could potentially cause problems to the accuracy of the self-reports. A doctor diagnosed but self-reported dementia included Alzheimer's disease, other dementias and memory problems. There have been a few attempts to assess the reliability of the self-reported dementia diagnosis and its possible effect on self-reported diseases. The self-reported dementia diagnoses given in the 2001 mailed survey were compared with death certificates for those who died by the year 2010 (Goebeler, 2009). The death certificates included immediate, contributing, intermediate, and underlying causes of death and in addition, all etiologies of dementia coded with the ICD-10. The comparison showed that for 70% of those for whom dementia was mentioned as one of the causes of death, it was also reported in the mailed survey. On the other hand, dementia was found in the death certificates for only 40% of those who reported dementia in the survey (Jylhä et al., 2013). The self-reported diagnoses were also compared with the hospital records in a subsample for 2001 survey (Goebeler, Jylhä, & Hervonen, 2007). Goebeler (2007) suggests that the inter-source agreement was relatively good among the oldest old even though there seems to be more discrepancy in the results than among younger age groups. Most diseases were underreported in the mailed survey, except from dementia, depression, and arthritis (Goebeler et al., 2007). Thus, it would be reasonable to think that the dementia diagnosis is rather over- than underreported in the current study. One probable reason for this is the definition of dementia, which included people with memory decline without a clinical diagnosis, and people with an early stage of dementia. The study allowed the use of proxy answers and for more than 30% of those with reported dementia, the answers were given by proxy. In addition, there is some evidence of the usability of the self-reports that are provided by people with decline in cognition. Walker and colleagues (2004) found that for people with mild-to-moderate cognitive decline, SRH was a predictor of mortality. Overall, even though memory problems are common among the oldest old, and cause uncertainty in the results, it is not likely that the self-reported data would jeopardize the reliability of this study.

Besides doctor diagnosed but self-reported diseases, other self-reported health outcomes were functioning and SRH. The indicators of functioning included ADL and mobility, which are common measures of functioning among older people. Katz and colleagues (1970) originally developed ADL indicators for objective assessment of functioning among older people and chronically ill. Considering the original purpose, functioning measured with these items should be a usable measure also for proxy respondents. The limitation in this type of self-reported measure of functioning in the mailed survey is that the information given may be based on the potential to perform these activities assessed by the respondent, and not on whether they in reality perform them. People who have not recently performed the activities of daily living may over- or underestimate the capacity to perform activities without help and on the other hand, people may be able but choose not to perform the activities by themselves (Guralnik et al., 1992). As Verbrugge and Jette (1994) point out, disability is not only a character of an individual but rather a gap between the capability and the demand of the environment. Thus, for example the living environment and the motivation to perform tasks without assistance may affect self-reported functioning (Verbrugge & Jette, 1994).

The proxy respondents were included in the current study. However, they were not included in the SRH analyses. The participants for whom the answer was given by proxy were older (median age 93 vs. 92), had poorer functioning, had dementia more frequently (84% vs. 31%), and lived less frequently at home (15% vs. 69%) than participants who answered themselves. Thus, analyses of SRH presumably include a healthier population than the analyses of functioning and multimorbidity.

Biomarkers

All of the biomarkers were categorized by using tertiles instead of clinical cut-off values. There were several reasons for this. First, there are no clinical cut-off values for all of the biomarkers studied. For example, clinically relevant thresholds do not exist for the inflammatory biomarkers used in the study. Second, it is not clear whether the clinical cut-off values are suitable for the 90+ population. Inflammatory biomarker levels are expected to be 2-4 times higher among older people than in the general population (Krabbe et al., 2004). Thus, the use of same thresholds could lead to the wrong conclusions. Third, also the subclinical conditions reflected by the biomarkers are suggested as relevant health indicators (Karlamangla et al., 2012), and the study aimed to assess the relative inequalities between the educational groups. Tertiles that were also used in other studies (Fabbri et al., 2015; Koster et al., 2005) were applied in order to be able to analyze the rather small dataset. However, the clinical cutoffs in this study came close to the clinical cutoffs available for the general population (HDL-cholesterol, triglycerides, CRP). There are, however, limitations in using tertiles as cut-off values. The use of BMI as a biomarker can be controversial, yet it is largely used as a biomarker, and has shown to be associated with morbidity and functioning also among the very old (Han, Tajar, & Lean, 2011; Lisko et al., 2015). Accumulation and redistribution of body fat, muscle loss and height loss complicate the interpretation of BMI among the very old people. The association between BMI and functioning is suggested to be U or J-shaped, implying risk of poor functioning for both under- and overweight people (Samper-Ternent & Al Snih, 2012). In the current study, the risk was indicated only in terms of overweight since based on the WHO's criteria (underweight (< 18.50 kg/m*2*), normal weight (18.50–24.99 kg/m*2*), overweight (25.00–29.99 kg/m*2*), and obese (≥ 30.00 kg/m*2*), there were only three underweight people in the study.

Register data

The study took advantage of the administrative register data on mortality and LTC use. Since administrative data is gathered for other than research purposes, it needs to be operationalized carefully (Sund, 2003). One disadvantage in using secondary data is that the quality of data for the research purpose is not known (Sund, 2003). Data on LTC use came from the national care registers, The Care Register for Health Care and The Care Register for Social Welfare. Sund (2012) has attempted to evaluate the accuracy of the Finnish Hospital Discharge Register, which includes the discharges of the Health Care Register. Personal identity codes enable reliable nationwide data linkage. The quality of the register data is systematically checked for some logical errors and data collectors review the data for changes with earlier years. In 2010, 99.5% of the personal identity codes in the register were correct. Based on the results of 32 studies, in recent years, more than 95% of the hospital discharges were identified when register was compared with information from the external data sources. Overall, the register is widely used and the quality is considered good. (Sund, 2012.) In the current study, the preceding quality assessment refers to the accuracy of the discharges of the inpatient wards of health centers and hospital, one form of LTC. The information on residential care and round-the-clock LTC in service homes came from the Social Welfare Register. The coverage of this register is suggested to be less complete than the health registers (Nihtilä & Martikainen, 2007). Sund and Kauppinen (2005) do not evaluate the quality of the register data as such but they suggest that the coverage for this data is better for the 85+ population than for younger people. On the other hand, they bring up the importance of data processing on determining LTC use. In the current study, an experienced statistician did the data cleaning and processing for the analyses. People move between LTC facilities and hospital. In the current study, data was constructed so that the transitions between LTC facilities did not break the LTC period. The LTC use definition was same for all participants, which is why it is unlikely that the results of LTC use between socioeconomic groups would be affected.

Register data on mortality were derived from Statistics Finland. The coverage of the deaths is about 100% since the data are verified from the Population Register. However, the cause of death was missing for 356 persons (0.7% of all deaths) in 2015. Most of the causes of death were based on clinical data. In 2015, a medical autopsy was performed for 5% and a forensic autopsy for 16% of the dead persons. (Official Statistics of Finland, 2015c). The reliability of the causes of death is discussed later.

Ethical considerations

The study was conducted adhering to good scientific practices. The data collection procedure respected the participants' autonomy. The study population was well informed (of how the study population was chosen, the aim of the study, the use of data and results, the people responsible, withdrawal of consent at any time) in order to be able to decide about their participation. If a person filled out the questionnaire and returned it or participated in interviews, it was considered as permission to use the data for research purposes. However, if the data from the questionnaires is linked with data from the authorities (registers on mortality and LTC use), signed informed consent is required (Kuula, 2011). Signed informed consent was requested for the data that were linked with the registers.

Confidentiality and the protection of participants from mental or physical harm are considered vital issues in research practice (Kuula, 2011). In this study, which took place in one city, it was important to maintain the anonymity of the participants. All information that could have made the identification of the participants possible was removed during the process of combining survey and health examination data with registers. Thus, even the researchers did not have the original identification numbers any longer. When the results were published, care was taken that a single person could not be identified from the data. The protection of participants was especially considered when collecting health-examination data. To avoid mental and physical harm, health care professionals conducted examinations. The examiner assessed participant safety for each task in health-examination.

Since the study was population based, it also included people living in institutions and people suffering from dementia and other disabling conditions, which raise the question about research ethics when conducting research on disabled persons. The *Medical research act* (Finlex, 1999) provides some examples of when research is justified among people who are not able to consent. First, the research results should benefit the participant directly or benefit people in the same age group. Second, the study should not cause harm to the participants. Third, the research could be justified if similar results would not be obtained with other study participants. This study meets the aforementioned guidelines well however, such general suggestions should not be the only justification for the study. Kuula (2011) raises another point of view for studying people who are not able to consent. She proposes that research should not systematically exclude special groups such as people with dementia from research studies since it would leave out an essential part of knowledge. People who are not able to consent commonly have the conditions that are the targets of public health interventions, thus it could be considered unethical to exclude the most vulnerable people from public health research.

The data from the mailed surveys in The Vitality 90+ Study are archived in the Finnish Social Science Data Archive. The data descriptions are found online (http://www.fsd.uta.fi/en/).

8.3 Discussion of the main findings

Absolute and relative inequalities

From the public health perspective, absolute and relative measures of health inequalities provide essential but slightly different information. Absolute measures describe the proportion of people with poor health in socioeconomic groups and thus show the importance of poor health in the total population. Relative measures, however, describe the risk of poor health in one group in comparison to another group, and thus show the magnitude of inequalities. (Mackenbach & Kunst, 1997). Mackenbach et al. (2015, 2016) discuss the interpretation of the direction of trends in mortality inequalities when analyses are conducted with absolute and relative measures. Are mortality inequalities increasing or decreasing if a rate ratio (relative inequalities) changes from 2.0 to 2.4 and a rate difference (absolute inequalities) from 100 to 70? Researchers argue that such opposing trends are common and that they are based on mathematics; if the background risk is low, relative inequalities tend to be higher. When the aim is to assess equality, researchers are interested in relative inequalities. Absolute measures show potential inequalities and additionally indicate the size of the "problem"; the size of a disadvantage group and its weight in the total population. Absolute measures provide useful information for policy makers by showing where improved health would most decrease health inequalities.

There are specific features in relative measures that require consideration in the context of the oldest old population. Earlier research has discussed the ceiling effect (Kaplan et al., 1999). It refers to a situation when the outcome of the study, e.g. morbidity, is very high among the study population. If the overall prevalence of the outcome is very high, it may complicate the detection of strong associations with risk factors. It may be difficult to show the excess risk in one group in comparison to another, if the disease prevalence is for example 50%. In such cases it is recommended to assess the absolute differences, too. (Kaplan et al., 1999.) The current study was based on the very old population with high morbidity; thus the main results are discussed in terms of both absolute and relative inequalities.

Functioning

One of the main discoveries of the study was that people with higher socioeconomic status (SES) had better functioning than people with lower SES. The proportion of those who were dependent on others or could not perform one of the studied activities varied from 24% for the upper non-manual class to 55% for the unskilled manual class among men and from 50% to 74%, respectively among women. There are no identical studies with which to compare results but Rostad and colleagues (2009) studied functional limitations based on occupational class that was categorized into two groups, non-manual workers and manual workers. They found that among women aged 80-84, 52% of non-manual classes and 53% of manual classes had limitations in daily activities. The corresponding figures among the 85+ years old were 45% and 65%. Arber and Cooper (1999) studied disability among the British 80+ years old. They found that people in managerial positions reported less disability than other non-manual workers and manual workers. The result was similar for men and women. Thus, absolute inequalities in functioning were similar for the three studies even though occupational class was defined differently.

This study showed that according to level of education, dependency in functioning varied from 29% for those with a high education level to 48% for those with a low education level among men and from 55% to 68% respectively among women. Huisman and colleagues (2003) studied limitations in daily activities according to level of education. The study of 11 European countries reported that among 80+ years old, the limitations in daily activities varied from 40% for high education level to 59% for low education level among men, and from 58% to 62% among women. The differences between educational groups were thus larger among men than among women in both aforementioned studies. Rostad et al. (2009) reported that among 80-84 years old women, from 40% for high to 51% for those with low education level had limitations in daily activities. The proportions were from 50% to 56% among those 85+ years old. All three studies had education categorized at three levels and the measure of functioning was very similar. However, the multinational study did not include institutionalized individuals and the age groups varied between the studies. Based on the available data, absolute inequalities in functioning seems to be larger among women according to education in the current study than in Norway or in the other 11 European countries combined.

In the current study, assessed with the relative measures, manual classes had poorer functioning than upper non-manual class, this result was observed for both genders. Such inequalities were not found among women aged 80+ in a study that was similar to the Vitality 90+ Study in terms of population based data, which was collected with the questionnaires, and with the same inclusion criteria (institutionalized persons included) (Rostad et al., 2009). Occupational class is less frequently used as a SES indicator for older people and especially for older women since their rate of labor force participation was lower than men's. However, in Finland, occupational class is used more as an indicator than elsewhere and the result in the current study is supported by a study that had a focus on persons 65-79 years old. Sulander and colleagues (2003) reported inequalities in functioning measured as difficulties in daily activities according to an occupational measure. They found that office employees fared better in several daily activities than industrial employees or farmers.

This study found that those with a low education level had poorer functioning than those with a high education level, however, this was only among men. The SWEOLD study that reported results together for men and women, found that among 77+ years old, those with a low education level had more problems in activities of daily living and mobility than those with a high education level (Fors & Thorslund, 2015). The multinational European study reported similar findings with the Vitality 90+ Study that relative inequalities in functioning existed for men among 80+ age group but not for women (Huisman et al., 2003). In addition, the Norwegian study supported non-existing inequalities for women (Rostad et al., 2009). It is plausible that education as an indicator of SES works better for men as there are more men in the high education level and in the middle education level category and there is therefore greater variation in the indicator. As Huisman and colleagues (2003) point out, a large portion of the population with a low education level is a homogenous group in terms of the level of education but they may differ in terms of other socioeconomic dimensions. This could lead to smaller inequalities in the sample among women.

This study suggests that socioeconomic inequalities in functioning exist among the oldest old. Inequalities were found according to occupational class and education for both genders, but not for women according to education as a relative measure. The finding shows the robustness of inequalities that are well established for younger old age groups in Finland (Sulander, Rahkonen, & Uutela, 2003).

Multimorbidity

Multimorbidity varied from 33% among the upper non-manual class to 70% among the unskilled manual class among men and from 55% to 73% among women. According to education, the corresponding figures varied from 25% for high education level to 54% for low education level among men and from 60% to 62% among women. Schöllgen et al. (2010) studied poor physical health defined as three or more diseases out of eleven (e.g. CVD, diabetes) in a German population based study. They found that in the combined analyses for men and women, the proportion of those with poor physical health was 52% among those with a high and middle education, and 61% among those with a low education in the 70-85 age group. It may be problematic to compare these results with the Vitality 90+ Study where the definition of multimorbidity is less demanding (two or more diseases out of six), education is categorized in three levels, analysis is stratified by gender, and the participants are 90+ years old. However, both studies suggest that multimorbidity is more common among those with a low education level than among those with a high education level.

With the relative measures, those in the unskilled manual class had higher multimorbidity than those in the upper non-manual class and those with a low education higher than those with a high education but only among men. A Swedish study that analyzed multimorbidity among 77+ years old, had similar findings to the current study that those with a low education level suffered more frequently from two or more chronic conditions than those with a high education level. Dichotomized occupational class, high/low, was also associated with multimorbidity showing higher multimorbidity for those with low occupational class. However, this was seen only in the crude model before adjustment for age, gender and education. (Marengoni et al., 2008). The study included both men and women, and was based on younger population than participants in the Vitality 90+ Study. Yet, the result suggest similarly that there are SES inequalities in multimorbidity although perhaps weaker than in functioning.

A summary score of multimorbidity was based on the six following diseases CVDs, diabetes, arthritis, hip fracture, depression, and dementia. It has been suggested that a summary score has higher accordance with medical reports than individual diseases when self-reported diseases from the questionnaires are compared with the medical reports. This is because a summary score is based on absolute number of diseases and individual items may neutralize each other. (Katz et al., 1996). In this study, assessed with relative measures, there were no statistically significant differences in multimorbidity among women. However, the more detailed analyses of individual diseases revealed that the morbidity profile was different according to SES. Hip fracture and arthritis seemed to be more common among people with high SES while dementia, depression and diabetes were more common among people with low SES. Thus, in this case, using only a summary score of diseases would have hidden important information.

Previous studies with younger populations have shown similar results to this study that low SES is associated with higher prevalence of dementia, diabetes and depression (Everson et al., 2002; Karp et al., 2004). However, association between SES and hip fractures has shown a different pattern in previous studies than in the current study e.g. (Farahmand et al., 2000). In this study, higher hip fracture prevalence among women with high occupational class or education may in fact reflect higher survival of hip fracture patients than higher incidence (Roberts & Goldacre, 2003).

Self-rated health

Poor SRH varied from 10% to 27% between occupational classes among men but did not show clear gradient. Among women, poor SRH varied from 18% for the upper non-manual class to 37% for unskilled manual class. According to education level, poor SRH varied from 12% for high to 25% for men with a low education. The corresponding figures were 18% for high, 30% for middle, and 29% for women with a low education. Arber and Cooper (1999) studied SRH according to occupational class among 85+ years old who responded to the British General Household Survey. They focused on good SRH, and found that among men, more than 40% of those with professional occupations assessed their health as good, while the percentage for those with manual occupations was approximately 30. The corresponding percentages were approximately 35 for those with professional occupations and 25 for those with manual occupations among women. Even though the study differed from the Vitality 90+ Study for example in terms of the study population, it similarly suggested that people with high occupational class assess their health as good more often than people with low occupational class. This was seen for both men and women although, in general, men tended to assess their health slightly better than women did. Huisman and colleagues (2003) explored poor SRH according to level of education with a large European study where the definition of poor SRH included also those who reported having an average level of health. They found that among 80+ age group, the proportion of men who reported poor SRH varied from 52% for high to 75% for those with low education and the proportion of women with poor SRH was 63% for high, 54% for middle, and 77% for low level of education. The study excluded the institutionalized population and does not mention the use of proxy respondents. In addition, the definition of poor SRH was different from the current study. However, both studies showed an educational gradient for men but for women, those with high education levels fared clearly better in the Vitality 90+ Study than those with low or middle education level, and in the multinational study, those with high and middle education level fared clearly better than those with a low education level. As discussed earlier, among older women education may not differentiate SES groups from each other well, which may cause instability to the results.

With relative measures, there were no statistically significant differences in poor SRH among men according to occupational class. Yet, among women, manual classes were more likely to report poor SRH than upper-non-manual class. According to education, men with a low education level had poor SRH more often than men with a high education level. Among women, both those with low and middle education levels reported poor SRH more often than those with a high education level. In the multinational study on educational inequalities in SRH, Huisman et al. (2003) found that for both genders, those with a high education level had poor SRH less frequently than those with low and middle education levels. In the current study, proxy respondents were excluded from the SRH analyses. This was because it would be impossible to report a subjective and personal evaluation of health on behalf of another person. Consequently, the study population is likely to be from the healthier end in SRH analyses. However, the results seem to be in line with another study (Huisman et al., 2003) that used education as a SES indicator. Inequalities in SRH were found among women but not among men when analyzed according to occupational class. The possible reasons for the gender difference might be related to methodological issues or for example to men and women suffering from different diseases that might affect the reporting style of SRH in general. There were more women than men in the study, and when the analysis excluded proxy respondents, there were even fewer men. The occupational class was categorized in five groups, while the level of education that showed inequalities in SRH was categorized in four groups. Thus, it is possible that there was lack of power to show inequalities for men according to occupational class. Another issue related to methodology is that the exclusion of proxy respondents might cause underestimation of inequalities, if more people from lower occupational classes with poor health were excluded. Thus, the inequalities would not be detected because of the bias. However, inequalities in SRH were found also for men when education was used as a SES indicator. There is also plenty of evidence that SRH is a valuable measure for providing information on the health status of both men and women (Burstrom & Fredlund, 2001). In addition, the reporting of SRH has been shown to have predictive value in terms of mortality in all socioeconomic groups (Burstrom & Fredlund, 2001; McFadden et al., 2009).

The analyses regarding functioning, morbidity and SRH were based on cross-sectional data. This leaves the door open for discussion about the causal directions of health inequalities. Blane and colleagues (1993) argued that the health gradients in old age could not be a result of social selection where poor health leads to lower SES since it is very unlikely that one changes SES after retirement. It is possible, though, that the downward mobility appears earlier in life. In the current study, participants were 90 years old. It is rather unlikely that people with very poor health early in life would be alive and thus able to participate in this study. This study took advantage of two SES indicators, occupational class and education. Education is considered as the most robust indicator regarding social selection among older people since it is often completed several decades before health deterioration (Minkler et al., 2006). In addition, several studies provide evidence of a causal direction where low SES predates the incidence of poor health in old age (Nilsson, Avlund, & Lund, 2010).

This study is among the first to provide evidence of SES inequalities in functioning, multimorbidity, and in SRH among the 90+ population. It was not possible to assess health inequalities for this same population earlier in life. There are however, studies focusing on mortality inequalities at younger age for people born in 1910s and 1920s in Finland. Martelin (1996) showed that the relative rate of death was higher for people in manual and lower white-collar occupations than for people in upper white-collar occupations among the 60-64 years old. Similarly, those with a basic or secondary education had higher death rates in comparison to those with a high level of education. Inequalities were pronounced for both genders, however, inequalities were clearly larger among men. Based on the earlier and current findings, it seems that for birth cohorts born in the beginning of 20th century social inequality existed in mortality at the younger old age as well as at the very old age. That inequalities are approximately at the same level for men and women at the very old age suggests that the selection at younger ages is higher among men. This study cannot answer the question of whether health inequalities accumulate, remain stable or decrease along with ageing. However, this study shows that the inequalities that are well established in younger populations in Finland also exist among the oldest old.

Other European studies have analyzed health inequalities in different birth cohorts to see whether the magnitude of inequalities varies with advancing age. Schöllgen and colleagues (2010) suggested that both absolute and relative inequalities in physical, functional and subjective health remained stable in a German population among the 40-85 years old. Huiman et al. (2003) studied 60-80+ years old men and women, and they suggested stability for men but a decrease in health inequalities for women. However, they discuss the possibility that the exclusion of institutionalized participants could artificially decrease inequalities especially among older women. The findings from the Vitality 90+ Study are supported by earlier studies in Finland for younger age groups but also by other European studies that suggest continuity for inequalities until very old age.

Biomarkers

Biomarkers reveal subclinical conditions and early states of diseases but also predict the progression of diseases (Colburn et al., 2001). When health decline is considered a gradual process, biomarkers may act as early signs of it. The importance of studying biomarkers in the context of SES inequalities is related to biomarkers being suggested to be in a causal pathway to how SES transforms into differences in health for example through longstanding stress (Brunner & Marmot, 2006).

Of the eight studied biomarkers that represent two major physiological regulatory systems, cardiometabolic and inflammatory, educational inequalities were found in HDL-cholesterol, leptin, and BMI. Those with a higher education level had higher HDL-cholesterol, lower leptin level, and lower BMI than those with low and middle education levels. Notable was that inequalities were minor in inflammatory biomarkers (IL-6, CRP, IL-1Ra). The comparison of the results of this study with others is problematic since earlier research has focused on study populations that are younger or healthier, inequalities are not studied for all biomarkers, and different thresholds are used for indicating health risk.

Elovainio and colleagues (2011) studied occupational inequalities in cardiovascular biomarkers among the middle-aged with the Whitehall II study sample. They found that at baseline, the level of HDL-cholesterol was higher and BMI was lower for those with higher employment class. During the 10 years of follow-up, HDL-cholesterol improved further and BMI increased less among the higher than among the lower employments. The result implies that disadvantage in adulthood may set a trajectory of unfavorable change in cardiovascular factors such as in adiposity. (Elovainio et al., 2011.) Education-based inequalities in HDL-cholesterol have been reported in two National Health and Nutrition Examination Surveys (NHANES). Muennig and colleagues (2007) showed that those with high education level had higher HDL-cholesterol (≥60 mg/dL) than those with low education level, and similarly Seeman and colleagues (2008) showed the same with different threshold (HDL-cholesterol ≥40 mg/dL). A Finnish nationally representative survey for 65-84 years old showed educational inequalities in obesity (BMI ≥ 30). Those with a high education had lower BMI throughout the 10-year study period among men and women. (Sulander & Uutela, 2007.) Despite the differences between the studies, they all had similar findings to the Vitality 90+ Study where thresholds were ≥46 mg/dL for HDL-cholesterol and ≥ 25.6 for BMI. However, inequalities were not addressed in the ratio of HDL- and total cholesterol, or in triglycerides. Seeman et al. (2008) found in their study that the association between education and biomarkers became weaker among older people. Thus, it is possible that there are no SES inequalities in the aforementioned biomarkers, or for example that the mortality selection affects the result.

Several studies suggest that people with higher SES have lower levels of inflammation. Both aforementioned NHANES studies found that highly educated have lower CRP values than those with low education levels (Muennig et al., 2007; Seeman et al., 2008). Similar findings are reported for the Framingham Offspring Study and for the Aging and Body Composition study for CRP and IL-6 (Koster et al., 2006; Loucks et al., 2010). However, all studies are not in line with the latter studies. Elovainio et al. (2011) did not find inequalities in IL-6 or CRP according to employment level. The reasons for minor differences in inflammatory biomarkers in the current study may be related to the concept of inflammaging (Franceschi et al., 2000), which refers to age-related low chronic inflammation. It has been suggested that inflammatory biomarker levels are higher among older people but still far from the levels of acute infections. (Krabbe et al., 2004.) Thus, it is possible that the inequalities found in inflammatory biomarkers among younger populations are not similarly detectable among the oldest old. It has also been suggested that the biological profile would be more similar for the oldest old since less healthy individuals do not survive until very old age (Crimmins, Kim, & Seeman, 2009).

Several studies have shown the association between SES and biomarkers, and there is stronger evidence of the association between biomarkers and functioning (Brinkley et al., 2009; Jensen & Hsiao, 2010). This study provided evidence of educational inequalities in functioning, and analyzed whether biomarkers explained the differences found. Results showed that cardiometabolic biomarkers had some, even though very small, explanatory value in the association between education and functioning. Koster and colleagues (2005) studied whether biomedical factors (e.g. BMI, inflammation, knee pain) explained educational inequalities in incident mobility limitation. They found that adjustment for these biomedical factors decreased educational inequalities in mobility limitations but did not explain all of it. The most important factors explaining the mobility inequalities were high inflammation, high BMI and, hypertension. Goldman and colleagues (2011) studied how biomarkers (including BMI, cholesterol, blood pressure) affect the association between education and functional limitations. In the study of three countries, US, Costa Rica, and Taiwan, they found that biomarkers did not affect or had only minor explanatory value in educational inequalities in functioning (Goldman et al., 2011). The studies are different in terms of age groups, measures of functioning and biomarkers, and exclusion criteria; yet, the findings mostly suggest that biomarkers have some explanatory value.

The role of biomarkers is complex among the oldest old. According to Krabbe and colleagues (2004), ageing is accompanied by the increase in inflammatory biomarkers. Such inflammatory biomarkers are associated with mortality also independent of morbidities (Volpato et al., 2001) however, there is lots of evidence that elevated levels of inflammatory biomarkers are associated with conditions (atherosclerosis and cognitive decline) that are common among the oldest old (Pepys & Hirschfield, 2003; Yaffe et al., 2003). The primary function of the inflammatory biomarkers, whether it is causal or counter-regulatory regarding the disease processes, is unclear (Krabbe et al., 2004). Research has also associated low-grade inflammation with lifestyle factors such as physical activity and smoking, the factors that are well known to differ between socioeconomic groups. Biomarkers can be considered as underlying mechanisms between the association between SES and functioning and thus, provide a research field for better understanding how social circumstances get under the skin.

Mortality

This study showed that mortality from all causes was lower for the upper non-manual class than for those with lower occupation classes. According to education, mortality differences were weaker but in the same direction. The earlier two survey studies that have explored mortality for the 90+ years old, and used education as an indicator of SES, found that there were no statistically significant differences in mortality according to education, similarly to what was found in this study (Formiga et al., 2011; Nybo et al., 2003). However, register-based studies have shown that those with a higher education have lower mortality than those with a low education (Huisman et al., 2004; Moe et al., 2012) also in Finland among men (Martelin, 1996). It is not clear why results from survey studies and register studies vary. The current study and a Danish survey study (Nybo et al., 2003) included also institutionalized individuals, but registers that include all deaths in the population are even more inclusive. Thus, it is possible that registers show greater inequalities in mortality because they include all people, and therefore include also those with the poorest health.

Fewer studies have explored mortality according to occupational class among the oldest old. Martelin (1996) found similar results to the current study that mortality was higher for people from lower occupational classes. The advantage of survey studies in comparison to register studies is often that they enable adjustments for other important explanatory factors. In the current study, multimorbidity and especially functioning explained a major part of the mortality inequalities. The result suggests that functioning is a risk factor for mortality in all socioeconomic groups. However, mortality was still higher for the unknown education group than for upper non-manual class after adjustment for functioning and morbidity. This is likely to reflect unspecific information on health status for this group or that the measures of functioning and morbidity do not cover health problems well enough.

Mortality inequalities were also assessed separately for the two most common causes of death, dementias and CVDs. Mortality from both causes of death was more common among lower occupations than among upper non-manual class however, the differences were not significant in CVD mortality. When analyzed according to education, there were no statistically significant differences in either of the causes of death. Russ and colleagues (2013) analyzed dementia mortality in the Health Survey for England according to occupational class and education. They found that women with a low education died from dementia more often than those with high education level and among men, inequalities, even though weaker, were found according to occupational class (Russ et al., 2013). Several studies have shown that the incidence of dementia is higher for those with a low education than for those with a high education however, less information is available for mortality from dementias. More research has focused on CVD mortality than on dementia mortality. There is plenty of evidence that people with a lower SES die more of often from CVD than people with a higher SES in Finland (Elo, Martikainen, & Myrskylä, 2014) and in other countries. For example, a study of ten European populations showed that ischemic heart disease mortality was higher for those with a low education than for those with a high education (Avendano et al., 2006). The previous studies, however, show results for the middle-aged or younger old age groups.

The causes of death are registered well in Finland. However, the decision of the underlying cause of death for an old frail person who suffers from multiple chronic conditions, and finally wastes away is complex. Gessert and colleagues (2002) and others suggest that it may be difficult to determine a disease-specific cause of death for very old people, and that poorly defined causes of death increase with ageing. Alpérovitch et al. (2009) studied the assessments of causes of death between the national mortality register in France and the study adjudication committee (hospital records, medical data, and proxy interviews). They found that the disagreement increased in 85+ age group and that the national register reported more cardiovascular diseases as the causes of death. The current study did not show significant differences in CVD mortality even though studies for younger populations provide convincing evidence for it. The result may reflect the fact that there are no differences in CVD mortality in this very old population or that the rather small number of CVD deaths decreases the power of the study. The result may also partly reflect the practices of how causes of death are registered for very old people.

Long-term care

This study showed that LTC use in total was rather similar between occupational classes during the study period 2001-2010 (+ 3 years of follow-up). However, people from the upper non-manual class were more frequently in privately provided LTC facilities than other occupational classes, especially at baseline. Not many studies have assessed inequalities in LTC use and those that have, show inconsistent results. Home ownership, that may reflect wealth, is most commonly associated with less frequent LTC use (Gaugler et al., 2007; Grundy & Glaser, 1997). A Finnish study that was based on large register data showed, however, that among the younger population (65+), those with higher income or occupational class entered LTC less frequently than the worse off (Nihtilä & Martikainen, 2007). In general, the use of different socioeconomic status indicators and LTC definitions as well as differences in studied birth cohorts complicates the comparison of studies. The use of LTC is highly context dependent, which is why international comparisons should be interpreted with caution. However, it seems that the higher LTC use in lower occupational classes among the younger population does not apply to this study with the very old population. Equality in health and social care use can be understood in many ways. It may refer to equal access to available care for equal need or for example equal utilization for equal need (Whitehead, 1992). In Finland, the health and social care system adheres to universal principles where people are entitled to services based on the need. This study showed that health inequalities exist among the oldest old thus, the rather similar use of LTC does not necessarily mean equality in LTC use. However, if the utilization (care seeking behavior) of LTC differs between socioeconomic groups, it does not necessarily mean inequality either.

The possible reasons why LTC use between occupational classes is more similar in this study than what is found among younger populations may be multifold. For example, living arrangements such as living alone is associated with higher rate of LTC entry (Nihtilä & Martikainen, 2008) and among the very old widowhood is more common than among the younger old. Having children or relatives nearby may increase the availability of all kinds of informal care (Pot et al., 2009), which is why its effect on LTC use may be unpredictable. Personal care and support may enable living at home for a longer time but on the contrary, help in care seeking may facilitate entry into LTC (Geerlings et al., 2005). People at a very old age also tend to have more complex health problems, and it is plausible that the need for care may be so comprehensive that it would be difficult to compensate even with other resources such as extensive home care.

This study found something interesting that echoes the structural changes in the organization of LTC in Finland. People from the upper non-manual class were more often in privately provided LTC in 2001, 2003, and 2007 but not in the last study year, in 2010. The policy aims at decreasing institutional LTC (residential homes and long-term inpatient wards) and encourages living in the community for as long as possible. As a result, the LTC use pattern has changed accordingly. In the 75+ population, institutional LTC use decreased 5% while LTC use in the community-based service homes with 24-hour assistance increased 5% during 2000-2013 (Väyrynen & Kuronen, 2015). LTC in service homes was originally provided only by private providers, which has increased the private provision that is, however, organized and largely paid by the municipalities. The study could not distinguish the very rare but existing privately purchased LTC from that which was provided privately but organized by the municipality. Yet, the finding can be interpreted in a way that in the earlier study years, the higher rate of private LTC use in the upper non-manual class was due to higher use of privately purchased LTC but later on other occupational classes used even more private LTC but they used private LTC that was organized by the municipalities.

8.4 Persisting health inequalities

SES inequalities in health are described as systematic, socially produced and unfair, and they are thought to be modifiable (Adler & Ostrove, 1999; Berkman & Glass, 2000; Marmot, 1999). A question arises of why socioeconomic inequalities are persistent even in welfare states and reach the oldest age groups. Mackenbach (2012) has proposed hypotheses about the possible explanations for existing health inequalities in the welfare states. First, he suggests that if welfare states were not able to eliminate inequalities in access to material and immaterial resources, inequalities would remain. Second, if the composition of people with lower SES has become more homogenous in terms of characteristics that are associated with the risk of poor health, health inequalities would persist. This selection would happen because of increased intergenerational mobility. Third, he hypothesizes the role of immaterial factors as one reason for persisting inequalities. He suggest that the importance of immaterial factors, such as cultural capital, has increased in welfare states since most people have access to material factors. Cultural capital is socially patterned and largely an area in which the welfare states have not interfered. The operationalization and the relevance of the theories need to be tested. However, they may help in understanding persistent health inequalities in the context of welfare states.

Several researchers have tackled the challenge of health inequalities and some have suggested concrete explanations of why policies to reduce inequalities may fail. Mackenbach (2011) has stressed the importance of the mandate to execute political decisions, create effective and carefully planned policies and the implementation of the programs in sufficiently large scale. Adler and Newman (2001) have emphasized the complexity of the causes behind inequalities and that inequalities develop during the life course. Thus, it is not plausible to find a single policy that would eliminate health inequalities. They also point out that if the action plans to reduce inequalities are not targeted at people who are worse off, it is probable that health promotion will increase health inequalities. The reason for this may be found from the diffusion of innovations theory (Rogers, 2003). Applied to this situation, it would mean that people with higher SES may adopt innovation or new behaviors earlier than people with lower SES. One example is smoking cessation. Smoking used to be very common in all socioeconomic groups in Finland and even more common among people with higher SES. Determined policy guidance with new legislations and enduring health education about the risks of smoking have decreased smoking however, the development has been faster among people with higher SES. Thus, overall beneficial changes at the population level have increased inequalities in smoking that is one of the most important health risks.

Earlier research has shown that socioeconomic inequalities in health are consistently found among the middle-aged and the younger old people. This study adds to the existing literature that health inequalities, measured with functioning, morbidity, SRH, cardiometabolic biomarkers and mortality also exist among the 90+ population. In addition, the study showed that the use of round-the-clock long-term care is rather similar in all occupational classes among the oldest old. Health inequalities arise from the societal structures that determine the availability of material and social resources. Unequal access to resources has a cumulative effect on health; those with fewer resources have a higher risk of facing health problems but they also have fewer resources to overcome health problems when they appear. Socially produced life circumstances affect health throughout the life span from the cradle to the grave. Thus, the policy implications to reduce socioeconomic health inequalities in old age should focus on improving the scope of action for people in vulnerable groups at all ages and on reducing the overall inequality in society.

The Finnish health policy has aimed at decreasing socioeconomic health inequalities since the 1980s. It seems, however, that the aim has not been achieved and there is even evidence of a widening health gap. (Kansallinen terveyserojen kaventamisen toimintaohjelma 2008-2011, 2008). Even though health inequalities would be difficult to narrow at the very old age, it should be taken into account in providing health education and for example when planning health and social care services. Policy actions to reduce inequalities have focused e.g. on setting the maximum waiting times for public sector health care and providing health checks for the unemployed. With regard to older people, public dental care has been extended to all age groups, the assessment of service needs has been harmonized, and all 80+ years old are entitled to get a needs assessment for non-emergency service by professionals in seven days (Wahlbeck et al., 2008). The policy also aims at decreasing round-the-clock long-term care and emphasize living at home. Accordingly, this study showed that the proportion of people using LTC decreased from 2001 to 2010. However, the study sample was not representative of the total population in all the study years since only the first entry to the study was taken into account for each person. Even though this study also showed that the LTC use was rather similar in all socioeconomic groups, the trend of decreasing LTC use raises concern. The number of very old people is increasing, which is why it is probable that the need for LTC use is not decreasing. Future studies should follow how the structural changes in the Finnish LTC provision affect the equality of the LTC use.

Social inequality may be problematic especially among the oldest old who need LTC services the most.

In the current oldest old population, the average level of education was low and the ethos of a career in one workplace was stronger than today. Higher education leads to better health, however, it remains to be seen how the rise in the average level of education affects social inequality in health among the future oldest old population. In Finland and in other countries, lifestyle and health-related behaviors are considered major determinants of health and mechanisms of poorer health in lower socioeconomic statuses (Lynch et al., 1997; Stringhini et al., 2010; Martikainen et al., 2014). Lifestyle factors and health behaviors, smoking, alcohol consumption, diet, physical activity and obesity have a great division by SES in the current middle-aged population in Finland (Prättälä et al., 2007; Martikainen et al., 2014). Thus, it is tempting to predict that socioeconomic health inequalities are prevalent among the oldest old also in future, even if the average level of health improves. However, these factors, lifestyle and health-related behaviors, do not explain all of the observed health inequalities.

The labor market is in constant change in terms of the structure, towards non-manual occupations, in terms of working hours and reachability of the employees, and there is political pressure to raise the retirement age. How do extended working lives shape retirement in terms of financial assets and health, and are the effects similar for all socioeconomic groups? The welfare state is also in a constant state of flux. The entitlements and responsibilities of the inhabitants are renegotiated, which has great influence on social inequality in the future. This has particular importance for the use of health and social care services. Most importantly, the number of the very old people increases and the consequences of that on health inequalities is difficult to predict. Social inequality in health is not a still image but rather an everlasting film, which can be edited.

8.5 Conclusions

The study suggests that socioeconomic health inequalities exist in the population that live beyond the average life expectancy. Inequalities were found according to occupational class and education, for both genders, and with absolute and relative measures; however, the magnitude of inequalities varied. It is notable that for the population that experienced high selection, that has high level of health problems, and that has a very high mortality, a social gradient was found in several health indicators. Life circumstances affect socially produced health inequalities throughout the life span. Thus, policies to reduce health inequalities in old age should focus on reducing social inequality in the society in general. Social inequality in health, especially in old age, emphasizes the importance of organizing health and social care services so that people in all socioeconomic groups have access to services based on their needs.

9 Acknowledgements

This study was carried out at the Faculty of Social Sciences and Gerontology Research Center at the University of Tampere in Finland. I warmly thank the Faculty for providing encouraging working environment and research facilities for conducting the study. The Juho Vainio Foundation, Finnish Cultural Foundation, Doctoral Programs in Public Health and the NordForsk project, Social Inequalities in Ageing, supported this work financially. The City of Tampere granted financial support for publication of this book.

I express my sincere gratitude to my supervisor, Professor Marja Jylhä. You took this journey with me from beginning to end. I was lucky to have a supervisor with such multidisciplinary expertise. I will always be grateful for you showing me what good science is about and acting as an example of internationally esteemed woman in science.

I wish to thank Professor Johan Fritzell for agreeing to be my opponent. The official reviewers of the thesis manuscript were Docent Kristiina Manderbacka (PhD) and Docent Karri Silventoinen (PhD). Thank you for the supportive comments and constructive criticism. I am also grateful for my advisory group, Professor Taina Rantanen and Professor Pekka Martikainen who made this journey possible. Thank you for providing statements for grant applications and being a backup for this long process.

I acknowledge all my co-authors Mari Aaltonen, PhD, Antti Hervonen, Professor emeritus, Mikko Hurme, Professor emeritus, Juulia Jylhävä, PhD, Terho Lehtimäki, Professor, Lily Nosraty, MSc and Jani Raitanen, MSc, for your valuable contribution and patience during the publications processes. I wish to thank especially Jani Raitanen who was always present and willing to help with the mysteries of the statistical analyses.

All long processes face ups and downs. I feel privileged to have such a co-workers who have supported me at the times of trouble and celebrated with me at the times of success. Thank you Jari Pirhonen, Kristina Tiainen, Lily Nosraty and Mari Aaltonen for making life a bit easier.

These years would have been lonely without a group of people with different state of academic career and with diverse research fields around me. I am grateful to all former and present members of the famous Gero-group including Jutta Pulkki, Leena Forma, Inna Lisko, Kirsi Lumme-Sandt, Ilkka Pietilä, Sari Stenholm, Outi Jolanki, Sari Heikkinen, Suvi Fried, Merja Vuorisalmi, Tapio Kirsi, Johanna Surakka, Pauliina Halonen, Vilhelmiina Lehto and Marjut Lemivaara for letting me grow as a researcher with you. I especially wish to thank Tiina Kangasluoma for her valuable support at every turn. Thank you all who shared your inspiring ideas as well as daily life with me at coffee rooms and corridors.

Several people beyond the academy made one of my dreams possible. I thank my family and relatives for supporting me throughout my life. The attitude of never give up, has a long history. I thank my friends for being there for me and so many times showing the best in life, joy. I also wish to thank my parents-in-law for their support and help in arranging the daily life. My greatest thanks belongs to my life companion Noora Valoma who has always undoubtedly believed in me. The support and understanding that you provide me is priceless. Your wisdom and patience makes me a better person.

Last, I want to express my gratitude to my mother who cannot be with me today.

Tampere, October 2017

Linda

Appendix table 1. The Barthel Index

FEEDING
0 = unable
5 = needs help
10 = independent
MOVING FROM WHEELCHAIR TO BED AND RETURN
0 = unable
5 = major help
10 = minor help
15 = independent
PERSONAL TOILET
0 = needs help
5 = independent face/hair/teeth/shaving
GETTING ON AND OFF TOILET
0 = dependent
5 = needs some help
10 = independent (on and off, dressing, wiping)
BATHING SELF
0 = dependent
5 = independent
WALKING ON THE LEVEL SURFACE
0 = unable
5 = wheelchair independent
10 = walks with help of one person
15 = independent
ASCEND AND DESCEND STAIRS
0 = unable
5 = needs help
10 = independent
DRESSING
0 = dependent
5 = needs help
10 = independent
CONTROLLING BOWELS
0 = incontinent
5 = occasional accident
10 = continent
CONTROLLING BLADDER
0 = incontinent
5 = occasional accident
10 = continent

(Mahoney & Barthel, 1965)

Appendix table 2. Studies on health (80+) and mortality inequalities (85+)

Author(s), year, countries	Indicators of socioeconomic status (SES)	Outcome	Study design	n	Age group	SES differences
Formiga et al 2011, Spain	Level of education: no studies, primary studies, high school, university degree	Mortality	Survey excluded institutionalized follow-up 60 months	186	mean age 93.1	No differences
Hoffman 2011, Denmark	Income: deciles	Mortality	Register study only men included 1980-2002	total population	90-99	Highest mortality for people in the lowest income decile
Huisman et al 2004, Finland, Norway, Denmark, England and Wales, Belgium, France, Austria, Switzerland, Spain (Barcelona and region of Madrid), Italy (Turin)	Level of education: primary vs. secondary and post-secondary Housing tenure: owner occupiers, tenants, institutionalized	Mortality	Register study 1990-1997 follow-up 1-6 years		90+	For a pooled sample, primary educated had higher mortality than secondary and post-secondary educated both in absolute and relative measures and for men and women No differences according to housing tenure
Martelin 1996, Finland	Level of education: basic, secondary, high Occupation-based social class	Mortality	Register study 1971-1990	total population	90-94	For men, mortality was higher for low educated than for high educated Mortality was higher for people with low occupational classes than for people with high occupational classes
Moe et al 2012, Norway	Level of education: primary or lower secondary vs. upper-secondary, post-secondary or tertiary	Mortality	Register study 1961-2009 follow-up 1 year	total population	85-94	Mortality was higher for low educated than for high educated for both, men and women
Nybo et 2003, Denmark	Education in years: <7 7-8 9-10 >10	Mortality	Cohort survey included institutionalized and proxy respondents, follow-up 15 months	2,249	92-93	No differences

Appendix table 2 continues

Zhu & Xie 2007, China	composite of education and urbanity	Mortality	Survey follow-up 4 years 1998	7,390	80, 90, 100	Rural noneducated had higher mortality than urban educated
Arber & Cooper 1999, Great Britain	Occupation-based social class	Self-assessed health, Disability	Survey excluded institutionalized 1992-1994	>14,000 for 65+-85+ age groups	80-84, 85+	People with low occupational class were more frequently disabled and assessed their health poor than people with high occupational classes
Huisman et al 2003, Belgium, Denmark, France, Germany, Great Britain, Greece, Ireland, Italy, Netherlands, Portugal, Spain	Level of education: less than second stage of secondary education, second stage of secondary education, vocational and university education Income quintile	Self-assessed health, Cut down in daily activities, Long-term disabilities	Survey excluded institutionalized 1994	4,340 (80+)	80+	Men with a low income or low education had more often long-term disabilities and assessed their health poor than the better off Women with a low education assessed their health poor more often than high educated No differences in cut down in daily activities
Rostad et al 2009, Norway	Education in years: ≤7 8-11 ≥12 Occupation-based social class	Self-assessed health, Limiting long-standing illness	Survey population-based only women included 1995-1997	1934 (80+)	80-84, 85+	Low educated assessed their health more often poor than high educated No differences according to occupational class

Appendix table 3. Status classification for occupations

1 Employers
- 10 employers in agriculture
- 11 other employers, upper non-manuals
- 12 other employers, lower non-manuals

2 Entrepreneur
- 20 entrepreneurs in agriculture
- 21 other entrepreneurs, upper non-manuals
- 22 other entrepreneurs, lower non-manuals

3 Directors and upper non-manuals
- 30 business directors
- 31 other upper non-manuals

4 Lower non-manuals
- 40 salesmen, office staff, insurance agents
- 41 shop assistants and sellers
- 42 other lower non-manuals

5 Manual workers
- 50 employees in agriculture, forestry and fishing
- 51 other skilled or specialized employees
- 52 other unskilled or unspecialized employees

6 Assisting family members (employer's)
- 60 in agriculture
- 61 other upper non-manuals
- 62 other lower non-manuals

7 Assisting family members (entrepreneur's)
- 70 in agriculture
- 71 other upper non-manuals
- 72 other lower non-manuals

8 Pensioners

9 Others
- 99 Pensioners, former profession not known

(Official Statistics of Finland, 1976)

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Original publications

This is a pre-copyedited, author-produced version of an article accepted for publication in The Journals of Gerontology, Series B, Psychological Sciences and Social Sciences. The original article is available online at https://doi.org/10.1093/geronb/gbt067

Do Socio-Economic Health Differences Persist in Nonagenarians?

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Running head: SES health differences in nonagenarians

Abstract

Objectives. Social inequality in health is well documented in younger adults and the younger-old, but data from the very old are scarce. We used a representative population sample to investigate socio-economic differences in health and functioning among nonagenarian men and women.

Methods. Data came from the Vitality 90+ Study. All individuals aged 90 and older in the city of Tampere, Finland, were included, irrespective of health or dwelling place. Data were collected from 1,283 participants whose age range ran from 90 to 107 years. Education and former main occupation were used as indicators of socio-economic status, and health was measured as functional ability, comorbidity and self-rated health. Data were analyzed in a cross-sectional design by using cross tabulation, ordered regression model with marginal effects and binary logistic regression model.

Results. Manual workers had poorer functional ability and health than upper non-manuals and the low-educated poorer than the high-educated. Most analyses showed a graded association between the lower socio-economic status and a poorer health outcome. On each level of the socio-economic hierarchy, men had better functional status than women.

Discussion. We found socio-economic differences in functional ability, comorbidity and self-rated health in nonagenarians. Our findings suggest that social disparity in health and functioning exists in very old age.

Key words: Comorbidity, Functional health status, Health inequalities, Oldest-old, Self-rated health, Socioeconomic status

Introduction

Earlier studies have well documented the association of socio-economic status with morbidity and mortality in younger and middle-aged people. The special characteristic of these differences is that they do not exist only between the highest and the lowest group but typically show a gradient across the socio-economic hierarchy (Huijts, Eikemo, & Skalická, 2010; Marmot, Ryff, Bumpass, Shipley, & Marks, 1997; Townsend & Davidson, 1982). Similarly, studies including home-dwelling individuals in the age range of 60 to 85 have demonstrated a heavier burden of diseases (CVD, arthritis, depression and the total number of diseases), and a higher disability among those with low education, poor financial assets or low occupational status (Chandola, Ferrie, Sacker, & Marmot, 2007; Laitalainen, Helakorpi, Martelin, & Uutela, 2010; Ramsay, Whincup, Morris, Lennon, & Wannamethee, 2008; Rostad, Deeg, & Schei, 2009; Rueda, Artazcoz, & Navarro, 2008; Schöllgen, Huxhold, & Tesch-Römer, 2010; Sulander, Rahkonen, Nummela, & Uutela, 2009), and a consistent association between poor self-rated health and low occupational status or lack of means (McFadden et al., 2008; McMunn, Nazroo, & Breeze, 2009). Among people aged 80 years or older, poor self-rated health and functional limitations have been associated with low socio-economic status (Arber & Cooper, 1999; Huisman, Kunst, & Mackenbach, 2003; Rostad et al., 2009).

In many countries, people aged 90 and older are the fastest growing age group. Yet it is not clear whether the socio-economic health differences exist among this oldest-old population (90+), where both the burden of disease and the level of mortality are high. We are not aware of any studies focusing on these differences in nonagenarians, but a couple of studies have information on mortality. In a European study which included 11 populations, relative differences in mortality between the low- versus the middle- and high-educated groups persisted at the age of 90+ although being weaker than in younger age groups (Huisman et al., 2004). In a nation-wide study in Finland, occupational differences remained at the age of 80, but disappeared by the age of 95+ (Martelin, 1996). In 90-year-old Danes, however, education was not associated with mortality (Nybo et al., 2003).

Different hypotheses have been put forward about the changes in socio-economic health inequalities that come with age, regarding increase, decrease, or stability. The hypothesis suggesting increasing differences refers to the cumulative advantage in resources throughout life which produces an increasing gap between the affluent and the underprivileged (Ross & Wu, 1996). Decreasing health disparity could be a result of the weakening effects of working conditions after retirement (House et al., 1994); inevitable biological frailty, especially in very old age (Herd, 2006); mortality selection, meaning that those in higher-risk categories have deceased at earlier ages with only the robust individuals remaining alive; and a ceiling effect, referring to a high risk of morbidity among both exposed and unexposed groups (Dupre, 2007; Kaplan, Haan, & Wallace, 1999). Schöllgen et al. (2010), based on their findings among 40-85-year-old Germans, suggest that health differences continue in the same magnitude until old age because socio-economic status influences life chances at an old as well as at young age. There is also some evidence that health disparity may peak in late middle age and then decrease along with ageing (Beckett, 2000). However the findings may differ for relative versus absolute differences. In cross-European analyses (Huisman et al., 2003; Mackenbach, 2006) both absolute and relative inequalities mostly declined from the age range between 60 and 69 years up to the age of 80+. In the Whitehall Study (Marmot & Shipley, 1996), the relative differences in mortality were smaller but the absolute differences larger at the ages of 70 to 79 compared with those aged 40 to 64. In Canada, using the Gini coefficient and adjusting for socio-economic status-associated earlier mortality selection, Prus (2007) found increasing inequality in mortality from the ages of 15-29 to the ages of 80+.

Several studies have found evidence that socio-economic health differences are wider among men than among women (Marmot et al., 1997). Men tend to have a more stratified occupational structure, which is one factor in producing the gender difference, but larger health differences were observed for men when the indicator of the socio-economic status was education (Matthews, Manor, & Power, 1999). Only a few studies have focused on gender patterns in socio-economic health differences in old age. A European study in 80+-year-old people found that when all 11 countries were analyzed together, men had larger differences in poor self-rated health, cut down in daily activities and long-term disabilities than women (Huisman et al., 2003). In another study, (Rueda & Artazcoz, 2009) a socio-economic gradient by education in poor self-rated health and limiting long-standing illness was discovered both in men and women aged 65-85, but women had larger differences in limiting long-standing illness than men. Gender differences in health according to socio-economic status are largely unknown.

Most studies on socio-economic health differences in old age include only community-dwelling individuals. This may compromise study reliability among the oldest-old, as the number of people living in institutions is high, and those persons are likely to have more health problems than others. In the Vitality 90+ Study information on a whole cohort in the geographical area was available, irrespective of health and dwelling place. The advantage in comparison to previous research is that our sample of nonagenarians is relatively large. We use two indicators of socio-economic status, occupational class and educational level, to describe the relative position of the individuals in the social hierarchy. The purpose is not to compare two indicators but to give a more comprehensive and reliable picture of the association of health with socio-economic status. In our data, both indicators are available for both men and women.

To our knowledge, this is the first study that focuses on socio-economic inequality in health among people aged 90 and older. By using a representative population sample, we investigate (1) whether in nonagenarians, functional ability, comorbidity and self-rated health are associated with occupational status and educational level, and (2) whether the health indicators on different levels of socio-economic status differ between the genders.

Methods

Study population

Data in this study came from the Vitality 90+ Study which is a multidisciplinary research project carried out among people aged 90+ in Tampere, Finland. This study uses cross-sectional data collected through a mailed survey in 2010. All individuals aged 90 years or over living in Tampere, irrespective of health status or dwelling place, were included. Names, addresses and places of residence of the target population (N=1686) were acquired from the Tampere City Population Register on 15 January, 2010. Questionnaires were mailed to 1,686 people but 74 died before receiving it and 6 moved to a different town. Thus, the basic population was 1,606 and 1,283 individuals participated which gave a response rate of 80%. Almost 59% of the participants answered independently and 24% chose the answers themselves but received help from someone else in filling out the questionnaire. For the remaining 18% (11% of men and 19% of women), the responses were provided by family members, relatives, friends, home helpers or the staff in institutions; these were categorized as proxy answers. Those whose answers were given by proxy had on average more diseases, poorer functional ability, were more likely to live in an institution and many of those belonged to the group ‘occupation unknown’. In women, proxy participants were also older and more often low-educated. The study was approved by the Ethics Committee of the City of Tampere.

Variables

Socio-economic status

Indicators of socio-economic status were the longest held occupation during a person's working years and the level of education. Occupational status was encoded according to the Occupational and Industrial Classification by Statistics Finland (1976) and was analyzed in four hierarchical groups: upper non-manuals (7%), lower non-manuals (34%), skilled manual workers (37%) and unskilled manual workers (6%). Besides these four occupational categories, housewives (10%) and those whose occupation was unknown (6%) were analyzed as separate groups. Housewives included women who had not participated in the labor market and those who had worked as an assisting family member for an agricultural entrepreneur (n = 19). Workers in agriculture and forestry (n = 18) and farmers (n = 20) were categorized as skilled manual workers. The self-employed were categorized either as upper non-manuals (n = 8) or as lower non-manuals (n = 53) depending on their job description.

During the 1920s when the participants went to school, basic education consisted of six-grade primary schooling which was compulsory for all 7 to 13-year-old children. Secondary education included secondary school (high school) and vocational education. Graduation from upper secondary school, a prerequisite for university studies, was rare and less than 10 per cent of the age group completed such studies in 1920. (Statistics Finland, 2007). After primary school both non-academic general education and vocational education was also available in institutions for adult education, "folk high schools". In our study, education was classified into three hierarchic groups: low (primary or lower secondary school 64%), middle (vocational education and folk high schools 20%) and high (upper secondary school, college-level training and university education 13%). In addition, a fourth group was formed of participants whose education was unknown (4%).

There was a clear association between occupational status and education. Among unskilled manual workers, 90% of men and 85% of women were low-educated and among upper non-manuals 84% of men and 66% of women were high-educated. On the other hand, among the low-educated 67% of men were manual workers and 67% of women were manual workers or housewives. Among the high-educated almost 98% of men were non-manuals and 94% of women were non-manuals or housewives.

Health measures

Health was measured according to three indicators: functional ability, comorbidity and self-rated health. Functional ability was studied by asking the participants whether they were able to get in and out of the bed, dress and undress, move indoors, walk 400 meters and use stairs (1) without difficulty, (2) with difficulty, (3) if someone helped, or (4) not at all; the alternatives (1) and (2) were categorized as independent and (3) and (4) dependent in each respective activity. Chronic conditions were revealed by asking the question, "Has your physician mentioned that you have some of the following conditions: cardiovascular disease (CVD), diabetes, dementia or memory problems, depression, osteoarthritis or hip fracture?" Self-rated health was assessed by asking, "How would you evaluate your present health: (1) very good, (2) fairly good, (3) average, (4) fairly poor, or (5) poor?" For self-rated health, only self-reports were included in the analyses while other health indicators also included proxy answers.

Statistical analyses

Cross tabulation, ordered regression and binary logistic regression models were applied to analyze variation in health according to socio-economic status. For the cross tabulation analyses, dichotomized measures were created. Functional ability was categorized as good functioning (independent in all five activities) versus poor functioning (dependent in at least one activity). Comorbidity was categorized as 0-1 versus 2-6 chronic conditions and self-rated health was categorized as poor (fairly poor and poor health) and good or average (very good, fairly good and average health).

Absolute health differences by occupation and education were tested with Pearson's chi-squared test, and if the conditions were not met, Fisher's exact test was used. Dichotomized variables were also used in binary logistic regression analyses to investigate gender differences in health along the social strata. The reference groups in the analyses were men on each socio-economic level. Odds ratios (ORs) and their 95% confidence intervals (CIs) were reported.

Ordered regression analyses were performed to examine socio-economic health differences separately for men and women. This method allowed the utilization of all the variation in the measures: six groups were considered in functional ability (independent in all activities, dependent in 1, dependent in 2, dependent in 3, dependent in 4 and dependent in 5), five in comorbidity (no chronic conditions, 1 condition, 2 conditions, 3 conditions and 4-6 conditions) and five in self-rated health (very good, fairly good, average, fairly poor and poor). Probit link function was used in comorbidity and self-rated health analyses according to the normally distributed health outcomes and complementary log-log link in functional ability analyses because the distribution was heavily skewed towards good functioning. The parallel lines assumption was tested and in three cases the assumption was not reached (for middle-educated, education unknown and occupation unknown women in functional ability). However, those groups were included in the analyses but irregularity was taken into account in STATA with hetero option for the ordinal generalized linear model (Williams, 2009). Coefficients and their 95% confidence intervals were reported. We also computed Average Marginal Effects (AMEs) after the ordered regression analyses. Marginal effects were computed for each case, and the effects were then averaged. For categorical variables with more than two possible values, the marginal effects show the difference in the predicted probabilities for cases in one category relative to the reference category. Data were analyzed by using IBM SPSS statistics 20.0 and STATA for windows version 12.1.

Results

The data consisted of 1,283 participants with 81% women and 19% men (Table 1). More than 60% of the participants lived in the community in ordinary housing. Men belonged to the high or middle-educated group more often than women and men also outnumbered women in the upper non-manual occupation group. In functional ability, participants had more difficulty in walking 400 meters and using stairs than in other activities. The three most common chronic conditions were CVD, arthritis and dementia. Only 10% of the participants were free of diseases and one out of three had more than two diseases. The self-rated health outcome followed the shape of the normal distribution for both genders. Women were more often dependent in all the activities than men, and they had a higher prevalence in all chronic conditions except for CVD and diabetes.

We first studied absolute differences in poor functional ability, CVD, diabetes, arthritis, hip fracture, depression, dementia, comorbidity, and poor self-rated health by occupation and education (Table 2). In contrast to other measures, proxy answers were excluded for self-rated health. Therefore, the population in these analyses was smaller and healthier than for the other indicators of health and

Table 1. Characteristics of the study population. Number and percentage.

	Women N = 1041	Men N = 242	Total N = 1283
	n, %	n, %	n, %
Participants			
In person	836 (81)	213 (89)	1049 (82)
Via proxy	197 (19)	27 (11)	224 (18)
Institution + Service home > 24 h	399 (39)	76 (32)	475 (37)
Median age in years (range)	92 (90−107)	91.5 (90−99)	92 (90−107)
Socio-economic status			
Occupation			
Upper non-manual	48 (5)	43 (18)	91 (7)
Lower non-manual	359 (35)	78 (32)	437 (34)
Skilled manual	378 (36)	101 (42)	479 (37)
Unskilled manual	69 (7)	11 (5)	80 (6)
Housewives	122 (12)		122 (10)
Occupation unknown	65 (6)	9 (4)	74 (6)
Education			
High-educated	114 (11)	48 (20)	162 (13)
Middle-educated	181 (17)	73 (30)	254 (20)
Low-educated	704 (68)	113 (47)	817 (64)
Education unknown	42 (4)	8 (3)	50 (4)
Health indicators			
Functional ability			
Independent in			
Getting in and out of bed	837 (81)	217 (91)	1054 (83)
Dressing and undressing	765 (74)	205 (86)	970 (76)
Moving indoors	824 (81)	209 (89)	1033 (83)
Walking 400 m	479 (47)	160 (68)	639 (51)
Using stairs	471 (46)	165 (70)	636 (51)
Diseases			
CVD	551 (55)	138 (59)	689 (55)
Diabetes	116 (12)	34 (15)	150 (12)
Arthritis	474 (47)	73 (32)	547 (44)
Hip fracture	192 (19)	26 (11)	218 (18)
Dementia	422 (42)	80 (35)	502 (41)
Depression	211 (21)	30 (13)	241 (20)
Self-rated health			
Very good	23 (3)	9 (4)	32 (3)
Fairly good	185 (23)	44 (21)	229 (22)
Average	381 (46)	110 (53)	491 (48)
Fairly poor	172 (21)	39 (19)	211 (21)
Poor	59 (7)	6 (3)	65 (6)

Table 2. Prevalence of poor functional ability, chronic conditions, comorbidity and poor self-rated health by occupation and education. Percentages and relative differences.

	Poor functional ability		CVD		Diabetes		Arthritis		Hip fracture		Depression		Dementia		Comorbidity		Poor self-rated health	
	%	Rd	%	Rd	%	Rd	%	Rd	%	Rd	%	Rd	%	Rd	%	Rd	%	Rd
Women																		
Occupation																		
Upper non-manuals	50		52		2		53		30		16		30		55		18	
Lower non-manuals	58	8	55	3	10	8	43	-10	17	-13	20	4	38	8	59	4	24	6
Skilled manual workers	69	19	52	0	14	12	51	-2	19	-11	21	5	41	11	59	4	30	12
Unskilled manual workers	74	24	64	12	8	6	46	-7	28	-2	29	13	50	20	73	18	37	19
Housewives	68	18	52	0	13	11	57	4	21	-9	18	2	45	15	64	9	34	16
Occupation unknown	68	18	61	9	17	15	29	-24	16	-14	28	12	62	32	69	14	25	7
N	1003		1009		1004		1002		1000		1002		1007		949		822	
chi-square test, p-value	0.004		0.46		0.10		0.004		0.12		0.27		0.005		0.16		0.10	
Education																		
High-educated	55		52		6		48		25		18		38		60		18	
Middle-educated	53	-2	65	13	12	6	44	-4	20	-5	17	-1	31	-7	57	-3	30	12
Low-educated	68	13	53	1	12	6	48	0	19	-6	22	4	44	6	62	2	29	11
Education unknown	77	22	38	-14	22	16	42	-6	5	-20	27	9	68	20	65	5	32	14
N	1003		1009		1004		1002		1000		1002		1007		949		822	
chi-square test, p-value	<0.001		0.007		0.09		0.72		0.07		0.31		<0.001		0.61		0.13	
Men																		
Occupation																		
Upper non-manuals	24		54		10		34		5		19		24		33		10	
Lower non-manuals	41	17	60	6	13	3	26	-8	15	10	5	-14	35	9	43	10	27	17
Skilled manual workers	44	20	55	1	16	6	33	-1	10	5	11	-8	39	15	52	19	23	13
Unskilled manual workers	55	31	82	28	46	36	36	2	27	22	36	17	50	26	70	37	10	0
Occupation unknown	50	26	100	46	0	-10	50	16	14	9	38	19	14	-10	71	38	17	7
N	230		234		232		229		230		234		232		219		208	
chi-square test, p-value	0.15		0.07		0.07		0.64		0.17		0.005		0.29		0.10		0.26	
Education																		
High-educated	29		46		11		30		6		13		22		25		12	
Middle-educated	36	7	68	22	15	5	28	-2	9	3	9	-4	35	13	49	24	22	10
Low-educated	48	19	57	11	15	4	35	5	15	9	16	3	40	18	54	29	25	13
Education unknown	29	0	83	37	33	15	43	8	17	11	14	1	33	11	67	42	20	8
N	230		234		232		229		230		234		232		219		208	
chi-square test, p-value	0.12		0.06		0.53		0.68		0.36		0.56		0.20		0.008		0.30	

functioning. Between the occupational groups, there were significant differences in the prevalence of poor functional ability, arthritis and dementia among women and in depression among men. In the occupational hierarchy from upper non-manuals to unskilled manual workers, the prevalence was lowest in the upper non-manual group for all conditions other than arthritis and hip fracture in women and depression and hip fracture in men; and, with one exception (poor self-rated health in men), it was highest among unskilled manual workers or those whose occupation was unknown. Poor functional ability, comorbidity and dementia in both genders and also depression in women showed a gradient of increasing prevalence with lower occupational status.

According to education, women had statistically significant differences in poor functional ability, CVD and dementia, and men in comorbidity. A gradient of an increasing prevalence of poor functioning, comorbidity, dementia and poor self-rated health was seen in men from the low- to the high-educated; in women, the gradient of the hip fracture showed lower prevalence in low- and middle-educated groups.

Relative health differences by occupation were analyzed with the age-adjusted ordered regression model (Table 3). We compared participants in other occupational groups with upper non-manuals and other educational groups with those having high education. The findings mainly followed a similar pattern to the absolute differences; the probability of most conditions was lowest in the highest group and increased gradually to the lowest in the hierarchy. The position of housewives and those with an unknown occupation or education varied. Skilled manual workers, unskilled manual workers and housewives had poorer functional ability than the upper non-manuals. In addition, in women, self-rated health was significantly poorer in skilled (borderline) and unskilled manual workers and housewives, and in men, comorbidity was higher among unskilled manual workers than among the upper non-manuals.

Marginal effects (provided in the supplementary data) were calculated for all health categories (6 categories in functional ability, 5 in comorbidity and 5 in self-rated health). For the most part, they repeated the findings of the earlier analyses, showing decreasing probability of good health outcomes and increasing probability of poor health outcomes with lower socio-economic status. In women, unskilled manual workers were 23% less likely to be independent and 12% more likely to be dependent in 5 activities compared with upper non-manuals. In all functional ability categories, except where dependent in 1 activity, both skilled and unskilled manual workers differed significantly from upper non-manuals. Unskilled manual worker women were 5% less likely to be free of chronic conditions. Both skilled and unskilled manual worker women were statistically less likely to report very good or fairly good self-rated health, and more likely to report it as fairly poor. For functioning and self-rated health, a regular gradient was found from upper non-manuals to unskilled manual workers on every level of the respective health outcome. In most categories, housewives showed poorer outcomes than upper non-manuals. With men, skilled manual workers were 24% less likely to be independent and approximately 7% more likely to be dependent in 1 or 2 activities than upper non-manuals. The likelihood of independence decreased and the likelihood of poorer functioning increased with lower occupational class. Unskilled manual workers had a lower probability of having no or only one chronic condition and a higher probability of having 3 conditions than upper non-manuals.

Relative health differences according to education in women showed that compared with the high-educated, the middle-educated were less likely to be dependent in all five activities, and both the middle- and low-educated were less likely to report good and more likely to report poor self-rated health. In comorbidity no significant differences were found. In men, the low-educated had a 22%

lower likelihood of being independent and a 5 to 7% higher likelihood of being dependent in 1, 2 or all 5 activities, respectively. In comorbidity, the low-educated men showed a poorer outcome throughout the comorbidity scale, and the middle-educated were also less often free from chronic conditions than the high-educated. In self-rated health, the likelihood of fairly good and fairly poor self-rated health in low-educated differed significantly from the high-educated. For both genders, most marginal effects showed a gradient of poorer outcome with lower education.

Table 3. Association of functional ability, comorbidity and self-rated health with occupation and education. Age-adjusted coefficients and their 95% CIs from the ordered regression model. Higher coefficient indicates worse health.

	Women			Men		
Occupation Reference: upper non-manuals	Coefficient		95% CI	Coefficient		95% CI
Functional ability						
Lower non-manuals	0.303		-0.13 to 0.74	0.694		-0.02 to 1.41
Skilled manual workers	0.499	*	0.07 to 0.93	0.784	*	0.09 to 1.48
Unskilled manual workers	0.704	**	0.20 to 1.20	1.02	*	0.01 to 2.04
Housewives	0.557	*	0.09 to 1.02			
Unknown occupation	0.712		-0.12 to 1.54	0.932		-0.23 to 2.10
Comorbidity						
Lower non-manuals	0.027		-0.30 to 0.36	-0.039		-0.45 to 0.37
Skilled manual workers	0.128		-0.20 to 0.46	0.111		-0.29 to 0.51
Unskilled manual workers	0.338		-0.06 to 0.74	0.998	**	0.25 to 1.74
Housewives	0.166		-0.20 to 0.53			
Unknown occupation	0.302		-0.11 to 0.72	0.567		-0.27 to 1.41
Self-rated health						
Lower non-manuals	0.115		-0.24 to 0.47	0.280		-0.14 to 0.70
Skilled manual workers	0.349	*	-0.00 to 0.70	0.318		-0.09 to 0.73
Unskilled manual workers	0.456	*	0.02 to 0.90	0.312		-0.44 to 1.06
Housewives	0.454	*	0.06 to 0.85			
Unknown occupation	0.177		-0.31 to 0.66	0.515		-0.42 to 1.45
Education Reference: high-educated	Coefficient		95% CI	Coefficient		95% CI
Functional ability						
Middle-educated	-0.062		-0.37 to 0.24	0.419		-0.25 to 1.10
Low-educated	0.245		-0.02 to 0.51	0.721	*	0.11 to 1.33
Unknown education	0.956	*	0.00 to 1.91	-0.084		-1.58 to 1.41
Comorbidity						
Middle-educated	0.015		-0.24 to 0.27	0.403		-0.01 to 0.82
Low-educated	0.128		-0.09 to 0.35	0.500	**	0.12 to 0.88
Unknown education	0.19		-0.22 to 0.59	0.816		-0.07 to 1.71
Self-rated health						
Middle-educated	0.357	**	0.08 to 0.63	0.246		-0.17 to 0.66
Low-educated	0.391	***	0.15 to 0.63	0.439	*	0.05 to 0.83
Unknown education	0.403		-0.12 to 0.93	0.596		-0.41 to 1.60

Notes: CI = confidence interval; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

The situation of those with an unknown occupation and an unknown education level varied, but whenever they differed statistically from the reference group, they showed poorer outcomes. In women, the likelihood of dependence in all 5 activities was clearly higher in these groups than in any other socio-economic category.

To see whether the findings observed were also true for the oldest part of our sample, we conducted binary logistic regression analyses to examine the associations of occupation and education with health and functioning in the subgroup of those aged 95+ (n = 272, 86% women and 14% men). In women, unskilled manual workers suffered statistically more often from poor functional ability than upper non-manuals. Otherwise, differences were not statistically significant, however, the number of men in this age group was very low.

Finally, to demonstrate the joint effects of gender and socio-economic status, we examined the association between gender and health outcomes within the hierarchical socio-economic groups, with the age-adjusted binary logistic regression analyses (Table 4). Women showed significantly poorer functioning than men in all occupation and education groups except in that of unskilled manual workers. Women also had higher odds of comorbidity on each level of socio-economic status but statistical significance was found only in lower non-manuals by occupation and in high-educated by education. For poor self-rated health, no significant gender differences were found.

Table 4. Association of poor functional ability, comorbidity and poor self-rated health with gender by the level of occupation and education. Age-adjusted ORs and 95% CIs. Reference category is men on each socio-economic level.

	Poor functional ability		Comorbidity		Poor self-rated health	
	OR	95% CIs	OR	95% CIs	OR	95% CIs
Occupation						
Upper non-manuals	3.19*	1.28 to 7.98	2.36	0.96 to 5.83	1.86	0.50 to 6.93
Lower non-manuals	1.89*	1.13 to 3.16	1.87*	1.12 to 3.15	0.86	0.48 to 1.55
Skilled manual workers	2.68***	1.67 to 4.31	1.35	0.85 to 2.15	1.42	0.80 to 2.50
Unskilled manual workers	2.39	0.57 to 10.00	1.10	0.25 to 4.87	5.10	0.59 to 43.97
Education						
High-educated	3.46**	1.59 to 7.53	4.28***	1.93 to 9.47	1.66	0.56 to 4.91
Middle-educated	1.81*	1.01 to 3.23	1.42	0.80 to 2.54	1.55	0.79 to 3.08
Low-educated	2.28***	1.50 to 3.48	1.36	0.89 to 2.06	1.18	0.72 to 1.94

Notes: OR = odds ratio, CI = confidence interval; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

Discussion

Socio-economic status is widely understood as one of the main determinants of health and functional status in young, middle-aged and younger-old people, but data on the very old has been scarce. We used a representative population sample to analyze whether the position in the social hierarchy is associated with health at the age of 90 or above, and if this association shows the social gradient usually observed in younger age groups. Our findings suggest a clear absolute and relative advantage in health and functioning for higher socio-economic groups, and even a graded inverse association between health and socio-economic status for several indicators, particularly for functional ability. A notable exception was seen for hip fracture in women, which was most frequent among upper non-manuals and showed a decreasing gradient towards lower education. Possibly, this is due to a higher survival after the hip fracture among upper social classes rather than a higher incidence (Roberts & Goldacre, 2003). In arthritis, differences between the social groups were very small among women. For self-rated health, only self-reports were included in the analyses. Those who were not able to answer the questionnaire by themselves were more likely to belong to lower socio-economic groups, which may lead to underestimation of socio-economic differences in self-rated health. In spite of that, self-rated health was significantly associated with occupation in both genders and also with education in women.

As we have no earlier information concerning this birth cohort, it is impossible to say how the socio-economic health differences have changed with increasing age. If we compare our results with earlier studies among the middle-aged and younger old, it seems that the magnitude in health differences in our study is somewhat weaker. In the 65+-year-old population in Finland, Rahkonen and Takala (1998) found more than a threefold difference in men between workers and white-collar workers in functional disability and in women the difference was twofold. In poor self-rated health differences between groups were twofold for both men and women. In a European study, the difference in poor self-rated health between the high- and low-educated Finns was approximately threefold for 25 to 69-year-old men and women (Kunst et al., 2005). Although no definite conclusions can be drawn, this seems to speak for decreasing, rather than increasing socio-economic differences towards very advanced age.

We employed two frequently used indicators, occupational class and educational level, to measure socio-economic status. These two together with the third common measure, income, capture different dimensions of social position, and are therefore not entirely interchangeable (McFadden, Luben, Wareham, Bingham, & Khaw, 2008). Still, when used as indicators of the relative position in social hierarchy, they have been found to produce basically similar results, although the magnitude of differences varies depending on the measure (Macintyre, 1997; Minkler, Fuller-Thomson, & Guralnik, 2006). Also in our study, measures of occupation and education were highly correlated. Our main findings regarding relative health differences were highly similar whether we used occupation or education as the socio-economic indicator, even if the exact coefficients and significances varied. Differences in findings also arise from the fact that education was divided into three hierarchical categories (high, middle and low-educated) with emphasis on low-educated and occupational status was analyzed in four categories. The reason why poor self-rated health in men, for instance, differed significantly between the extreme ends according to education but not according to occupation may relate to the fact that nearly 70% of the low-educated were manual workers and the weight was greater for that group than for the divided categories of skilled manual workers and unskilled manual workers.

In addition to hierarchical socio-economic groups, we included in the analyses separate categories for housewives and those with an unknown occupation or education. The apparently heterogeneous groups seemed to have in general poorer health outcomes than the reference groups. In the 'education unknown' group, half and in the 'occupation unknown' group 40% of the answers were given by proxy. Participants in these groups had high levels of disability and comorbidity and, women with an unknown occupation, had a particularly high rate of dementia and institutionalization. It is likely that poor health and memory problems in addition to having the answers given by proxy are the main reasons why the occupation was not known for them, but they also are more likely to belong to lower than higher socio-economic groups.

We also demonstrated the differences in health and functioning between men and women respectively, on all hierarchic levels of occupation and education. Women showed significantly poorer functioning in all socio-economic groups except for that of unskilled manual workers, and also a higher comorbidity among lower non-manuals and the high-educated. This gender pattern was highly regular although the differences did not always show statistical significance. Our findings suggest that the well-known female disadvantage in disability in old age (Murtagh & Hubert, 2004; Newman & Brach, 2001) probably should not be attributed to the lower socio-economic position of women, but is a result of mechanisms effective on each socio-economic level.

Several studies have discussed the suitability of one's personal occupational status and education as socio-economic indicators for women and older age groups (Bartley, Sacker, Firth, & Fitzpatrick, 1999; Huisman et al., 2004). Differences in years of schooling are smaller among nonagenarians than among middle-aged people (Grundy & Holt, 2001) which may hide the social differences. In most studies with older people, the participants retired a long time ago and all women have not participated in paid work outside the home. In Finland, the employment rate for women has been exceptionally high, and in 1950, when our study participants were from 20 to 35 years-old, altogether 57% of women aged 15 to 64 were employed outside the home (Statistics Finland, 1964). Additionally, the association between occupational status and mortality has been found to be similar irrespective of whether the woman's own occupation or that of the spouse is considered (Martikainen, 1995). In our study, we were able to use occupational status as an indicator of socio-economic status in four hierarchical categories for both men and women.

In a cross-sectional analysis, it is not possible to clarify causal relationships between socio-economic status and health. While it is obvious that poor health and disability can weaken possibilities for extensive education and increase the possibility of landing in less specialized occupations (Elovainio et al., 2011), there is a strong consensus among researchers that rather than health-based selection, the relation between socio-economic status and health throughout societies is one of social causation (Minkler et al., 2006; Chandola, Bartley, Sacker, Jenkinson, Marmot, 2003; Bartley & Plewis, 1997; Doornbos & Kromhout, 1990). For our participants, the educational choices and decisions about occupations are far in the past, and it is unlikely that the present chronic conditions could have had a major influence on them. It is plausible to believe that the health differences in old age, as during younger ages, are determined by differences in "conditions in which people are born, grow, live, work and age" (Marmot, Allen, Bell, Bloomer, & Goldblatt, 2012), including social inequalities in access to and utilization of care. Life-long health disparities also lead to disparities in mortality. In the 1960s, 2.6% of men and 2.8% of women aged 40 to 44 years living in Tampere had passed the matriculation examination, an upper secondary school requirement for university studies, while in our data 20% of men and 11% of women had high education (Statistics Finland, a). In the 1970s in Tampere, out of those who were born between 1915 and 1920, 29% to 36% (depending on the classification) were non-manuals, but in our data 40% of women and 50% of men were non-manuals (Statistics Finland, b). Thus, it is likely that mortality selection has some influence on our results.

The major strength of this study is that a whole age cohort in a geographical area was included and the participation rate was high. Unlike with many other studies, our reasonably large data set consisted of people living in home-dwellings, service homes and institutions and no exclusion criteria was used, which means that the whole spectrum of health was represented. Two indicators of socio-economic status and several indicators of health were available. However, there are also important limitations. There were noticeably more women than men in the study sample although the participant-strength was relatively the same as in the basic population. The small sample sizes compromise the reliability of the results among men in the unskilled manual worker group and in groups with an unknown social status. Even though unskilled manual worker men had statistically poorer functional ability than the reference group, in the marginal effect analysis only one out of six categories reached statistical significance. Another limitation is the lack of information concerning the participants' cognitive level. The mailed survey was based on self-reports and a great proportion of the participants had dementia or memory problems. However, more than a third of the responses from those suffering from dementia were given by proxy. It has also been shown that the prognostic validity of self-rated health is high in people with mild to moderate cognitive decline (Walker, Maxwell, Hogan, & Ebly, 2004). Therefore, it is not likely that this jeopardized the reliability of our findings. Furthermore, we cannot exclude the possibility that people of differing socio-economic status could use different criteria for assessing and reporting health status, a problem our study shares with all others based on self-reports.

On the basis of our findings in a representative population-based cohort, we conclude that the well-established socio-economic health disparity identified in younger old age groups persist in very old age. In spite of selective mortality during the life course and increasing heterogeneity in health in the oldest age groups, better education and higher occupational status are associated with health advantage even among nonagenarians. This implies that among the oldest-old, avoidable morbidity and disability also exists, even in a country that has a universal health and social care system. It is plausible that measures targeting social inequality at younger ages would also be effective in diminishing discrepancies in old age. However, with increasing numbers of very old people expected in the future (Statistics Finland, 2009; Statistics Finland, 2011) special attention should be paid to prevention and care of old people in lower socio-economic positions.

Funding
This work was supported by the Pirkanmaa Hospital District Competetive Research Funding, Tampere, Finland (grant numbers 9M025, 9K039, 9N019 MJ) and the Juho Vainio Foundation (LE).

Acknowledgements
Gerontology Research Center is a joint effort between the University of Tampere and Jyväskylä. The authors wish to thank municipal and private home care and elderly care units in Tampere for their help in data collection.

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This is a pre-copyedited, author-produced version of an article accepted for publication in The Journals of Gerontology, Series A, Biological Sciences and Medical Sciences. The original article is available online at https://doi.org/10.1093/gerona/glv105

Cardiometabolic and Inflammatory Biomarkers as Mediators between Educational Attainment and Functioning at the Age of 90 Years

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Running head: SES, biomarkers & functioning in old age

Abstract

Background: Low socioeconomic status (SES) is associated both with poorer functioning and elevated levels of inflammatory and cardiometabolic biomarkers, however knowledge of such relations for the oldest old is limited. Our aim was to study whether education is associated with cardiometabolic (cholesterol levels, BMI and leptin) and inflammatory (CRP, IL-6, IL-1Ra) biomarkers for the 90-year-olds who participated in the Vitality 90+ study. In addition, we investigated whether these biomarkers explain educational inequalities in functioning.

Methods: All persons in Tampere, Finland, who were born in 1909 or 1910, were invited to participate, irrespective of their health status or dwelling place. The sample consisted of 262 participants who went through the home interview and blood tests. The SES indicator used was the highest education, and physical functioning was assessed using the Barthel index. The association of education with individual and combined biomarker scores, and with functioning, was analyzed cross-sectionally applying generalized linear models.

Results: The low- and mid-level-educated participants had greater odds of belonging to the high risk group in cardiometabolic biomarkers than did the high-educated. Differences were statistically significant in three individual biomarkers (HDL-cholesterol, leptin, BMI) and in a cardiometabolic score. There were no educational differences in inflammatory biomarkers. When all biomarkers were combined, they mediated educational differences in functioning on an average of 23%. After controlling for smoking, alcohol use and diseases, biomarkers mediated part of the differences between the mid-level- and high-educated.

Conclusions: High education was associated with better cardiometabolic biomarkers and functioning among the 90-year-olds. In part, educational inequalities in functioning were explained by cardiometabolic biomarkers.

Key words: Health Disparities, Longevity, Biomarkers, Socioeconomic status, Functioning

Introduction

Higher exposure to psychosocial stress, deleterious environments and unhealthy behaviors are considered to be pathways from low socioeconomic status (SES) to poorer health (1). Mechanisms for indicating how SES is transformed into differences in physical health are still poorly known. One pathway, proposed by McEwen and Seeman (2), suggests that perceived stress initiates physiological responses. Cumulative or long-standing exposure to physiological stress mediators (neuroendocrine, cardiovascular, metabolic and immune systems) changes the optimal physiological operating ranges; this can cause dysfunction in organ systems and may lead to various diseases.

Education has influence on the occupation and income. These three common SES indicators have impact on health through different pathways but they show largely similar health patterns. In many studies, low SES is associated with adverse inflammatory and cardiometabolic biomarker readings. Higher levels of C-reactive protein (CRP) and interleukin-6 (IL-6) are reported for 52-79-year-olds who had low SES (3-5). Cardiometabolic biomarkers, lower high-density lipoprotein (HDL) cholesterol, higher body mass index (BMI) and metabolic syndrome are regularly associated with low SES in the middle-aged (6-9). For older people, similar associations are found in some (10, 11), but not all (4, 12), studies. Instead of one biomarker, SES differences in biomarkers are often studied with a combined biomarker measure of allostatic load, a concept that reflects the functioning of several regulatory organ systems (13). The association of SES with the allostatic load measure has been shown to be stronger than its association with individual biomarkers (14-16).

Among older people, SES differences in functioning, measured as physical performance, mobility or activities in daily living, are demonstrated by a number of studies (17-19). There is also a growing body of evidence that shows, respectively, an inverse association between inflammatory (20-24) and cardiometabolic (25-27) biomarkers with functioning. Suggested associations between biomarkers and functioning are direct if, e.g., high BMI burdens muscles and cardiorespiratory systems or IL-6 accelerates the progression of disability. Associations may also be indirect if metabolic alterations influence functioning through cardiovascular consequences or through increased inflammation (28-30).

Studies that disentangle associations between SES, biomarkers and functioning are rare and knowledge, especially regarding the oldest old, is limited. We focused on the indicators of two major physiological regulatory systems, cardiometabolic and inflammatory, both of which, independently, predict the progression of diseases and are potential pathways through which SES contributes to health differences. In addition to more traditional measures, we included BMI as one of the cardiometabolic indicators. Even though BMI is not an ideal measure of body fat among the very old it still predicts morbidity and physical disability in this group (31, 32).

The purpose of this population-based study was to examine (1) whether education is associated with five cardiometabolic biomarkers, BMI, leptin, HDL cholesterol, a ratio of HDL and total cholesterol and triglycerides, and with three inflammatory biomarkers, IL-6, CRP and interleukin-1 receptor antagonist (IL-1Ra) among 90-year-olds and (2) whether the biomarkers mediate differences in functioning between the educational groups.

Methods

Study Population

Data came from the Vitality 90+ study which is a multidisciplinary research project concerning people 90 years old or older living in the city of Tampere, Finland (33). Participants in the present study were derived from the Tampere City Population Register in January 2000. All individuals living in Tampere, born in 1909-1910, irrespective of health status or dwelling place, were invited to participate (n = 535). According to the National Population Register, 66 people died before the study began and another 42 died before being examined, leaving 427 eligible people. During the study, 86 individuals refused to participate referring to poor physical or mental condition and seven could not be reached. Another 45 refused blood tests and took part only in the interviews. The study population initially numbered 289 but the final sample of those who went through the home interview and blood tests dropped to 262 (61% of the eligible population). Interviews and blood tests were carried out at the participant's place of residence. The study protocol was approved by the Ethics Committee of the Pirkanmaa Hospital District and the Ethics Committee of the Tampere Health Center. All participants, or their legal representatives, gave written informed consent.

Education

We used the highest attained education as an indicator of socioeconomic status. Education creates the opportunities for employment and income and has an influence on health even in old age through the resources gained in adulthood (34). Education was categorized into three hierarchic levels: high (at least 9 years), mid-level (4-8 years) and low (less than 4 years).

Biomarkers

Cardiometabolic markers

Blood samples were taken in the morning after an overnight fast. Biomarkers were analyzed from plasma or serum, separated by low-speed centrifugation and stored in aliquots at −80°C. HDL, total cholesterol and triglyceride concentrations were analyzed using a Cobas Integra 700 automatic analyzer (Hoffmann-La Roche Ltd). Leptin, which is a surrogate for body fat and is produced primarily by adipocytes was measured from serum (35). Leptin concentrations were analyzed with a luminex-based multiplex analysis system (Bio-Plex 200 System, BioRad Laboratories, Inc.) BMI was calculated as weight in kilograms divided by height in square meters. The number of missing values was 18 in leptin and 12 in BMI.

Inflammatory markers

The concentrations of IL-6 and IL-1Ra were determined using commercially available enzyme-linked immunosorbent assay kits (Pelikine Compact human IL-6 ELISA kit for IL-6 and Quantikine R&D Systems for IL-1Ra). High sensitivity CRP concentrations were analyzed using a Cobas Integra 700 automatic analyzer. The number of missing values was 4 in IL-6 and 2 in IL-1Ra.

Functional status

The Barthel index, which shows the degree of independence in functioning, was used as a measure of functioning. The individual variables (feeding, bathing, grooming, dressing, bowel and bladder control, toilet use, transfers bed to chair and back, mobility and stair-climbing) each provide 0, 5, 10 or 15 points, resulting in a summed count that varies between 0 and 100 points. The higher the points the greater the independence in functioning. (36).

Covariates

Multivariate analysis was controlled for confounders that are known to be associated with both SES and functioning. Diagnoses of heart disease (I0-50), infectious disease (A00-99 and B00-99), diabetes (E10-14), dementia (F00-03, G30) and arthritis (M15-19) were coded according to the International Classification of Diseases, 10th Revision. When a participant had at least one disease in the respective category, it was coded as 1 disease. The number of diagnoses varied from 0 to 5. Smoking was categorized as i) current, ii) former or iii) never a smoker and alcohol use as i) more than 2 times a week ii) less than 2 times a week iii) rarely iv) never.

Statistical analyses

Participants' biomarker characteristics by gender are described as medians with the interquartile range, stratified by education. Educational differences in biomarker levels were tested with the Kruskal-Wallis Test and pairwise comparisons were studied with the Dunn-Bonferroni test. For all other analyses, results are shown together for men and women because the association between education and biomarkers was highly similar, and, based on interaction terms, there was no reason to stratify analyses by gender.

Binary logistic regression models were applied to calculate the odds ratios of having high risk value in each individual biomarker. High risk was defined as the highest third of the values except for HDL-cholesterol and for the ratio of HDL and total cholesterol; for these, the lowest third signified high risk (Table 1). We decided to use tertiles because it is not clear if the same clinical cut-offs should be applied for the 90+ population as for the general population and there are no agreed clinical thresholds for the inflammatory markers. Also, it is possible that health risks may increase even below the clinical thresholds. All the biomarkers were studied individually and as two scores: cardiometabolic (BMI, leptin, HDL-cholesterol, triglycerides and a ratio of HDL and total cholesterol) and inflammatory (IL-6, CRP and IL-1Ra). Individual biomarkers were coded as 1 when the participant had a high risk value and the number of high risk biomarkers were summed to form two continuous variables ranging from 0-5 and 0-3, respectively.

Table 1. Cut-off points for high risk readings in individual biomarkers.

	Cut-point	Median (interquartile range)
CARDIOMETABOLIC BIOMARKERS		
Body mass index (kg/m^2)	≥ 25.6	24.2 (22.1-26.4)
Leptin (ng/mL)	≥ 16.9	11.7 (5.9-21.8)
High-density lipoprotein (HDL) cholesterol (mmol/L)	≤ 1.20	1.38 (1.11-1.67)
Ratio of HDL and total cholesterol	≤ 0.22	0.25 (0.20-0.31)
Triglycerides (mmol/L)	≥ 1.81	1.44 (1.14-1.99)
INFLAMMATORY BIOMARKERS		
Interleukin-6 (pg/mL)	≥ 3.84	2.64 (1.63-5.07)
C-reactive protein (mg/L)	≥ 2.90	1.70 (0.50-4.20)
Interleukin-1 receptor antagonist (pg/mL)	≥ 444	372 (276-487)

Educational differences in cardiometabolic and inflammatory scores were examined using order logistic regression. Both biomarker scores were categorized into three equal groups: a cardiometabolic score of 0, 1-2 or 3-5 and an inflammatory score of 0, 1 or 2-3 high risk measurements. The parallel lines assumptions were tested and fulfilled.

The associations between functioning and biomarker scores were examined with the Kruskal-Wallis Test. For the analysis, functioning was divided into three categories where summed count 100 points indicated independence in functioning, 61-99 moderate disability, and 0-60 severe disability. The biomarker scores were used as continuous variables. In order to study differences in functioning according to education, a summed count variable was formed of functioning and a negative binomial regression analysis with a log link was applied. The analysis was first adjusted separately for cardiometabolic and inflammatory scores, second for a combined score including both cardiometabolic and inflammatory biomarkers, third for smoking, alcohol use and diseases and finally for a combined biomarker score, smoking, alcohol use and diseases. Percentage reduction was computed as $[(RR_{model\_1} - RR_{model\_2}) / (RR_{model\_1} - 1)] \times 100$. Data were analyzed using SPSS version 20.0 (IBM Statistics).

Results

Out of 262 nonagenarians who participated in the study, 74% were women and 81% community-dwelling. Descriptive biomarker statistics stratified by education are presented in Table 2. For women, differences by education were statistically significant in BMI, leptin and HDL-cholesterol. After the pairwise comparisons, the high-educated had lower levels of leptin than mid-level-educated (p = 0.03) and lower BMI than the low-educated (p = 0.01). For men, differences were not statistically significant. Overall, women had lower education and higher HDL-cholesterol and leptin readings than did men (p = 0.03, 0.04 and <0.001).

Sex-adjusted associations between education and individual biomarkers from binary logistic regression are shown in Figures 1 and 2. An education gradient was seen in BMI, HDL-cholesterol, triglycerides and in the ratio of HDL and total cholesterol but only a few differences were statistically significant: the low-educated had higher BMI than the high-educated (OR 5.76, 95% CI 2.00-16.60) and the mid-level-educated had higher odds of having higher leptin and lower HDL-cholesterol levels than the high-educated (OR 2.75, 95% CI 1.07-7.09 and 2.46, 1.04-5.81).

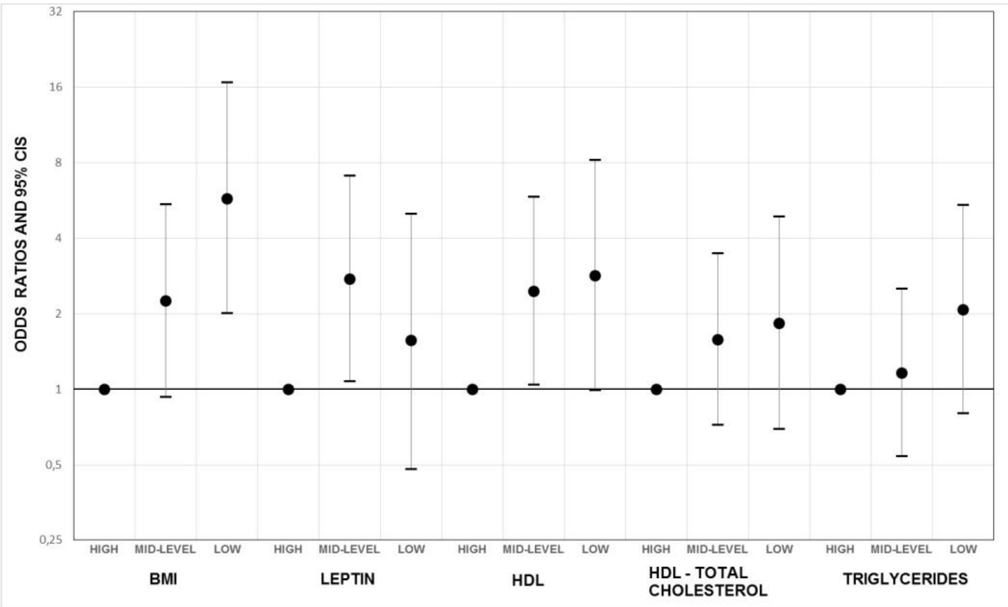

Figure 1. Odds ratios of having high risk readings in cardiometabolic biomarkers according to education. Participants in the vitality 90+ study. Sex-adjusted binary logistic regression models.

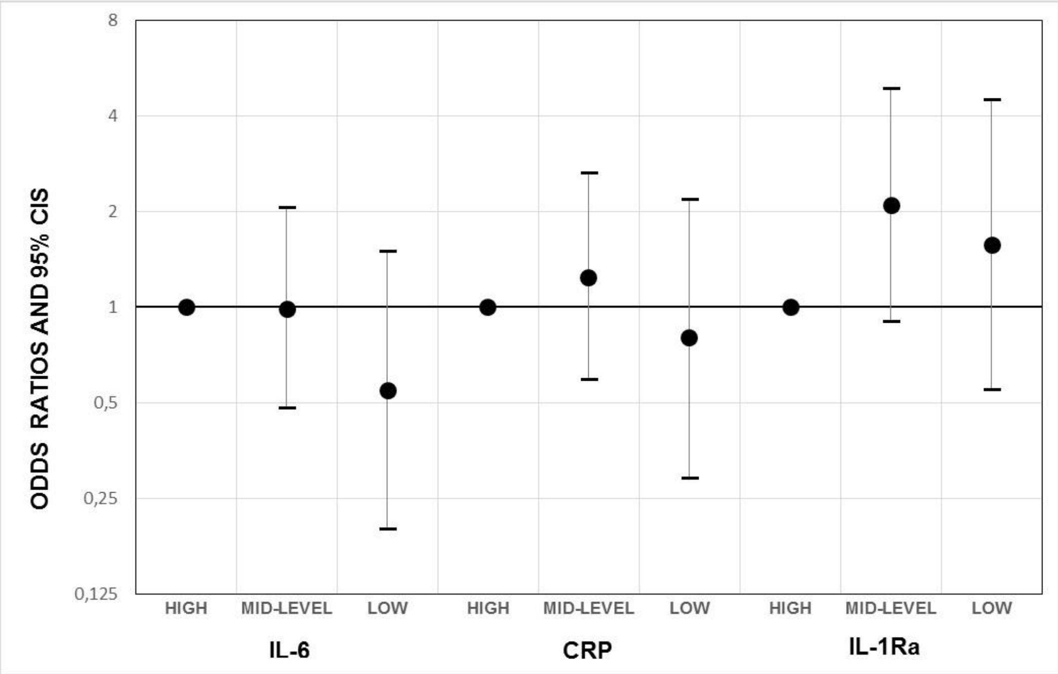

Figure 2. Odds ratios of having high risk readings in inflammatory biomarkers according to education. Participants in the vitality 90+ study. Sex-adjusted binary logistic regression model.

Ordered logistic regression analysis showed that the cardiometabolic score was higher for the mid-level- and low-educated (logit coefficients, 0.84 95% CI 0.14-1.53, 1.10 95% CI 0.20-1.99) than for high-educated (results not shown). There were no significant differences in the inflammatory score according to education. However, a higher inflammatory score was associated with poorer functioning ($p < 0.001$) while in the cardiometabolic score, there seemed to be a similar association, but statistical significance was not reached ($p = 0.08$) (Table 3).

Table 4 shows the association between education and functioning and the potential mediating effect of biomarkers in this association. In the sex-adjusted negative binomial regression model, rate ratios indicated better functioning for the high-educated in comparison to the low- and mid-level-educated (RR 0.92, 95% CI 0.84-1.00 and 0.88, 0.83-0.93). When the cardiometabolic score was added to the model, educational differences in functioning decreased, but the inflammatory score did not reduce the differences. In the model with the combined biomarker score, differences in functioning decreased 13% between the high- and the low-educated and 33% between the high- and mid-level-educated. In the model with smoking, alcohol use and diseases, high-educated still had better functioning than the mid-level-educated. In the final model with smoking, alcohol use, diseases and the combined biomarker score, functioning differences between the educational groups disappeared.

Table 2. Cardiometabolic and inflammatory biomarker levels by education; descriptive statistics are given separately for women and men.

	Education			*p* Value
	High	Mid-level	Low	
WOMEN, N (%)	24 (12)	137 (70)	34 (17)	
CARDIOMETABOLIC BIOMARKERS				
Body mass index, kg/m^2	22.6	23.9	25.3	0.015
	20.5-24.8	22.1-26.3	22.9-28.2	
Leptin, ng/mL	7.3	14.7	12.6	0.032
	5.5-13.6	6.9-30.1	8.1-23.5	
High-density lipoprotein cholesterol,	1.66	1.40	1.36	0.048
(HDL) mmol/L	1.33-1.94	1.10-1.70	1.08-1.69	
Ratio of HDL and total cholesterol	0.28	0.26	0.25	0.301
	0.22-0.34	0.20-0.31	0.19-0.30	
Triglycerides, mmol/L	1.35	1.46	1.73	0.436
	1.14-1.85	1.19-2.01	1.11-2.42	
INFLAMMATORY BIOMARKERS				
Interleukin-6, pg/mL	2.98	2.80	2.36	0.324
	1.69-6.95	1.65-5.30	1.36-4.15	
C-reactive protein, mg/L	1.40	1.70	1.20	0.528
	0.50-5.05	0.50-4.15	0.18-3.53	
Interleukin-1 receptor antagonist, pg/mL	284	402	385	0.134
	243-433	292-516	303-475	
MEN, N (%)	15 (23)	45 (69)	5 (8)	
CARDIOMETABOLIC BIOMARKERS				
Body mass index, kg/m^2	23.9	23.9	26.8	0.055
	21.5-27.4	22.4-26.0	26.1-31.3	
Leptin, ng/mL	4.9	8.3	8.9	0.401
	3.0-13.3	3.6-15.0	6.9-16.1	
High-density lipoprotein cholesterol,	1.32	1.18	1.33	0.333
(HDL) mmol/L	1.16-1.63	1.04-1.53	1.13-1.56	
Ratio of HDL and total cholesterol	0.25	0.25	0.24	0.736
	0.22-0.30	0.20-0.32	0.20-0.26	
Triglycerides, mmol/L	1.24	1.41	1.82	0.525
	0.91-1.86	1.09-1.79	1.14-2.30	
INFLAMMATORY BIOMARKERS				
Interleukin-6, pg/mL	2.46	3.19	1.52	0.081
	1.99-10.90	1.93-5.56	1.42-2.35	
C-reactive protein, mg/L	2.20	2.60	1.30	0.078
	0.30-2.60	1.05-5.70	0.45-2.30	
Interleukin-1 receptor antagonist, pg/mL	348	356	364	0.900
	256-422	261-452	245-698	

Notes: Median and interquartile range, p-values from the Kruskal-Wallis Test.

Table 3. Cardiometabolic and inflammatory scores according to the level of functioning.

	Biomarker scores	
Functioning	Cardiometabolic (N = 235)	Inflammatory (N = 258)
Barthel index points	range 0-5	range 0-3
0-60	1.86	1.63
61-99	1.73	0.90
100	1.33	0.83
p-values Kruskal-Wallis Test	0.08	< 0.001

Table 4. Rate ratios of having good functioning according to education.

	Adjustments for						
	Sex	Sex and cardiometabolic score	Sex and inflammatory score	Sex and combined biomarker score		Sex, smoking, alcohol use and diseases	Sex, smoking, alcohol use, diseases and combined biomarker score
EDUCATION	RR (95% CIs)	RR (95% CIs)	RR (95% CIs)	RR (95% CIs)	% Red. ƚ	RR (95% CIs)	RR (95% CIs)
High	1.00	1.00	1.00	1.00		1.00	1.00
Mid-level	0.88 (0.83 to 0.93)***	0.91 (0.87 to 0.97)**	0.88 (0.82 to 0.95)***	0.92 (0.87 to 0.97)**	33	0.92 (0.86 to 0.99)*	0.95 (0.89 to 1.02)
Low	0.92 (0.84 to 1.00)*	0.93 (0.85 to 1.01)	0.90 (0.81 to 0.99)*	0.93 (0.85 to 1.01)	13	0.96 (0.87 to 1.05)	0.95 (0.87 to 1.04)

Notes: Negative binomial regression with a log link, rate ratios and their 95% confidence intervals.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

ƚ Percentage reduction in rate ratios is from the sex-adjusted model to combined biomarker-adjusted model.

Discussion

In this population-based study on 90-year-olds, higher educational attainment was associated both with beneficial cardiometabolic biomarker levels and better functioning, but an association with inflammatory biomarkers was not clear. In the individual biomarkers, high-educated had lower BMI than low-educated and lower leptin and higher HDL-cholesterol levels than the mid-level-educated. Similar findings are reported for BMI and HDL-cholesterol in the US National Health and Nutrition Examination Survey (15) and in the nationally representative Finnish survey for 65-84-year-olds (10). We are not aware of studies that show associations between low SES with high leptin levels. Higher CRP and IL-6 levels are reported for well-functioning 70-79-year-old community-dwellers in the Health, Aging and Body Composition study (3) and for 52-70-year-old participants in the Framingham Offspring Study (4) who had low SES, but our study showed more vague associations with inflammatory markers. We performed a sensitivity analysis by excluding those who died within a year of the analyses but the result remained the same. It is likely that survival selection occur in the 90+ population which decreases educational inequalities in health.

We found that high-educated had less risk values in the cardiometabolic biomarkers than the other educational groups but this was not seen in the inflammatory score. In the general population, a cumulative burden of inflammatory, metabolic and cardiovascular biomarkers was found to be lower for the higher educated (15), though the same study reported weaker differences for older participants. We did not adjust analyses for the diagnosed diseases when studying educational differences in biomarkers because our chosen biomarkers may also reflect pathology of those diseases.

The inflammatory score was inversely associated with functioning, indicating that those who had more high risk readings had poorer functioning. We also showed that the high-educated had better functioning than the low- and mid-level-educated when measured with the Barthel index.

Finally, we studied whether biomarkers mediated the association between education and functioning. We found that cardiometabolic and inflammatory biomarkers together explained on average 23% of the functioning differences. Further adjustments for smoking, alcohol use and diseases also decreased educational differences in functioning, especially between the high- and low-educated. After adjustments for smoking, alcohol use and diseases, biomarkers had some independent value in mediating functioning differences between the high- and mid-level-educated. In the Health, Aging and Body Composition study, an average of 41% of the educational differences in incident mobility limitation was explained by biomedical factors and the strongest explanatory factors were the BMI and the inflammatory index (11). In the Health and Retirement Study, the high-educated had less risk values in cardiovascular biomarkers than the lower educated in the 53+-year-old population, especially in women, but biomarkers had only a negligible impact on reducing differences in functional limitations (37).

In summary, our results are in line with other studies with respect to educational differences in cardiometabolic biomarkers and their mediating effect on functioning; but, in contrast to some other studies, we found no educational differences in inflammatory biomarkers. Our study differs from the earlier ones in the sense that the participants in this study were very old, had many chronic conditions and no exclusion criteria were used. Low chronic inflammation (inflamm-aging) is found to be characteristic of advanced old age and is related to disability and comorbidities (38, 39). If every participant suffers from a low-grade proinflammatory state, it may hamper the identification of differences between educational groups. Nevertheless, the inflammatory score associated negatively with functioning and earlier studies using the same data have shown that these biomarkers are predictors of mortality (40). Some studies suggest that SES differences in biological risk factors peak in middle age and the biological profile becomes more similar in old age because of the mortality selection bias (41). Koster and colleagues (2006) reported that low SES is associated with high levels of proinflammatory markers, but participants in that study were well-functioning 70-79-year-olds and the associations were mainly explained by behavior factors, such as smoking, alcohol use and physical activity. In our data, smoking and alcohol use were rare and did not really differ between the educational groups.

We decided to determine the high risk category using tertiles instead of the clinical cut-offs because there are no clinical cut-offs for all of the biomarkers and it is not clear if the thresholds are valid for the oldest old. Yet our high risk thresholds correspond well to other studies; triglycerides and IL-6 (16, 42), HDL-cholesterol (11), CRP (15) and to clinical cut-off values in triglycerides, HDL-cholesterol, a ratio of HDL and total cholesterol, CRP and BMI. Our threshold for BMI was lower than in other studies. Because of the accumulation of body fat and muscle loss, negative health effects may occur at a lower BMI in older people (32). Not much is known about the thresholds for leptin and IL-1Ra for the oldest old, but compared with other studies, our threshold for IL-1Ra seems to be high (42). Studies suggest, that even though clinical cut-offs might not be exceeded, subclinical pathologies could increase adverse health effects (43).

To our understanding, this is the first study that investigates the role of biomarkers as mediators between the education and functioning in the oldest old. The strengths of the study rely on the wide range of information, including biological, behavioral and social data, for the well-defined population-based sample. There were limitations in the study. First, analyses were cross-sectional which means that the association between biomarkers and functioning can be either way. Second, because some individuals refused to participate, referring to poor health status, it is probable that our sample represents the healthier end of the basic population as is the case in most of the studies focusing on the oldest old. Third, the study sample was rather small for the epidemiological analyses but not particularly small given that it provides data on biological measures in the very old population. The vast majority of the participants were women however, the study population corresponded to the general gender distribution in this age group.

The biomarkers we studied, represent two major physiological regulatory systems, cardiometabolic and inflammatory, which independently and together, predict the progression of diseases. They are also potential pathways through which SES influence on health differences (43). This study suggests that part of the educational differences in functioning in the oldest old can be explained by cardiometabolic biomarkers. Life-course studies with social and biological data are needed to better understand the role of biomarkers in the mechanisms that link SES to health.

Funding

This work was supported by grants from the Academy of Finland to MJ (250 602), MH (132704) and TL (286284); the Competetive research funding of the Pirkanmaa Hospital District to MJ (9N019) and MH (9M017, 9N013); the Finnish Foundation of Cardiovascular Research to TL; the Tampere University Hospital Medical Fund to MH and TL; Yrjö Jahnsson Foundation to MH and TL; the Tampere Tuberculosis Foundation to MH and TL.

Acknowledgements

The Gerontology Research Center is a joint effort of the Universities of Tampere and Jyväskylä.

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This is a pre-copyedited, author-produced version of a letter to editor accepted for publication in The Journals of Gerontology, Series A, Biological Sciences and Medical Sciences. The original response is available online at doi:10.1093/gerona/glw176

Letter to the Editor

Response to Oztin et al.

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In the Letter to the Editor in the Journal of Gerontology: Medical Sciences, Hasan Oztin, Mehmet Naharci and Huseyin Doruk comment on the article “Cardiometabolic and Inflammatory Biomarkers as Mediators Between Educational Attainment and Functioning at the Age of 90 Years” authored by Linda Enroth and colleagues. We thank the commentators for opening discussion on the article. The main argument in the letter is that the article would be more relevant if morbid conditions and medication were taken into account in the analyses. Commentators point out that chronic diseases and polypharmacy increase along with aging and that they both may cause inflammation and decline in functioning.

We agree with the commentators with the well-known facts that they raise in the letter. However, the aim of our study was to assess whether educational attainment was associated with pro-inflammatory biomarkers (CRP, IL-6 and IL-1ra) that are known to predict the progression of the diseases and decline in functioning. The pro-inflammatory biomarkers form a potential pathway through which educational attainment influence on health differences. As referred to in the article, high inflammation can be directly deleterious for functioning but the effect can also be indirect through cardiovascular and other pathological consequences. All the biomarkers in the study were risk factors for cardiovascular diseases. We did not adjust logistic regression analyses (Figures 1 and 2) for the diagnosed diseases since biomarkers are risk factors for the diseases and in that they are on the same pathway. By adjusting analyses for the diseases, we would adjust, at least partly, for our outcome. Chronic diseases may raise biomarkers levels but the situation can also be vice versa. The study was conducted in the cross-sectional setting, which means that causality for the associations could not be analyzed.

Participants in the study were 90 years old, had on average 1.4 diseases out of those that were included in the study and 13% were free of those diseases. However, we think that biomarkers as such describe the physiological status and may reflect dysregulation even in preclinical conditions. We studied the graded association between education and pro-inflammatory biomarkers because health risks may also occur below the clinical cut-off for the disease. Another thing is that even though inflammation is a marker of chronic disease it is also suggested that very old people suffer from low-grade inflammation without diseases, the phenomenon is called inflamm-aging.

We acknowledge the importance of medication and especially polypharmacy, which are common among the oldest old, to disease management and functioning. Nevertheless, the study relies on the assumption that cumulative or long-standing exposure to physiological stress mediators change the biomarker profile, which may lead to disease. However, if for example, high total cholesterol or CRP are under control because of the medication, it is possible that serious consequences can be avoided. We did not control our analyses for the medication since the ultimate purpose was to see if the biomarker levels, as the level was with or without medication, differed between the educational groups.

The indicator of physical functioning was Barthel Index, which describes the level of independence, and is widely used as a measure of functioning for older people. When it comes to the comment on the decline in functioning due to chronic diseases and polypharmacy, we are aware of those, and several other factors that are associated with functioning such as living arrangements and health behaviors. Earlier research has shown that people with low socioeconomic status have more difficulties in functioning also in very old age (1). In general, socioeconomic health differences exist because of the unequal distribution of resources, yet the biological mechanisms, through which low education causes poorer functioning than high education, are not well known. This study focused particularly on the role of biomarkers and their possible mediating effect between educational attainment and functioning.

The commentators said that chronic diseases were left out of the study, yet we did adjust negative binomial regression analyses (Table 4.) for sex, smoking, alcohol use and diagnosed diseases and the result showed that after adjustment, biomarkers had a small independent effect in mediating differences in functioning between the high- and mid-level-educated.

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This is a pre-copyedited, author-produced version of an article accepted for publication in Age and Ageing. The original article is available online at https://doi.org/10.1093/ageing/afu092

Is socioeconomic status a predictor of mortality in nonagenarians? The vitality 90+ study.

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Abstract

Background: Socioeconomic inequalities in mortality are well-known in middle-aged and younger old adults, but the situation of the oldest old is less clear. The aim of this study was to investigate socioeconomic inequalities for all-cause, cardiovascular and dementia mortality among the people aged 90 or older.

Methods: The data source was a mailed survey in the Vitality 90+ Study (N = 1276) in 2010. The whole cohort of people 90 years or over irrespective of health status or dwelling place in a geographical area was invited to participate. The participation rate was 79%. Socioeconomic status was measured by occupation and education, and health status by functioning and comorbidity. All-cause and cause-specific mortality was followed for three years. The Cox regression, with hazard ratios (HR) and 95% confidence intervals (CI), was applied.

Results: The all-cause and dementia mortality differed by occupational class. Upper non-manuals had lower all-cause mortality than lower non-manuals (HR 1.61 95% CI 1.11-2.32), skilled manual workers (HR 1.56 CI 1.09-2.25), unskilled manual workers (HR 1.88 CI 1.20-2.94), housewives (HR 1.77 CI 1.15-2.71) and those with unknown occupation (HR 2.33 CI 1.41-3.85). Inequalities in all-cause mortality were largely explained by the differences in functioning. The situation was similar according to education but inequalities were not statistically significant. Socioeconomic differences in cardiovascular mortality were not significant.

Conclusions: Socioeconomic inequalities persist in mortality for 90+-year-olds but their magnitude varies depending on the cause of death and the indicator of socioeconomic status. Mainly, mortality differences are explained by differences in functional status.

Key words: Inequality, Occupational class, Education, Functioning, older people

Introduction

A non-manual labour market position [1-3], high education [3-6] and high income [7, 8] are consistently associated with better health and lower mortality compared with those who are worse off. For middle-aged and young old, a social gradient has been found in mortality regardless of the social position indicator [1, 3, 9] applied. However, less is known of the most rapidly growing oldest segment of population, those aged 90 or older [10].

Only in a few studies, researchers have analysed mortality inequalities specifically in very old people. In a Finnish data, including all deaths from 1971 to 1990, mortality inequalities according to occupation and, for men, also according to education prevailed until the age group of 90-94 years although the differences were weaker and more inconsistent than for the younger age groups [11]. To our knowledge, this is the only study that demonstrated occupational mortality differences in very old people. Higher mortality for the low-educated in comparison to the mid-level- and high-educated 90+-year-olds was found in a study with 11 European populations [12], but not in a Danish survey study for 92- or 93-year-old born in 1905 [13]. Higher mortality in the lowest income decile compared with other groups was found in a register study for 90–99-year-olds in 1980–2002 [14]. Inequalities in cause-specific mortality or the role of health status in mortality inequalities in very old people are largely unknown.

In the Vitality 90+ Study, we have the opportunity to study socioeconomic mortality inequalities in a well-defined cohort of people aged 90 years or older. Information on socioeconomic status, functioning and comorbidity was linked with the dates and causes of death. Both all-cause mortality and mortality from dementia and cardiovascular disease were analysed.

Methods

Study population

The data came from the 2010 mailed survey in the Vitality 90+ Study [15]. All people aged 90 years or older in the city of Tampere, Finland, irrespective of health status or dwelling place, were invited to participate. Names, addresses and places of residence were derived from the Tampere City Population Register. Questionnaires were mailed to 1686 people but 72 died before receiving it and 6 had moved out of Tampere. Total population came down to 1608 of which 1276 individuals participated, producing a response rate of 79%. The Ethics Committee of the City of Tampere approved the study and the participants gave their informed consents.

Socioeconomic status

The mailed survey included a question concerning participants' former longest held occupation. Occupational status was categorised into four hierarchical groups: upper non-manuals, lower non-manuals, skilled manual workers and unskilled manual workers according to the Occupational and Industrial Classification of Statistics Finland (1976) [16]. Workers in agriculture, fishery and forestry as well as farmers (N = 39) were categorised as skilled manual workers. The self-employed were categorized either as upper non-manuals or as lower non-manuals depending on their job description. Women who had not participated in the labour market and those who had worked as an assisting family member for an agricultural entrepreneur were categorised as housewives. Those who did not answer this particular question but had other information available were encoded as having unknown occupation.

Education was categorised into three hierarchic groups: low (primary, maximum 6 years), mid-level (lower secondary, vocational education, folk high schools, 7−9 years) and high (upper secondary, college-level training, university education, at least 9 years). In addition, a fourth group was formed of participants whose education was unknown.

Covariates

The participants were asked whether they were able to perform the following five activities: dressing and undressing, getting in and out of bed, moving indoors, walking 400 meters and using stairs (1) without difficulty, (2) with difficulty, (3) if someone helps, or (4) not at all. Alternatives 1 and 2 were encoded as independent and 3 and 4 as dependent in the respective activity. In the analyses, the variable ranged from independent in 5 activities to independent in 0 activities.

Comorbidity was studied by asking the participants if a physician had told them that they had cardiovascular disease (CVD), diabetes, stroke, hip fracture or dementia (included Alzheimer's disease, other dementias and a decline in cognition). The comorbidity variable ranged from no to 5 chronic conditions.

Mortality

The dates and causes of death were drawn from the Finnish Causes of Death Register and linked with the survey data by using the Personal Identity Codes. In the all-cause mortality analyses, the follow-up period was from 23/2/2010 to 31/1/2013 ~ 36 months. For cause-specific mortality, data were available from 23/2/2010 to 19/11/2012 ~ 33 months. The underlying causes of death were categorised by using the International Classification of Diseases, 10th Revision. The two most common causes of death were CVDs (I00-I99) and a combined category for Alzheimer's disease (G30) and other dementias (F01-03), below: dementia. Of CVDs, more than half (56%) were ischemic heart diseases and 24% were cerebral blood circulation diseases. In the dementia category, 66% of the deaths were caused by Alzheimer's disease and 34% by other dementias.

Statistical analyses

It has been suggested that magnitude of inequalities in mortality may be different whether studied in absolute or relative setting [12]. We studied age-controlled predicted probabilities for absolute all-cause mortality after 36 months follow-up drawn from logistic regression analysis with a command adjust in STATA statistics. Mean follow-up times for all-cause, dementia and CVD mortality by socioeconomic status came from Kaplan-Meier survival analysis. For relative inequalities in mortality, Cox proportional hazard model and the extended Cox model were applied with SPSS statistical software. First, we analysed mortality in the age- and sex-adjusted model. As our earlier analyses [17] have shown socioeconomic differences in functioning and morbidity in nonagenarians, we investigated whether the possible inequalities in all-cause mortality are explained by these health indicators. We added comorbidity and functioning into the analysis, first separately, and finally all covariates together. Functioning was added as time-dependent covariate and we used the extended Cox model with the time-covariate interaction term. The extended model was used because, tested with Schoenfeld residuals, the assumption for proportional hazards did not hold for functioning. In cause-specific analyses, the particular cause of death was encoded as 1 and all the other causes of death, including those that were censored, were encoded as 0. As the sample sizes were rather small, no covariates were included in these analyses.

For relative mortality differences, combined results for men and women are given, as the interaction term between sex and occupation and education, respectively, was not significant. However, we also conducted all-cause mortality analyses separately for both sexes and found no major differences. Cause-specific mortality was analysed for men and women together to retain statistical power.

Mortality risks in socioeconomic statuses were reported with hazard ratios and their 95% confidence intervals.

Results

The median age of participants was 92 years, out of 1276 respondents 81% where women and 37% lived in institutions. In the study, 59% of the participants answered the questionnaire by themselves, 24% received help in filling out the questionnaire and 18% of the answers were given by proxy (family, friends, home helpers or staff in the institutions).

All-cause mortality

The study population was categorised as upper non-manuals (7%), lower non-manuals (35%), skilled manual workers (38%) and unskilled manual workers (7%). Besides these hierarchic categories, housewives (10%) and those whose occupation was unknown (4%) were included in the analyses (Table 1). After a 36-month follow-up, overall mortality was 49% for men and women. In the social hierarchy, age-controlled absolute all-cause mortality was lowest for upper non-manuals (37%) and highest for unskilled manual workers (56%). Mortality for housewives was 51% and for those with unknown occupation 62%.

Education was categorised as high-educated (13%), mid-level-educated (29%), low-educated (54%) and unknown-educated (4%). In the social strata, mortality was lowest for the high-educated (44%) and highest for the low-educated (50%); for the unknown education group, it was 65%. For men, occupational and educational differences followed the social hierarchy, for women, there were some exceptions. However, differences were not statistically significant.

In a model adjusted for age and sex (Table 2), mortality was higher for all the other occupational groups when compared with upper non-manuals (lower non-manuals HR 1.61, 95% CI 1.11-2.32; skilled manual workers 1.56, 1.09-2.25; unskilled manual workers 1.88, 1.20-2.94; housewives 1.77, 1.15-2.71; and unknown occupation 2.33, 1.41-3.85). When comorbidity was added to the model, it reduced mortality differences, but hazards remained significantly higher for the other groups compared with the reference group. When age- and sex-adjusted analysis was controlled for functioning, differences in hierarchical occupations were no more significant. The final model, with both, comorbidity and functioning, decreased only marginally hazard ratios if compared with the model that included solely functioning. According to education, the rate of death was lowest for the high-educated, but only those with unknown education differed significantly from this group. After adjustments for comorbidity and functioning, the difference attenuated, but still remained significant.

Table 1. Population by occupational and educational status at baseline (N) and mortality after a 36-month follow-up (%, CI).

	At baseline			Mortality after 36 months					
	All	Women	Men	All		Women		Men	
	N 1276	N 1036	N 240	N 627	%, CI	N 510	%, CI	N 117	%, CI
Occupation									
Upper non-manuals	92	48	44	34	37 (28-48)	17	36 (24-51)	17	37 (24-52)
Lower non-manuals	441	364	77	211	49 (44-54)	177	50 (45-55)	34	45 (34-57)
Skilled manual workers	487	384	103	241	49 (44-53)	187	48 (43-53)	54	52 (43-62)
Unskilled manual workers	83	72	11	47	56 (45-66)	38	52 (40-63)	9	82 (49-96)
Housewives	124	124		65	51 (42-60)	65	51 (42-60)		
Unknown occupation	49	44	5	29	62 (48-75)	26	62 (47-75)	3	66 (24-92)
Education									
High	162	113	49	68	44 (36-51)	47	44 (35-54)	21	41 (28-55)
Mid-level	373	293	80	179	49 (44-55)	142	50 (44-56)	37	47 (37-59)
Low	694	591	103	349	50 (46-53)	296	49 (45-53)	53	52 (42-61)
Unknown education	47	39	8	31	65 (50-77)	25	63 (46-77)	6	75 (37-94)

Age-adjusted predicted probabilities from logistic regression analysis and 95% confidence intervals (CI).

Table 2. All-cause mortality in a 36-month follow-up separately by occupational and educational status and mean survival times (maximum 1073 days).

	Adjusted for age and sex		Age, sex and comorbidity		Age, sex and functioning		Age, sex, comorbidity and functioning		Mean survival time	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	Mean in days	95% CI
Occupation										
Upper non-manuals	1		1		1		1		935	(883-987)
Lower non-manuals	1.61*	(1.11-2.32)	1.55*	(1.07-2.26)	1.43	(0.99-2.09)	1.42	(0.97-2.08)	802	(769-835)
Skilled manual workers	1.56*	(1.09-2.25)	1.46*	(1.01-2.11)	1.33	(0.92-1.93)	1.31	(0.90-1.92)	806	(776-836)
Unskilled manual workers	1.88**	(1.20-2.94)	1.65*	(1.05-2.60)	1.55	(0.98-2.45)	1.45	(0.91-2.31)	782	(706-857)
Housewives	1.77**	(1.15-2.71)	1.63*	(1.06-2.52)	1.59*	(1.03-2.46)	1.55	(1.00-2.41)	778	(715-840)
Unknown occupation	2.33***	(1.41-3.85)	1.90*	(1.13-3.18)	1.56	(0.92-2.64)	1.48	(0.87-2.51)	743	(636-849)
Age	1.11***	(1.08-1.14)	1.10***	(1.07-1.13)	1.06***	(1.04-1.09)	1.07***	(1.04-1.10)		
Sex										
Male	1		1		1		1			
Female	0.88	(0.72-1.09)	0.83	(0.68-1.03)	0.72**	(0.57-0.89)	0.71**	(0.57-0.89)		
Comorbidity[a]			1.42***	(1.31-1.55)			1.24***	(1.13-1.36)		
Functioning[b]					1.52***	(1.40-1.66)	1.47***	(1.35-1.61)		
Functioning*time					1.00**	(1.00-1.00)	1.00**	(1.00-1.00)		
Education										
High	1		1		1		1		875	(828-922)
Mid-level	1.23	(0.93-1.63)	1.17	(0.88-1.54)	1.26	(0.95-1.68)	1.21	(0.91-1.61)	812	(778-847)
Low	1.24	(0.96-1.62)	1.18	(0.90-1.53)	1.14	(0.87-1.49)	1.12	(0.85-1.46)	799	(773-825)
Unknown education	1.98**	(1.29-3.03)	1.87**	(1.21-2.89)	1.58*	(1.01-2.48)	1.62*	(1.03-2.54)	654	(540-768)
Age	1.10***	(1.07-1.13)	1.10***	(1.07-1.13)	1.06***	(1.03-1.09)	1.06***	(1.04-1.09)		
Sex										
Male	1		1		1		1			
Female	0.94	(0.77-1.15)	0.89	(0.72-1.09)	0.76*	(0.62-0.94)	0.76*	(0.61-0.94)		
Comorbidity[a]			1.43***	(1.32-1.56)			1.25***	(1.14-1.36)		
Functioning[b]					1.52***	(1.40-1.66)	1.47***	(1.35-1.60)		
Functioning*time					1.00**	(1.00-1.00)	1.00**	(1.00-1.00)		

Cox hazard ratios (HR) and their 95% confidence intervals (CI), mean survival time with 95% confidence intervals from Kaplan-Meier analysis.

Statistical significances for HRs at * P-value < 0.05, ** P-value <0.01, *** P-value < 0.001.

[a]Comorbidity = CVD, diabetes, dementia, stroke, hip fracture.

[b]Functioning = independence in getting in and out of the bed, dressing and undressing, moving indoors, walking 400 m, using stairs.

Cause-specific mortality

We studied cause-specific mortality from CVDs and from dementia. During the 33-month follow-up, of 581 deceased, 191 (33%) owed the underlying cause of death to dementia and 263 (45%) died of CVDs.

Controlled for age and sex (Table 3), dementia mortality was significantly higher in all the other occupational groups when compared with upper non-manuals (lower non-manuals HR 2.58, 95% CI 1.11-6.01; skilled manual workers 2.42, 1.04-5.60; unskilled manual workers 2.95, 1.13-7.70; housewives 2.77, 1.10-7.00; and unknown occupation 5.16, 1.91-13.91). According to education, mortality from dementia seemed to be higher for the mid-level- and low-educated than for the high-educated, but only those with unknown education differed significantly.

Hazards of dying from CVDs were 30 to 91% higher for other groups than for the upper non-manuals, but only housewives differed significantly from the reference group (HR 1.91, 95% CI 1.03-3.54). According to education, the hazards of dying from CVDs were 9-25% higher for other groups than for the high-educated, but differences were not significant.

Discussion

In this population-based study on 90+-year-olds, absolute inequalities in all-cause mortality after a 36-month follow-up were not significant but showed a trend by social status. In analysis of relative differences, all-cause mortality was significantly lower for upper non-manuals than for other groups, and, in the social hierarchy, mortality was highest for unskilled manuals. Inequality was mainly explained by the differences in functioning. The high-educated seemed to have lower mortality than the low- and mid-level-educated, but these differences were not significant. In a cause-specific analysis, inequalities by occupation were found in dementia mortality. The hazards of dying from CVDs were 30 to 91% higher for lower occupational positions than for upper non-manuals, but showed significantly higher mortality only for housewives, and no differences were found according to education

To our knowledge, only one earlier study has demonstrated occupational mortality inequalities in very old age. Consistent with the current study, Martelin [11] reported lower mortality for upper non-manuals in the five-year age group for 90-94-year-olds in a comprehensive nationwide data. The CLESA study, however, using harmonised data from five European countries and Israel, showed no mortality differences according to occupation for 75+-year-olds [18].

Educational inequalities were found by Huisman and colleagues [12] in all 11 studied European populations for younger than 90 years old; and, when all the populations were combined, even in the aged 90 or over. In the CLESA study [18], higher education was associated with lower mortality only in Netherlands and in other survey studies with a focus on 90+-year-olds, education has not been associated with mortality [13, 19].

Very little is known about socioeconomic differences in cause-specific mortality in the oldest old. In our study, the differences by occupation were clear for dementia but not for cardiovascular causes. Many, but not all [20], studies have reported a higher incidence of Alzheimer's disease and other dementias for those in lower social positions [21-23]. In a Swedish study of 75+-year-olds, the incidence of Alzheimer's disease and other dementias was higher in low-educated but mortality from those diseases was not higher than in the general population [24].

Table 3. Association of occupation and education with a 33-month cardiovascular and dementia mortality and mean survival times (maximum 1000 days).

	Cause of death dementias				Cause of death CVDs			
	HR	95% CI	Mean in days	95% CI	HR	95% CI	Mean in days	95% CI
Occupation								
Upper non-manuals	1		976	(954-998)	1		921	(878-964)
Lower non-manuals	2.58*	(1.11-6.01)	912	(891-934)	1.36	(0.79-2.35)	889	(865-913)
Skilled manual workers	2.42*	(1.04-5.60)	914	(894-934)	1.36	(0.80-2.33)	884	(861-907)
Unskilled manual workers	2.95*	(1.13-7.70)	895	(841-949)	1.57	(0.80-3.08)	862	(802-922)
Housewives	2.77*	(1.10-7.00)	894	(850-938)	1.91*	(1.03-3.54)	855	(806-903)
Unknown occupation	5.16**	(1.91-13.91)	850	(765-936)	1.30	(0.55-3.06)	898	(823-973)
Age	1.17***	(1.12-1.22)			1.09***	(1.04-1.13)		
Sex								
Male	1				1			
Female	1.13	(0.75-1.72)			0.93	(0.67-1.30)		
Education								
High	1		944	(916-970)	1		912	(878-947)
Mid-level	1.06	(0.61-1.84)	934	(913-955)	1.25	(0.83-1.90)	882	(856-907)
Low	1.42	(0.86-2.35)	903	(885-921)	1.09	(0.73-1.61)	881	(862-901)
Unknown education	3.23**	(1.62-6.45)	770	(668-871)	1.11	(0.51-2.42)	869	(780-957)
Age	1.15***	(1.10-1.21)			1.09***	(1.05-1.14)		
Sex								
Male	1				1			
Female	1.25	(0.83-1.88)			1.02	(0.74-1.41)		

Age- and sex-adjusted Cox proportional hazard ratios (HR) and their 95% confidence intervals (CI), statistical significances at * P-value < 0.05, ** P-value <0.01, *** P-value < 0.001.
Mean survival time with 95% confidence intervals from Kaplan-Meier analysis

Mortality from CVDs is related to a lower social position in middle-aged and young old adults [2, 25, 26] but there were no differences in a social hierarchy in our data. CVDs are the leading cause of death also in the oldest old. However, at very old age, death often results from aging-related frailty and multi-organ failure rather than a specific pathology in one organ system [27, 28]. In this age group, most death certificates are based on clinical examinations rather than autopsies, and it is likely that deaths without an evident specific cause are mainly recorded as being caused by CVDs. If CVDs as a cause of death constitute a biologically heterogeneous group, it is understandable that there are no clear socioeconomic differences.

In the study, functioning played a major role in explaining mortality differences whereas comorbidity was not as important. This finding supports the role of functioning as the most important and comprehensive health indicator in old age [13].

Outside the usual occupational hierarchy, groups of housewives and those with unknown occupation or education showed high mortality rates. The seemingly heterogeneous group of housewives included also women who assisted family members in agricultural work. In this group, mortality was comparable to that of manual workers. Similar to our study, a Norwegian health survey found higher all-cause and cardiovascular mortality for women who did not participate in the labour market [3]. Among those with unknown status, dementia diagnosis, institutionalisation and proxy respondents were common, and to a large extent these factors explain both the missing information and the high mortality.

In many countries, women's labour market participation has traditionally been low, which complicates socioeconomic status classification for the oldest old [29]. In the Finnish context it has been common that women participate in the labour market at least for some years and in our data participation was as high as 84%. This enabled us to use a personal longest held occupation as a measure of socioeconomic status also for women.

Unfortunately, we did not have information on the social status at earlier ages of the entire birth cohorts but only for those who participated in the study; this prevented us from evaluating mortality selection. As our study only included 90+-year-olds, we could not directly compare the magnitude of inequalities with younger age groups. However, nationwide analyses imply that for middle-aged and younger old people, socioeconomic mortality differences are more prominent than in our study [26]. Relative differences may be smaller at older ages because of selective or high overall mortality [30]. However, in our study, significant differences were found in relative all-cause mortality but in spite of a clear social gradient, not in absolute mortality. From the public health perspective, relative differences imply that there are "avoidable deaths" even among the very old, and even at this age, remaining life expectancy would be higher without social inequality. In clinical terms, higher morbidity, disability and mortality is a special challenge for health and social services, and particular attention should be paid to old people in lower social classes.

The clear advantages of our study include population-based, reasonably large data, inclusion of both community-dwelling and institutionalised people, use of reliable and exhaustive mortality information from the Finnish Causes of Death Register, and a high response rate (79%). Availability of demographic and mortality data also allowed comparisons between the participants and the non-response group (21% of the population, N 332). The hazard of dying was higher (HR 1.47; 95% CI 1.25-1.73) in those who did not respond, but the groups were similar with regard to age and sex distribution. Similar findings are reported by Ferrie and colleagues [31], and, in their study socioeconomic status did not interfere with the association between non-response and mortality.

A potential problem is caused by including people with dementia in a study based on self-reports. “Dementia” in our study included also people with cognitive decline without a clinical diagnosis, and those with an early stage of dementia. Our own analyses [32, 33] and those of others [34] suggest that these people are able to provide information sufficiently reliable on their health status. For more than a third of the people with dementia, the answers were received by proxy, a relative or most often from a nurse in an institution where clinical conditions are well registered. Therefore, it is not plausible that this would jeopardize the reliability of the study.

Although the study focused on one geographical area only, it represents 90+-year-olds at a national level in respect to sex distribution (18-21% men), and the relative proportion of those aged 90 or over in the population (0.6%). It included both urban and rural areas. However, in generalizing results, specific attention should be paid to women’s high labour market participation and to the fact that we had limited information on the real status of the housewives.

In conclusion, our study showed significant hierarchic socioeconomic differences in all-cause and dementia mortality in a population sample aged 90 and older. The differences were largely explained by differences in health, measured as functional status and comorbidity. The findings demonstrate that even in the very old population that has been exposed to social selection throughout the life span and that experiences very high basic mortality, a social position persists as a major determinant on the length of remaining life.

Funding

This work was supported by the Juho Vainio Foundation and the Finnish Cultural Foundation, Pirkanmaa Regional Fund (LE). Competitive Research Funding of the Expert Responsibility Area of Tampere University Hospital, (grant number 9M025 to MJ).

Conflict of interest

None declared.

Acknowledgments

The Gerontology Research Center is a joint effort between the Universities of Tampere and Jyväskylä. The authors wish to thank municipal and private home care and elderly care units in Tampere for their help in the data collection.

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